Abstract

Versatile and convenient, automobiles remain our dominant choice for personal transportation. Intelligent highways and intelligent vehicles will greatly improve present road capacity to handle numerous vehicles, but the technology will do little to reduce energy consumption, increase average speed, or help parking density. An intelligent highway implemented as a track, however, as this paper will show, can greatly affect energy consumption by the exclusive use of small, lightweight vehicles and by configuring them as aerodynamic trains at high speed. A track motivates users to buy small energy-efficient vehicles by delivering faster travel, indeed services only this specialized vehicle type, and then provides both safety by isolating them from other types of threatening traffic. A track enables designers to deliver lightweight vehicles intended for limited street use at low speed, and the benign environment of a track at high speed. An electrified track distributes renewable energy as it reduces battery requirements. Configured to provide that power, occasionally elevated to successfully co-exist with today's streets, tracks can be configured with amazingly small structures. Thus track line will possess the finesse to thread successfully through existing infrastructure. Even interchanges, needed in any non-stop grid-based network, can be built above ordinary street intersections. Energy efficiency, capacity, speed, and safety in a new roadway genre.

Background and Impact

One should properly salute the automobile and our resulting automobile-based society, triumphs of the 20th Century, enabling unparalleled mobility and freedom for the individual, but then lament their obvious limitations. The limited capacity to transport large numbers of people is clear, and is ascerbated by the continued use of mixed vehicle types and frequent street intersections. Encumbered by these limitations, the automobile-based society is rightly accused of promoting urban sprawl, incapable of supporting dense, livable urban communities. Consuming space and destroying neighborhoods, freeways are clearly incompatible with a compact urban landscape. Our congested streets and freeways thus limit automobiles in cities so severely, they move on average at 20% their designed top speed. Requiring enormous energy, our large and powerful vehicles are built for five passengers on the open road but are largely used in the metropolitan scenarios with one or two. Moving people consumes fully 20% of this nation's entire energy budget, and moving people in metro areas consumes the majority of that value. The capital cost of parking a vehicle in urban areas is thought to exceed the cost of the vehicle itself. Yet automobiles remain our dominant choice for personal transportation, and, worldwide, the automobile is on a path to quadruple in number by 2050.
Proposed is a new generation of roadway for existing cities and suburbs; superimposed upon existing infrastructure, and using existing right-of-way. Small structures will support small electric vehicles exclusively, extending our concept of strictly controlled access, and relegate large trucks to our present correspondingly huge freeways. Full, high-capacity interchanges, also tiny in size by comparison to the monsters of the freeway, are to be built above the footprint of ordinary urban intersections, and thus allow ubiquitous penetration of the urban interior. All traffic flows without interruption. Reliable computer networks, redundant sensors, electric motors, and speed-of-light communications assume control from human drivers on these new roads. Equipped with small adapters for the tracks, the small vehicles are driven both on the new roads and on the old streets. The computer drives the new roadway; the individual drives the local streets. The new roadway motivates the driver to buy a small vehicle by promising faster transport, and then isolates them both for protection.

Since the new vehicles must only withstand the rigors of limited use on low-speed city streets, and be most commonly designed in recognition that 90% of our travels require only one or two passengers, they can be built to be very light. Thus, using available Prius-equivalent energy efficiency, the energy consumption of such a vehicle would be 100 mpg equivalent on city streets. When slip-streaming at high speed within a “train” of vehicles on the new roadway, the vehicle’s consumption calculates to be 200 mpg equivalent at 100 mph. Propulsion by an electrified roadway would not only constitute a much desired electric distribution network, but also empower these small electric vehicles with modest and inexpensive battery packs. The close proximity of the adapter to the track allows for efficient energy transfer -- in contrast to the difficult energy transfer to an open road vehicle.

The new road has the small size and finesse to thread through existing infrastructure and co-exist with our present transportation system, but with electronically controlled spacings, uninterrupted traffic flow, and very short vehicles, the new roadway can move roughly 50 times the number of vehicles that a city street can when configured to fit on the small city street, and by a similar margin of 50, for a given width, compared to that of a freeway when configured for high speed. Door to door transit times would be roughly half that of today’s typical surface street trip, or of a mixed surface street/freeway trip. Parking density for a ‘public’ garage would be 10 times compared to today’s, allowing commuter parking for, say, New York’s Manhattan Island. Nationally, replacing roughly a quarter of all surface travel, the new Roadway would have safety to save roughly seven thousand lives and half a million injuries a year. Thus the new roadway would enable a car-based society to support larger cities with greatly increased population densities and allow them to properly function with convenient transportation. Larger cities would be free to safely evolve without congestion, with transportation for their very mobile citizens consuming only 2% of today’s U.S. per-capita total energy budget, while achieving low-cost efficient access to renewable sources of that energy. Fast, convenient transportation would allow citizens to truly communicate with entire large metropolitan areas as if those areas were their local neighborhood.

In summary this writing envisions a transportation system for people, massive numbers of people, each traveling their unique door to door routes, each with their unique timing, each in the comfort of their private vehicle, while consuming roughly 10%
of today's per-mile energy. No trucks, no buses, no SUVs allowed. No stop signs, no red lights, no intersections. No transfers, no congestion. A transportation of people with time efficiency, space efficiency, and fuel efficiency. Automated, safe, pleasant to use.

Technology

A small vehicle -- presumably electric, presumably privately owned, but perhaps rented in private transactions or a public asset available for single trips -- is needed. Designed for low-speed urban and suburban streets and the benign environment of a track at higher speeds, it can be light. It can also be small if individuals supplement its use with a general purpose family or rented "highway" car, needed only on occasion. An intelligent car, mechanically or virtually attached to the track, can be evolved from technology presently in active development.

Power dissipated by a moving vehicle is largely the sum of three components: road drag - generally considered to be proportional to the weight of the vehicle, wind drag - generally proportional to the square of the vehicle's velocity, and power train friction - largely proportional to the size of the engine. Thus a small car, yet one tall enough to be safely seen in traffic [e.g. 1.5m] and wide enough to seat two passengers side-by-side, can greatly reduce these three components. First, it will reduce wind drag by travelling at low urban speeds [e.g. less than 35 mph]. Second, it will possess a small engine which will be adequate for the low speeds intended. Third, its small size, small engine, and lack of hardware for high speed will allow for light-weight construction. A Toyota Prius, built for high speed [105 mph] with an efficient moderately-sized engine and regenerative power system, gets about 50 mpg in the city. Given the advantages listed here, the vehicle proposed is calculated to get above 100 mpg.

Though built for low speed on the road, the vehicle's characteristics change on the track. Again, three features allow for it to obtain far higher speed when rolling on the track. First, travel is non-stop, and a small engine can, in time, accelerate the vehicle to higher speed on a smooth track. One point design uses a 15 hp motor achieving a top speed of 60 mph. Second, with an intelligent vehicle on an intelligent track, multiple vehicles -- grouped on a first-come first-included basis in moderate to dense urban traffic -- can be tightly platoonied in train-like configurations. Preliminary aerodynamic calculations indicate top speeds of 100 mph for trains of several or more vehicles using 15 hp each. Vehicles may or may not have drag-reducing fairings. Finally, the benign track environment bodes well for superior performance of the proposed lightweight tire-wheel-suspension system even at these high speeds.

The track can distribute power and drive vehicles thus permitted to have very modest and inexpensive battery packs. At this time, given battery technology, such an approach would reduce vehicle cost by about 50%, and is a 'holy grail' for the electric car industry. The track provides a low-cost, ready-made conduit for electric transmission-line cable, but progress must be made in the technology to transfer power to the vehicle. Third rail and pantograph sliding contacts are established methods. Reactive drives are presently used for so-called light-rail trains and for ascending roller coasters. Resonant circuit non-contacting power transfer is a research subject for intelligent highway approaches. While resonant power transfer is not proven, a track
provides major advantages compared to open-road to vehicle geometries. The cost of these latter techniques is key.

An intelligent, electrified track will provide a narrow defined path, regulate vehicle travel and relative positions, including contention resolution and routing. But the track must be elevated -- at least for key stretches. This requirement follows partially from the fact that, since the track must co-exist with existing streets and freeways, it would be disruptive to expend existing right-of-way for the track's development. Second, and more importantly, the speed and capacity of any grid implementation depends on non-stop traffic flow enabled by interchanges -- an intrinsically multi-level and thus elevated structure.

Many modern bridge-structure designs now provide guidance for graceful and mechanically minimal track structures. The light vehicles become an easy burden. The century-old elevated track we know today in our established urban areas, as built a hundred years ago for immensely heavy trains, is no guide as to what could be.

The interchange is a major Achilles Heel for today's urban freeways. A high-speed, fully-functional freeway interchange subtends fully 40 areas, and the purchase of urban land dominates its cost of construction. A high-speed tracked interchange can be designed on about one acre. A low-speed interchange designed for right and left turns at 25 mph and non-turnings traffic at 40 mph can be fabricated in a 10 meter square area. This surprising size would allow construction above an ordinary street intersection and allow a non-stop transit grid in dense urban cores.