System Design Parameters for Replacing the Private Automobile

COLLAPSE

Jared Diamond's book "Collapse" details the demise of a number of cultures, some small like Easter Island others large like the Mayans. The one thing they had in common is that they all overused their resources. The scenario Diamond paints is of a resource deficiency building over a long period finally culminating in a precipitous collapse. The collapse is often triggered by an outside event like a drought or changed weather pattern and sometime comes just after the zenith of the culture.

The members of these societies could often see their good fortunes diminishing. They either could not figure out why it was happening or, more disturbingly, could not manage to make the changes needed. Both individuals and societies tend to cling to whatever has worked previously and only at the very end of the process find the opportunity to change has passed.

When I leave my home in the middle of Pennsylvania and drive east on I-80 into the New York metro area I am alway astonished and frightened by the sight of thousands of cars streaming along. Our current living arrangements has us using a ton and a half to three ton vehicle to carry just one person. We all know this is obscene and can't go on forever. A collapse in fuel supplies would leave our society completely unable to function. Large cities would become like bee hives with their entrance holes plugged.

It is absolutely imperative to replace the automobile with a sustainable system. Given the conservative nature of people and the automobile dependent condition of the culture, it is equally imperative that any solution incorporate current automobile habits and infrastructures. It cannot be expected that folks will stopping using their cars. Most people dislike and are uncomfortable with changing their habits and at present there are no attractive alternative.

LETS FACE IT

For sixty years or more designers, including myself, have been proposing alternative transportation systems. Very few of these systems have made it into operation and all of those are in small contained situations like airports.

When automobiles started to replace horses the transition was relatively seamless. My garage in Pennsylvania was built in 1905 as a carriage house with a hay loft on the second floor. Slowly at first, then quickly and gratefully, people gave up their horses for motors but they didn't have to change their habits to make the switch. Motors let them do what they had already had been doing, just easier and faster. For a while horses and automobiles coexisted on the same roads and even in the same barns.

The current user is a person with a car nearby which they can take at a moments notice to any desired location and back. It is that personal transaction which has defined modern life and the investment of trillions of dollars in automobile defined infrastructure. The automobile has great faults and these have caused great damage but a replacement system will not likely succeed unless it maintains and improves the personal automobile transaction.

What follows is an analysis of the problems inherent in using the automobile for transportation and the resulting design parameters for a replacement system.

PRIVATE OWNERSHIP

The goal of any successful PRT system must be to replace private owned cars with a utility owned vehicle. Personal transportation should become a utility like electricity, water, gas, phone and data services.

Owning and driving a private automobile is expensive and involves the responsibilities that ownership brings like repairs, upkeep, and insurance.

Americans drive each car an average of 12000 miles a year, at 40 mph that would require 267 hours of driving or just .03 % of the hours in a year. The AAA report below uses 15000 miles per year but most estimates, including my insurance company's, puts vehicle milage around 12,000 miles. I use the small sedan estimates because that is the size of the vehicle TGT proposes.

AAA Report 'Your Driving Costs' for 2011

The overall findings of the 2011 'Your Driving Costs' study include:

Based on Driving 15,000 miles annually	*Small Sedan*	*Medium Sedan*	*Large Sedan*	*Sedan Average*	*SUV 4WD*	*Minivan*
Cost Per Mile	45.1 cents	57.3 cents	73.2 cents	58.5 cents	74.9 cents	63.3 cents
Cost Per Year	$6,758	$8,588	$10,982	$8,776	$11,239	$9,489

A utility can use the vehicle during the 97% of the time it is normally inactive. Recycling vehicles to other customers reduces the number of vehicles needed and greatly compacts and simplifies parking logistics. Automobiles in all their aspects: buying, maintaining, driving, and parking are very expensive. Any business plan that creates greater efficiency in most or all those aspects, can thrive.

Utility own vehicles and guideways need to replace private ownership.

VEHICLE

Ultra light vehicles are attractive as an energy saving design feature but may be in conflict with the threshold of acceptability for vehicles that also need to operate on normal roads. One extreme is driving a 6000 pound Hummer because its size and bulk gives the illusion of safety. The task is to find a widely acceptable vehicle that will not over load guideway specifications. Guideway dimensions are a factor of the cross section profile of the vehicle which in turn is determined by the dimension needed for two people sitting comfortably side by side. The requirement for stability in the wheel track configuration is also a consideration.

There are over a hundred years of vehicle design in the automobile industry with vehicles ranging from the 1960's era Fiat 500, which weighed 1100 pounds and was powered by a 13 hp motor, to any number of behemoths. The proposed TGT system uses the electric Mitsubishi i-MiEV as a proto vehicle for both guideway and street use. Interestingly i-MiEV was enlarged when the market was expanded to North America to accommodate bulkier occupants. Watching the i-MiEV adjust offers some insights into the market, regulatory, and functional pressures on design.

From "Car and Driver"

(The U.S. i-MiEV's body has been enlarged, and both the front and rear bumpers have been redesigned for compliance with our crash-test regulations... the car is 11.2 inches longer and 4.3 inches wider than the Japanese-spec model, offering more interior space —although at just 144.9 inches by 62.4) http://blog.caranddriver.com/electric-2012-mitsubishi-i-miev-priced-20490-after-federal-tax-credit/

The American i-MiEV has gained 200 pounds over its Japanese version and now weighs 2579 pounds. While this is a lot heavier than I would like, it is between 800 and 1200 pounds lighter than the other major brand electrics, Ford, Chevy, Nissan. The curb weight for the new Fiat 500 is 2416 pounds and Mini Cooper 2668 pounds, both gas models. The new Fiat 500 has more than doubled the weight of its 1960's predecessor. Given the need for creature comforts and crash worthiness, 2500 pounds may be target vehicle weight and set the engineering requirements for the guideway.

I owned and drove the original Fiat 500 in the 1960's. I had fun with it in my contrarian way but it was very underpowered and minimalist. It was very popular in the tight economic times, narrow streets, mild weather, and short distances of Rome but it never gained even minimal acceptance on American roads.

The readers blog entries to Car and Driver tended to be very critical of the i-MiEV. They thought it was too expensive for a short range commuter car, some doubted its safety in a crash, and they hated the way it looks.

Cost and range criticisms are also applicable to other main brand electrics but disappear when the vehicle becomes utility owned and uses guideways for distance travel. European safety test gave i-MiEV a good rating so that much is misperception. I would have to agree, however, that it is an unattractive design. Any vehicle paired to automated guideway travel would need a number of modifications and hopefully a better looking skin would be one of them.

As the new guideway and road configuration became establish the vehicle will evolve along with the users understanding of this new interface. Vehicles like the i-MiEV will be the intermediate, horseless carriage, stage. Successor vehicles may become lighter but the dimensions, which are determined by the space needed for occupants, will remain stable.

ENERGY

Almost all current and proposed alternative systems would provide a great energy savings over the automobile. Most use electricity as their power source which is the universal power solvent and allows for the prospect of significant renewable energy use. Electric propulsion is also more efficient than combustion motors. The Mitsubishi i-MiEV which is the proto vehicle for TGT claims 112 mpg equivalent energy for open road travel.

From an AUTOWEEK car review By: [Mark Vaughn]() on 10/14/2010

> In all I used 441 kilowatt-hours of electricity in 1,853 miles of driving. Electricity costs 13 cents per kilowatt-hours at my house and, if I assume it's the same cost at my office (they were never able to tell me how much it cost them), that's 4.2 miles per kilowatt-hour. Three months of daily commuting and weekend driving cost me $57.33. It costs me about that much to fill up our 15-mpg Volkswagen Eurovan with gasoline.
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> Read more: http://www.autoweek.com/article/20101014/CARREVIEWS/101019944#ixzz1ihKmCzV5

Unlike the Car and Driver readers, Mark Vaughn who reviewed the I-MiEV for AUTOWEEK loved the car and recently bought one.

In a guideway environment with close headways energy use would be less and in the TGT proposal with the air moving at the same pace as the vehicle, considerably reduced. Given these savings, guideway mounted solar panels can produce a significant portion of the power needs. The TGT guideway covered with solar panels would provide over 21,000 trips a day in 8 hours of sunlight. When the just announced new EPA air regulations are finally in place, even electricity produced in fossil fuel power plants will become cleaner than emissions from autos.

Electricity is the most flexibility and efficient power source. The energy savings of guideway travel make renewable sources, especially solar, viable.

OPEN OR CLOSED SYSTEM?

In closed systems the vehicle stay in the system as in light rail and most PRT designs. In open systems, auto expressways, interstate highways, and dual mode PRT designs, the vehicle enters and leaves the guideway. Closed systems improve and personalize mass transit while open systems improve the automobile.

One of the complaints about closed PRT systems and light rail is that they don't scale up efficiently. In closed systems, vehicles stay in the system and have to be stored and retrieved in times of high usage which adds to operation cost. Closed systems need stations, which are sometimes extensive with significant vehicle handling facilities. An open system only needs exits and in-ramps and can scale up easily from a few cars at 2:00 am to thousands at 8:00 am.

An open system has significant advantages over a closed system. These include much greater flexibility in the use and storage of vehicles when off the guideway. An open dual mode system would mostly overlay expressways.

Closed systems have trouble delivering passengers to specific locations such as home or office. Open systems use the already existing infrastructure of secondary and neighborhood roads to bring the rider door to door.

DANGEROUS

Automobiles are dangerous. Thirty-five thousand are killed and two million injured every year in the U.S. which ironically is statistically one of the safest places to drive in the world. Local roads without a separation between lanes and intersections are the most dangerous places. Neighborhood streets are usually quite safe, it is the secondary two lane roads that connect towns that seem to be the killers.

URBAN EXPRESSWAYS

Dense urban thruways are safer than many secondary roads but using them to commute to work is a daily nightmare. Phoenix has well designed expressways connecting its large sprawled out development. As an Easterner, I expect traffic to flow into the center in the morning and out in the evening. Phoenix with many centers has traffic flowing in both directions all day and seemingly all night long.

Phoenix achieved its growth from a small city to a large metro area totally under the influence of the automobile. Its living, shopping, and work patterns are all automobile defined and dependent. While phoenix has a line of light rail and some busses, its explosive sprawling expansion has overwhelmed any attempt at public transportation. Every morning, the TV news program uses an interactive map to show where the expressways are congested or stopped.

With thousands of cars at or beyond the speed limit, overreaching their headway and switching lanes to enter or exit, expressways work better than would be expected. If expressways didn't already exist, no engineer would propose the current situation and no government agency would dare to fund it.

Expressways are natural hosting corridors for an open automated guideway system.

EXPRESSWAY THROUGHPUT CAPACITY

City expressways are inefficient due to their limited throughput capacity per lane. The consensus observation of highway engineers puts the maximum throughput during rush hour at 2000 cars per lane per hour. The underlying problem is headway, the space between cars. The recommended safe operating distance between cars is 2 seconds. Most of us cheat this down to 1.5 seconds in rush hour traffic. At 65 mph a car is traveling 95 feet per second or 143 ft per 1.5 seconds. An 18 foot long car keeping a second and a half headway constitutes a 161 ft unit. At any moment a mile can accommodate 32.8 units or 2131 cars per hour past a given point at 65 mph. This theoretical projection is reasonable close to what traffic engineers have observed. Speed doesn't impact throughput very much. At 100 mph with a 1.5 second headway throughput is barely more, 2218 cars per hour, while at 20 mph throughput is not that much less, 1703.

Speed has much less effect on throughput than headway. If a system can't form trains, platoons, or operate with very small headways, it will be inefficient regardless of the vehicle speed.

For instance, a configuration operating on a guideway at 70 mph with ten car trains (platoons) and a 4 second headway between trains yields a capacity of over 7000 cars an hour. More than a three lane expressway.

Given this limit on expressway throughput, traffic engineers have only one tool to increase an expressway's carrying capacity which is to add lanes. The problem is that more capacity begets more traffic and eventually more development near exits. Interstate 495 around Washing D.C. is six or more lanes in each direction. Whatever they build it is never enough. More than once I have been on I-495 with packed traffic six lanes deep crawling around Washington at 15 or 20 mph.

SINGLE OCCUPANCY

The High Occupancy Vehicle lanes, which have been added to many urban expressways at great expense have been a failure. One of the defining characteristics of the American commuter is that he or she travels alone. The average occupancy in rush hour traffic is 1.16 persons per car.

I had a demonstration recently when my wife and I were traveling through Phoenix during rush hour. Being that we were two in a car, I went into the HOV lane. We soared along at nearly 80 mph with hundreds of feet between our car and the next while the three remaining lanes were packed with cars moving 50 to 60 mph. This wasn't news for the drivers in those crowded lanes, they do it every working day, perhaps 200 hundred times a year. Nevertheless they haven't made the personal accommodations for the sharing rides needed to access the HOV lane. If any designer is counting on people using their system to change their habits, take a ride in the HOV lane.

If a PRT system is counting on multiple passengers per vehicle, it will likely fail.

Americans only depend on mass transit in large dense metro areas like New York City where automobile use is so difficult it precludes that option for most.

INTERSTATE HIGHWAYS

Interstate highways work reasonable well but they are too slow for the distances being traveled. A successful system would need to augment what the automobile already does which is to go from slow local distribution roads to fast intercity systems without changing conveyances. Obtaining 150 mph on a guideway would make ground travel time competitive with air travel for trips of 300 miles or less. Here is a case where speed counts because it directly effects customer satisfaction. A 300 mile trip at 150 mph would take 2 hours, faster than the time needed to fly when preflight and post flight time is factored in.

A system vehicle that can go directly to high speed intercity travel can successfully compete for the short haul air travel dollar.

FREIGHT

Urban and intercity expressways mix heavy freight haulers and passenger cars. The great differences in size between cars and trucks and to a lesser degree their differing speeds is highly stressful and dangerous. Trucks have a tendency to bunch up and then engage in turtle races going up hill. Getting caught in the middle of a melee of trucks using both lanes on an interstate can be both frustrating and terrifying. Separating passenger vehicles from freight vehicles will be better for both.

Guideway systems offer the possibility of automatic freight delivery. It is possible to modularize most truck loads to fit a vehicle with the approximate size of the passenger vehicle. There are options to segregate the functions by limiting the hours of freight use, perhaps to the middle of the night. If a large vehicle freight operation is needed it should be on a separate system.

Attempts to accommodate large freight vehicles and passenger vehicles on the same system will cause one or both functions to be suboptimal.

PARKING

The requirement to park near shopping and work has decimated older urban centers by destroying needed buildings for parking. Shopping is a pedestrian activity and a continuity of buildings along the street front is required for a successful shopping experience. Newer cities, like Phoenix, are almost totally defined by the automobile and offer plenty of parking but lack the community and quality of life I have come to expect living in a small eastern city. Even there, an aerial photo of that small city shows 40% of the downtown is taken up by parking.

Driving this extraordinary use of space for parking is private ownership of automobiles. Suppose every time you went to the supermarket you had to retrieve and use your own personal shopping cart. Reuse of vehicles not only lowers the number of vehicles needed but also makes storage much more compact and retrieval much easier. Utility vehicles can self park or return via guideway to another location to accommodate other users. Vehicles can be parked tightly together or in automated storage facilities.

The customer can always take the nearest vehicle.

GUIDEWAY RIGHT-OF-WAY AND COSTS

In the nineteenth century, the federal government ceded a wide right-of-way across the country to entice private money to build the transcontinental railroads. Today public utilities are given rights aways access to public roadways. The rational, I believe, is to save money for access that the public would have to pay to the utility and to avoid cutting and junking up the landscape and neighborhoods with unnecessary corridors. Although it would undoubtedly take some negotiating fitting, a guideway into expressway and interstate right of ways would be both logical and essential.

Guideways need to be isolated on grade activity. I agree with the solution of most designers which is to elevate the guideway on pylons. Pylons put a small footprint on the earth and relinquish the ground level to other traffic, pedestrians, or in some cases wildlife. Varying the length of pylons is an inexpensive way to adjust the guideway's grade. Use of an expressway lane on grade would work if barriers protected the guideway from other traffic.

Any guideway system that becomes widely adopted will be much less expensive than a highway because it is a component system with manufactured parts. Highways require sculpting great quantities of earth and are all custom built. For example, the $20,000 automobile that comes from the dealer cost several million dollars when it was first custom built as a prototype. The price differential between highway construction and guideway assembly will not be as great but still quite significant.

Guideways will need to gain access to already existing highway right-of-ways.

COST COMPROMISES

Designers sometimes make compromises to reduce costs. Costs, however, are not a determining factor in the adoption of a system. As noted above, assembling guideways is much less costly than constructing highways and one guideway has the potential to carrying the traffic load of a multi lane expressway. The costs of the guideway should be compared not with a lane of road but to building an expressway. Below is a project description for a spur of the Pennsylvania Turnpike with construction cost estimates of 35.6 million dollars per mile or 17.8 million per direction.

These estimates are about the system costs projections for building the PRT Rosemont system in the late 1990's. Rosemont was a prototype, custom built system, with vehicle weight in the range of the TGT proposal. Its estimated costs were roughly comparable to typical turnpike construction.

> The Uniontown to Brownsville project consists of approximately 17 miles of new limited access highway between US Route 119 and PA 51 in Uniontown, to PA Route 88 west of Brownsville with an estimated total construction cost of $605 million. The total project cost is estimated at $880 million, which includes construction, preliminary engineering, environmental impact studies, final design, utility relocations, right-of-way acquisition, design management and construction management. To date, approximately $32 million in federal highway money has been committed to the project.
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> http://www.mfe-union-to-brown.com/description.htm

When guideway components are standardized, in production, and there is competitive bidding, their costs will become significantly less.

Costs are not the determining factor in system adoption.

Enclosed or Tubular Guideways

The proposal to operate within an enclosed guideway is nearly unique. I know of only one other system that uses this configuration. Many, but not all, proposed and operating systems shield the running gear from direct weather exposure. Given the tight tolerances needed it is unacceptable that traction would be compromised by rain or ice.

Enclosing the guideway increases costs but offers compensating advantages. Enclosure allows modified electric automobiles to use a guideway with tight operating tolerances that exposure to weather on the running surfaces would preclude. A tubular guideway organizes air flow and greatly reduces air resistance. The enclosing structure also provides a surface for mounting solar panels.

Experimental solar cars are extremely light weight and aerodynamic and are able to run at moderate speeds in direct sunlight using only solar power. The roof surface of an enclosing guideway provides several times the area per car for capturing solar energy this combined with the reduced air resistance within the guideway would make solar input significant.

Enclosure brings a new set challenges which include tight lateral control of the vehicle within the guideway. There is a need to clean the underside of the car upon entry to the guideway to keep ice and debris out of the guideway. Vehicles need to have their operating condition certified when entering the guideway.

Tubular or enclosed guideways will allow a lightly modified electric automobile to be used as a guideway vehicle.