THE TEV PROJECT

TRACKED ELECTRIC VEHICLE SYSTEM
Reference Booklet version 7.15

In a few years this battery powered car, and others like it, will be able to drive endlessly - even across continents - ***without recharging or burning fuel of any kind.*** *These EVs will not only be the equal of your present, fuel-burning car, they will be* ***vastly superior****. Surprisingly, their secret is not in improved batteries, or even the design of the cars. Their secret is a* ***dedicated, electrified guideway inspired by the simple slot car track****. Welcome to a better future, welcome to TEV.*

Our prediction: Electric cars will become dominant all over the world – but only when they have a low-cost, safe, fast and efficient electric highway system like TEV.

Introduction

This booklet

This booklet describes a simple modification to our existing transportation system to carry people and light freight. It uses conventional, **production** electric vehicles such as cars, taxis, vans and minibuses but in a safer and more efficient way. It is a "user-friendly" addition to our present road system to be built over a few decades. Think of it as a ***new, electrically powered, smart highway*.** Here are some highlights:

- The system is called TEV, which stands for "Tracked Electric Vehicles". (TEV rhymes with BEV as in Beverly)
- TEV vehicles are ***electrically powered*** so they do not burn carbon-based fuels. However, ***engine powered*** vehicles are compatible and could be used initially.
- All vehicles run on rubber tires; there are no rails. (But see a completely separate design for cargo vehicles in the appendix).
- Some of the vehicles can be driven on normal roads as well as on the TEV tracks. These are called "Dual Mode".
- Other vehicles never leave the track, but go from one Stop to another. These are called "Single Mode".
- The track system forms an ***international electric highway*** network with all countries using the same design standards.

TEV is not another well-meaning public-transit scheme designed for city-folk. Nor another academic exercise based on technology that doesn't exist. TEV is very practical and down to earth. It is compatible with city AND suburban living. It handles public AND private transport functions equally well. It also tries to please the customer so it is likely to be very popular.

Compared with our evolved hodgepodge system of roads and rails, TEV will be:

- faster
- safer
- more flexible
- more comfortable
- more energy efficient
- better for the environment
- cheaper to build and maintain

TEV will require no government subsidies because it will be a good investment, and it will have a **much higher** passenger carrying capacity that any practical medium-range to long-range system ever conceived, including high speed trains. Door to door it will also be faster and safer than any land based system.

Furthermore, TEV will burn no precious oil, or carbon based fuels, or inefficient hydrogen for that matter. It can be sustainable in energy for at least **the next several centuries and probably for millennia. But that is just** a beginning because it will also reduce problems like:

- traffic jams
- highway fatalities
- diesel fumes
- road noise
- parking shortages
- potholes
- fog-snow-ice or debris on the roads
- drivers who are drunk, speeding or incompetent
- speeding tickets, speed traps
- road rage and stress.

Best of all, the basic technology for TEV already exists. It doesn't need any "breakthroughs" to make it work; no magic batteries, no weird propulsion systems; nothing risky at all. All it needs is competent engineering. TEV is basically **so simple** that, on a technical level, it has virtually **no risk of failure**.

Automated Highway System (AHS)

At first sight, TEV looks like a variation of a 1980s concept called "automated highways" which, due to brilliant advances made by Google and the car companies recently, is now being accepted by the public as a near term possibility.

But ***all AHS systems have one fatal limitati***on. They must be restricted to slow speed city and suburban driving because they are too dangerous to carry people at high speed under automatic control in bad weather, like a rainstorm or when there is ice on the roads. If you add a mix of traffic from heavy tractor trailers to motorcycles, AHS becomes a safety nightmare.

By contrast, TEV has ***restricted access which*** puts them in a class of their own. If the tracks are covered by a roof, one could drive safely at any speed in any kind of weather.

Furthermore, TEV tracks can be made from precise standardized parts, manufactured in clean factories with modern equipment and professional quality control – and then installed on foundations with laser accuracy. There will be no potholes on a TEV track.

Happily, ***TEV vehicles already have all the features of self-drive vehicles*** so they can serve as low speed driverless vehicles in cities but, for longer distances, they can run at high speed on safe, dedicated tracks.

Investment

The capital cost of dedicated TEV tracks will be high, of course, like any major infrastructure project. But due to TEV's enormous traffic-carrying capacity, the **cost per passenger-mile is quite low**. For example, a two lane TEV track will cost much less to build than a 6-lane Interstate Highway and yet have three or four times more carrying capacity, a much higher cruise speed, vastly better safety, and much higher energy efficiency. (See Chapter 12 for details of the costs of highways).

Another benefit is that the TEV system can accommodate cars with IC engines on the track - if they meet certain standards. We discuss this later.

TEV will be a **genuine investment** that will pay for itself quickly though user tolls, automatically collected from tollbooths. It will also eliminate many wasteful subsidies now given to marginal public transport schemes, especially railways.

Getting funding should not be a problem; the present trend in road construction is towards a "public private partnership" (3P) where the risk is transferred from the public to investors. In some countries bond issues underwritten by governments could also do the job, just as they did for the Interstate Highway system in the USA. But, preferably, the TEV project should be funded privately as a profit-making enterprise. Governments will then tax the proceeds as usual so they will be happy.

TEV is not just for developed countries and there is no point in stopping pollution in the USA and Europe if China, India and other large countries are stuck with an oil-burning transportation system. TEV is exactly what these countries need to build sustainable economic growth without ruining their environments. Being largely an infrastructure project TEV will also create a lot of well-paying jobs for people in their own countries. **TEV is open source** so there are no royalty payments.

So welcome to our idea of the future! Welcome to TEV. We hope that you will become as optimistic as we are that this efficient, pleasant, and environmentally ***sensible*** system could be your gift to your grandchildren. Please help make it come to life.

How this book is organized

Chapter 1 is a short story about an individual who uses a **private** electric car, like a Nissan leaf or a Tesla, on the TEV system to get to a meeting in really bad weather. The story touches briefly on taxis and minibuses and mini-vans along with their benefits. This chapter alone will give you a good, non-technical feel for the TEV concept, particularly how simple it is.

The other chapters provide more detail of the system such as passenger capacity (huge), parking (automatic), freight handling (low cost), and so on. One of these chapters is about nuclear power production and is a ***must read for techies.*** There is a small section about the “hydrogen economy” (no such thing) and fuel cell cars (OK, but so what).

The technical information is straightforward and provides proof of the stunning superiority of TEV over **any of our present systems** based on roads and railways.

We also hope that this little book will leave you with a sense of astonishment that such intimidating problems like traffic jams, pollution and oil dependency can be solved **with ease**.

Will Jones
Freeport
The Bahamas

PS:
We would love to hear from engineers and specialists of all kinds like tires, tunnels, aerodynamics, structures, costing, power transmission and other fields.

Please feel free to challenge our assumptions and calculations on: www.tevproject.com

Contents

1 A ride into your future

On the road

It's 8 am in your New York suburban home. The Chairman just called from Washington, DC, and asked you make a presentation at the board meeting today. You are thrilled at the opportunity. However, the meeting starts in just three hours, Washington is 200 miles away, and a severe snow storm is forecast for the entire North Eastern seaboard. The only transport you have is your electric car. No problem; you will use the TEV system.

Grabbing your briefcase, you open the garage door and climb into a streamlined but otherwise normal looking compact car. The electric motor hums as you drive out onto the tarmac road on your way to the TEV Station, just a few miles away. This particular car is a "pure" electric vehicle (EV) powered by batteries. It has no engine at all, and consumes no fuel of any kind. You don't need enormous batteries because, for long distance travel, this car runs on electrically-powered guide-ways. On these "TEV tracks" ***you never have to stop for recharging*****.** In fact your battery gets charged as you drive**!**

This Nissan Leaf and other conventional EVs are ideal for TEV

On the track
A few minutes later, with snowflakes starting to fall, you turn in to the TEV Portal. This is your local entry point to the TEV Electric Highway network and is the connecting point between the normal roads system and the TEV system. You can see the slim, elevated Express Track overhead, supported by pylons. It looks too small to have much passenger carrying capability, but you know better, *because* ***nothing on earth compares with TEV on that score***.

As you approach the Portal, a polite female voice says, *"Welcome to the TEV network. Enter destination number, please".* You punch in your exit destination code, which is the number of the TEV Station where you will disembark. The computer will not allow you on the track without giving this information. You could have programmed it last night. *"Thank you,"* says the voice*, "You will be in Lane One."*

The car steers into one of several parallel lanes that look a bit like tollbooths and stop behind a handful of waiting vehicles. In periods of heavy traffic, the TEV computer arranges the departing vehicles into groups or "convoys". In quiet periods you just go straight on to the track without waiting.

There is a slight clunking sound from the front of the car as a mechanism called a "Switch" drops in to a guide slot on the track. The Switch is just a safety device; ***it does not steer the car***. Automatically, the car windows close, the doors lock, and the outside mirrors fold flush with the bodywork to reduce aerodynamic drag. The car is now in full autopilot mode for the duration of the trip. "Drive by wire" controls have taken over the accelerator and brakes, and the disconnected steering wheel turns harmlessly if touched. The computer has checked the safety of all systems on the vehicle down to the tire pressures. TEV doesn't allow on to the track any vehicles with unauthorized trailers, roof racks or appendages of any kind that may fall off. If the vehicle fails this inspection, it is rejected. Safety standards are very high compared with normal highways ***which have essentially none.***

"Prepare for takeoff," announces the cheerful voice. The cars in your convoy begin to move forward in unison, climbing up the entry ramp and on to the long acceleration lane next to the main track. The acceleration itself is firm, but less than that of a commercial airliner taking off. In less than half a minute your little convoy is traveling at 120 mph (200km/h). The cars then merge smoothly sideways on to the Express Track itself just like joining a normal highway. A second

slight clunk from the front of the car indicates that the Switch has locked you safely on to the main track. Your car is now in cruise mode and you can relax.

The 2-lane elevated track you are driving on is like a rectangular tube. Next to your tube, on the left, is an identical tube for vehicles coming the other way. Each tube or enclosure is a little wider than the vehicles inside it and has a ceiling or roof that is high enough that a person can walk inside in an emergency. In other words, it is snug, and much less wasteful of space than a typical highway lane. There is no passing lane, no hard shoulder and no slow lane: all vehicles go at the same speed on a TEV track.

This is a section of a 2-lane elevated TEV track in open countryside. It looks more beautiful and is far quieter than a regular motorway even though it has a greater capacity than any highway on earth. The tracks can also be laid on the ground, on old freeway lanes, replace old railway lines, and in low cost, small-diameter tunnels.

In between the two track lanes there is a continuous translucent window to keep out wind buffeting from vehicles coming the opposite way. On the driver's right side there is a continuous window opening that gives an airy feel because you can see the outside world. In some locations this opening may be covered with wire mesh to keep birds and other animals out. In other locations, these side window may be partly covered in glass to keep bad weather out – as well as keep any noise the TEV vehicles make inside the enclosure and not disturb the local people. A continuous safety barrier is provided on either side of the track. Emergency exits are also provided.

TEV vehicles run on rubber tires, both on the track and on the roads; there are no steel railway lines or other such contraptions on a TEV track. On the floor of the enclosure, under the tires, are two continuous strips of “roadway” which look more like wide strips of sandpaper than a normal road surface. These “friction surfaces” are detachable and are simply removed and replaced by specialized strip-laying equipment when they become worn with use (see Chapter 7). On the floor is the safety guide slot for the Switch. Nearby there are two electrical contact strips that power the car on the track - and also recharge the main battery while under way. (Note: the details of these features are to be decided in the Design Review phase of the project).

In built-up areas the enclosure is carefully designed with sound-absorbing material so that most of the tire and wind noise is contained inside. Everything is optimized for energy-efficient travel at speed with banked turns, smooth road surfaces, streamlined vehicles and, most efficient of all***, no stopping and starting*****.**

Your particular Express Track is elevated on pylons so that it can fly over suburban roads efficiently. It has just two side-by-side lanes, one for each direction, the total width is only a little wider than the two cars. But while it does not look very big or impressive, amazingly, each of these slim lanes can move more people than *ten lanes of conventional highway*. That’s not a misprint; this narrow pair of tracks has a capacity roughly equivalent to a ***20 lane highway***; far more than any conventional highway on earth!

The TEV computer moves incoming vehicles forward to tuck in behind the convoy in front. This creates space behind the convoy for other vehicles to get on to the track. Convoys substantially improve the energy efficiency of the system by reducing drag on the cars (AHS studies suggested about 50% but TEV will do better) The TEV vehicles and the track structure are designed to take advantage of this effect.

Despite the high cruising speed, the ride is very smooth because there are no potholes or bumps on this roadway. Each vehicle in the convoy is separated from its neighbor by only a meter or so. But there is no mechanical connection between the cars, just a computer-maintained distance. Many people thought that close driving was dangerous but, the opposite is true. ***You simply can’t crash into a car that is only a few feet in front of you.***

Unlike high-speed railway systems, which tend to have a side-to-side jerkiness due to the rigidity of steel-wheels on steel-rails, the TEV cars can flex a little laterally making for a more comfortable ride, just like a conventional road car.

The suburbs are quickly left behind, replaced by hedges and fields flashing by. The snow is now coming down hard and the countryside looks like a Christmas card. A small herd of deer wander calmly under the track, undisturbed by the enormous momentum above. It is a relief that animals and humans can share the countryside in peace. Where necessary, the track goes underground to avoid conflicts with man or nature.

Some of the cars ahead of you have left the convoy at various exits and others have joined up behind you. A feature of TEV is that any vehicle in a TEV convoy ***can exit at full cruising speed*** without disturbing the other vehicles. This is a very important feature and vital to any future transportation system. It gives TEV tremendous flexibility which trains, trams and other types of rail-bound vehicles, can never match.

Unlike trains, TEV vehicles ***never stop on the track,*** except for emergencies. They pull off the track to stop and let the main traffic go by at full speed.

Freight and public service vehicles

As you fly over an industrial area you glimpse some windowless TEV mini-van vehicles, equipped with commercial signs, on a nearby track. These are ***driverless,*** parcel-delivery vans which have revolutionized the light freight business with their low-cost and on-time deliveries coupled with environmental cleanliness. They carry packages and pallets to factories and distribution centers and make deliveries at all times of day and night. On a normal road system the cost of the human driver has a big effect on total freight cost so the larger the truck the more economical it is. Unfortunately, this encourages the construction of monster trucks often with multiple trailers. But on the TEV system, with driverless vehicles, small really is best, and many large road-going trucks can now be replaced with small, non-polluting TEV vans which run a just-in-time delivery service.

There are also other kinds of driverless vehicles on the TEV network including mini-cabs, mini-buses and mini-trains. Most of these have flexible schedules and will run whenever the people need them. So, in many ways, they are ***more convenient*** than private cars. Further, they work in seamless conjunction with private cars and, off the track, with conventional trains, buses and aircraft to form a superbly advanced, integrated public transport system. The result is that many city dwellers no longer use their cars for city commuting.

You smile to see that the old lady in the Robo-cab in front of you seems quite relaxed doing 120 mph - with no driver on board. The truth is that she is very safe. The TEV computer - called Hal of course - is a much better driver than emotional humans will ever be. Hal never gets drunk, upset, tired or aggressive. And Hal never dithers. He has electronic foresight and knows what is going on over the horizon. It is reassuring to remove the deadly risks associated with human drivers, at least from some of the driving experience. TEV saves thousands of lives every year.

The snow is now causing serious problems on the roads below. Visibility is bad and the traffic is backing up everywhere. Commuters who drove on the regular roads, automatically driven or otherwise are going to be late for work today. But you don't have that problem. Inside the TEV enclosure, you are unaffected by the weather and don't even have to slow down. Usually, the energy of the rubber tires on the track friction strips keeps ice at bay during normal traffic conditions. But if the weather gets really bitter, the friction strips are automatically warmed by electrical heaters.

In these bad weather conditions it becomes obvious that the weakest links of the conventional road system are the *intersections*, particularly cross roads and T-junctions. By contrast, on the TEV system there are ***no intersections**,* only ON ramps and OFF ramps, so ***you can never T-bone (run into the side of) another vehicle***. One of the efficient feature of TEV is that the wasted time of stopping and starting in traffic is almost completely eliminated. Another feature is that TEV is automatic and you don't have to drive. So, you relax, pour yourself a cup of coffee from a flask, and brush up on your presentation before settling down for a short nap.

What traffic jams? What parking problems?
The switch clunks again and wakes you. The car is leaving the Express Track on an exit ramp. Banking gracefully around a curve as it slows, it automatically merges on to a commuter track crossing below. Daylight dims as the new track enters a tunnel. You are now driving under the suburbs of a major city at 60 mph (100km/h) without disturbing anyone on the surface. This one electric track removes tens of thousands of vehicles every day from the surface roads, with enormous benefit both to the local inhabitants above and to the travelers below.

In fact, even the "surface" roads are more pleasant to drive on these days. The local drivers are seldom in a hurry and the impatient "outsider" traffic has all but disappeared.

A different and surprising contributions of the TEV system is the way it solves the age-old problems of competition for space in cities. Rather than build divisive rights of way on the surface, such as train tracks and highways do, the TEV system simply uses elevated tracks or tunnels *under the cities*. Not just one tunnel here and there, but ***lots of tunnels, all over the place!*** This solution is only possible because:

- TEV tunnels are small and relatively cheap to bore – far cheaper per mile than urban highways on the surface.
- They can carry so many vehicles
- The cars are electrically powered.

This simple approach curtails the endless political arguments that used to accompany any new transportation improvement: ***there are no existing rights of way underground!***

In the past, some well-meaning public servants have aimed to solve congestion by *making it worse*, thereby adding to the public stress. But life is not a zero-sum game; it is about new opportunities. TEV doesn't make traffic jams worse, *it makes them obsolete; it* doesn't add stress to people's lives*, it adds peace!*

"Approaching destination," the lady in the computer announces. With a clunk from the Switch, the car exits the track, merges on to an exit lane and, still underground, decelerates into a small, brightly lit Station. The track splits into parallel lanes and the car enters one of these lanes and stops.

"Select parking option and disembark promptly, please," orders the computer lady firmly. Slow compliance here will cost you money because the TEV system relies on cooperation and discipline to work efficiently. There are separate "slow bays" for handicapped folk, of course.

You touch the option on the screen marked "One Day Parking", collect your briefcase and climb out on to the platform. You will waste no time looking for a parking space because TEV will do that for you. As you walk away, you press a button on your mobile phone. Your now driverless car moves off into a tunnel and heads for an automatic parking zone which may be located nearby or miles away. Who cares?

Most short term parking areas these days are nothing more than loops of TEV tunnels located underground so the cars never even go up to the surface streets unless they are driven there for a purpose. The technology is more like storing data on the hard-drive of a computer than traditional parking. Indeed, TEV technology is more closely related to packet-switching technology used in telecom systems than it is to older transport systems.

Later, when you want to go home, you will push the TEV app button on your mobile phone. The car will retrieve itself and be waiting for you at the Station at which you disembarked, already warmed up for your comfort. Or, if you prefer, it will meet you ***at any other Station in the entire network***. Or it can even drive itself back to your home Station where your spouse can pick it up, if you want it to. How convenient is that? The TEV system ***aims to please you*** by giving you options, unlike most present public transport schemes that inevitably limit options. (Have you tried catching a bus at 3 am?)

Therefore, on top of its other contributions, TEV also solves *city parking problem* - and does so with such embarrassing ease that one wonders why it took so long to implement. All this is from a system whose main virtue is reducing oil dependency and global pollution.

(Note: Ending parking problems in cities will make cities **blossom**. Cities will, once again, be a hub of specialized destinations that are easy to get to and enjoy). The drudge of car parking will be history.

Please note, in passing, that all these TEV benefits are available to taxis, Robo-cabs, and mini-buses. ***You don’t need to own a car.***

Happy ending

You climb the exit steps of the TEV Station, emerging on a quiet street a few blocks from the White House. Despite the urban surroundings, the absence of traffic noise and pollution makes it quite serene. Cities are so much more green and pleasant now.

You walk to your appointment refreshed and in plenty of time. The Chairman looks at his watch and nods in appreciation. You have covered over 200 miles, almost door to door, in less than two hours – in extremely bad weather. All the while, you have been safe, comfortable and productive. What’s more, as a good citizen, you have consumed very little energy and produced no local pollution. Now you are going impress the board with your brilliant presentation and be home for dinner with your family. Hey, life doesn’t get any better than this!

2 Single mode and dual-mode vehicles

A basic feature of the TEV system is that it uses familiar vehicles such as cars, mini-vans and minibuses as the primary transport modules for people and goods. This has three major benefits.

- First, there will be little or no resistance from the public to convert to the new system because it will simply be seen as a convenient extension of the present road system.
- Second, the enormous expenditure required for developing special vehicles will be avoided because the automotive companies will be willing and able to do the relatively minor vehicle development required.
- Third, many of the vehicles will be paid for by their owners, just like our present road vehicles, and not by public bodies, thereby avoiding yet more public capital expenditure.

(Note: Any transport system which uses private vehicles may seem politically incorrect to those who see the future in terms of state-owned public transport systems. But, since TEV solves the public transport problems so well, and at a much lower cost than existing systems, TEV will soon appeal to them too).

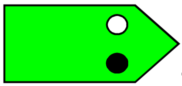
A second basic feature of TEV is that it uses a ***restricted track system*** where many conventional vehicles cannot go. These "TEV Tracks" are purpose-built, optimized guide-ways, where vehicles are driven, often at high speeds, under full automatic control. Think of the track system as a new type of ***electric interstate highway.***

A third basic feature is that TEV vehicles are divided into two types called **Single-mode** vehicles and **Dual-mode** vehicles. Single mode vehicles are restricted to the track at all times during operation, unlike most present day trams or trains, and are usually driverless. Dual-mode vehicles, on the other hand, can likewise drive on the tracks under automatic control, but *can also be driven on normal roads by humans just like conventional cars and vans. (Note: As noted earlier, TEV cars are fully compatible with self-drive cars like the "Google car" and other robotic cars when they are available).*

Let's start with Dual-mode vehicles

The use of "dual-mode" vehicles which can drive on normal roads as well as on the high-speed tracks makes TEV very different from conventional transport systems that use trains, buses, cars or trucks. The icons below represent various kinds of dual-mode TEV vehicles, beginning with the *dual-mode cars*. All these vehicles are advances over existing cars and vans, but some are truly revolutionary in their abilities and functions.

The specific shapes of the icons are not relevant. A white circle represents a human driver and a black circle represents a passenger. Let's review the vehicles in sequence.



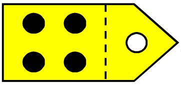
1. The TEV car: a truly revolutionary advance; a privately owned, dual-mode personal transport for the masses

This dual-mode vehicle car can drive on both restricted TEV tracks and on public roads. It enters and leaves the track network at special points specifically called **Portals** because TEV also uses the terms "**Stations**" and "**Stops**" for other specific structures. For the present, at least, dual-mode vehicles need human drivers when they are driven on the roads. However, they operate automatically on the track – even without a driver. For example, a driverless TEV car could be sent to an airport to pick up a passenger. It could also be sent across the country. Amazing new possibilities are now available.

This dual–mode car may be a "pure" electric vehicle (EV) with battery power only, or a hybrid with a small engine-generator on board. It could also have fuel cells instead of an engine – if these ever become practical. On the track, however, ***it is ideally a pure electric car*** that produces no local pollution.

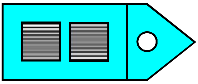
Of course, this is an idealized scenario because most vehicles in the near future will still be engine driven. Can we allow such vehicles to run on TEV tracks? The answer is yes, it is possible, with some restriction: long tunnels and dirty exhausts come to mind. But there is no fundamental reason why they should not be allowed especially during the startup decade or two to help pay the tolls that built the system.

.



2. A dual-mode taxi

This vehicle is a TEV-compatible taxicab that has a human driver. It can take a passenger from door to door, just like any normal cab. However, since it can also use the high speed TEV track, its operating range is greatly extended which improves its value to customers and increases the revenue to the taxi driver. Off the track, it is powered by a hybrid engine to ensure adequate range on the highway.



3. A dual-mode parcel van

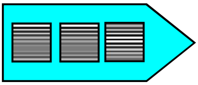
This is a dual-mode commercial delivery vehicle used by post offices and other package handling companies to make deliveries. A human operator picks up parcels from existing distribution centers, drives the van to a local TEV Portal and gets on the automatic track. Later, the van exits the track at another Portal and the driver takes it by road to the final destination. These vehicles may eventually have their own freight track system, operating at a lower speed (see appendix). Initially, however, they would be allowed to operate on passenger carrying TEV tracks, but only under strict regulations.

Author's note: The basic concept of "dual-mode" vehicles is quite old and many such systems have been proposed over the years. Some are sensible but others are impractical. However, all of their creators have made a contribution to the art and should be commended.

None of these creations are true "inventions" though they may contain specific inventions. Rather, they are alternative "designs" - variations of known concepts. This includes TEV. The advantage of TEV is that it is a simple, practical design that will actually work in the real world. We are not interested in technological breakthroughs. Our aim is to bring a reliable and efficient transportation system into operation quickly.

Now let's look at some "single–mode" vehicles on the TEV system.

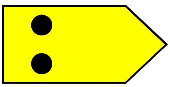
"Single-mode" vehicles in the TEV system are just as revolutionary, in their own way, as the dual-mode types. They use the same or similar tracks but, in normal operation, they are driverless and *do not leave the track network to exit on to public roads*. Instead, they stop to pick up and deliver their passengers (or parcels) at prearranged places called "**Stops**" which may be public or private**.** These Stops are analogous to conventional bus stops and are smaller and simpler buildings than "**Stations".** (Portals, as already described, are the specialized interfaces between road and track). Single-mode vehicles are like horizontal elevators; you get in, the doors close, you are taken to your destination of choice, and you get out.



4. Robo-van: a revolutionary, single-mode, driverless parcel- delivery vehicle

This is the TEV vehicle that will quietly revolutionize parcel delivery. ***In a sense, it may be the most important vehicle in the entire TEV flee***t. Owned by firms such as UPS, FedEx, and other logistic companies, these robotic vehicles will deliver parcels and light freight, often overnight when energy costs are lower. They will travel over hundreds, or even thousands, of miles with virtually no labor cost and no double-handling. For example, parcels can go directly from a supplier in Poland to a factory in England – or to India for that matter. Deliveries will be timelier, costs will be lower, and breakages much reduced. Just-in-time deliveries for manufacturers will make factories more efficient. Most importantly, according to initial calculations, it is probable that the revenues from TEV freight delivery alone *will pay for much of the construction cost of the TEV Electric Highway network.*

(*Note: These driverless vehicles can be adapted to exit on to* ***private*** *roads, and even on to factory floors. By following electronic guide-ways, they can deliver their payload to a specific assembly line*).



5. Robo-cab: a single-mode, driverless taxi

Robo-cab is another revolutionary vehicle that TEV makes possible. It is a driverless taxi cab that is summoned from any **TEV Stop**. The procedure is that you go to a TEV Stop, swipe a credit card or enter an order on your smart-phone, along with your destination number. This can be literally any other TEV Stop in the entire system. When your cab arrives, it displays your identification number. Another swipe with the same card or signal from the phone opens the cab door so you are assured of keeping your place in the passenger queue.

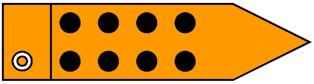
Video cameras record all vehicle entries and exits for security reasons. Robo-cabs can therefore be used by children, old people or handicapped people and can go across town or across the country if required. The price of using these cabs will be very low compared with driver-type taxis and this alone will make them immensely popular. The limitation, of course, is that Robo-cabs will only take you to the your nearest TEV Stop, not all the way home. On the other hand, it will be a cheap ride.

6. Robo-Minibus serves the suburbs

Robo-Mini-buses are simple horizontal elevators for people. They will be used for short trips on moderate-speed urban or suburban tracks. They are not intended for high speed or long distances but will bring the suburbs much closer to the city centers. They use the same kind of TEV Stops as the Robo-cabs. They are not truly revolutionary vehicles, perhaps, because similar designs already exist, usually in airports. Robo-trams will be a very useful form of public transport because they can use the same, well-developed hardware and software of the TEV system. Like many TEV vehicles, their schedules can be automatically adaptive to public demand. They can be used in convoys for commuter service, just like a train, but they are better employed as express vehicles that go directly to specific stops in the city. Remember, TEV vehicles do not stop on the tracks, so **express trams can bypass stopped trams**. Just imagine the saving in time! In time, these will replace crowded commuter trains which are amazingly wasteful of the priceless rights of way that they occupy.

.

Minibus: a nice public transport way to get into town without parking



7. The Robo-train; yet another part of the TEV revolution

The Robo-train is a good example how TEV can bring back good public transport service, long considered to be too expensive in the modern age. These small driverless trains will normally run at high speed for *long distances* between cities. The absence of a driver cuts their cost of operation substantially which allows them to provide high-quality transportation even to remote villages and communities. Their high speed on express tracks, makes them a wonderful improvement over slow buses and infrequent trains. A toilet in the rear, just like a tour bus, might be possible - if the vehicles were tall enough. If not, the trains could stop periodically for breaks. Scheduling would be flexible to ensure low ticket prices.

Fleets of these Robo-trains might replace normal trains in some instances. Ironically, ***that act alone would release some of the most valuable real estate in the world***, the rights of way of many underused railway lines, for use as TEV tracks. On each converted railway track, a ***pair of stacked TEV tracks might*** be installed, yielding a gigantic increase in passenger and light freight carrying capacity. This is explained later.

Could we really allow engine powered cars on the TEV system?
It may seem odd but it is quite practical to run combustion engine powered cars on the TEV track – so long as they have the same or compatible controls as the EVs. It doesn't make much sense in the long term because these cars use petroleum fuel. However, in the short term, especially during the startup decade of TEV, it would be a very good way to help pay for the construction costs.

Most of the car companies have been working on "self-drive" engine powered cars like those used in the AHS highway developments and these work very well. So, in the early years of TEV, there is little reason not to allow these vehicles to use the track – after all, they pay tolls. Everyone would gain confidence in the TEV system a lot quicker this way rather than waiting for everyone to change to EVs.

We propose, therefore, that approved ICE vehicles, either new cars or certified professionally converted used cars, could be used if they were capable maintaining full track speed and had suitable brakes and safety features. Classic cars and other marginal vehicles would not be allowed. It is certainly worth considering as a startup strategy.

3 Vehicle designs

Private transport

The typical private TEV car is a "compact" electric car with room for four people plus luggage, just like the majority of cars presently seen on the streets everywhere in the world. TEV cars are quite normal in appearance by modern standards. Indeed, it is a basic part of this TEV project strategy to use mildly-modified, mass-produced cars to operate on the TEV system. Among other benefits, this will radically simplify the TEV system's development and speed up its introduction. *In most cases, the cars will be powered by pollution-free electric motors on the track*. On the road, there will be other options.

A basic design feature of all TEV cars, and indeed all TEV vehicles, is that they are equipped with rubber ***tires*** which are used not only on normal roadways but also on the TEV tracks; more on this later.

In addition, each car has "drive by wire", computer-controlled systems for the accelerator and brakes that override the driver's pedals. These types of controls have already been developed by the automotive industry and some are already in production.

It is possible to equip each TEV vehicle with a "mechanical safety switch" mechanism attached, for example, below the front bumper. This mechanism, discussed in more detail later, locks the car loosely into a guide slot in the track for secure control when the car switches from an entry ramp on to the main track or vice versa. It does not steer the car, which is done by software, but is a fail-safe hardware backup in case of total system failure.

The use of modified conventional cars gives TEV a practical advantage over other dual-mode transportation proposals that require specially-designed vehicles. The modern car is an ***extraordinarily well-developed appliance***, having had literally *billions of dollars* spent on its chassis, suspension, power-steering, air-conditioning, anti-lock brakes, traction-control, electric windows, remote door locks, air-bags, seatbelts and other systems. So it makes a lot of sense to develop a track system that is compatible with the modern car.

Electric vehicles and other options

The ideal TEV car from an environmental viewpoint is *a pure EV*, having principally a battery, an electric drive-train and the special controls that permit it to drive in track mode. It will burn no fuel and produce no local pollution. It is likely that many of the TEV cars in the future will be of this type, at least in city areas. However, as mentioned, the TEV concept is flexible enough to accommodate fuel-burning cars; for example a hybrid vehicle that can run on petroleum fuel on the roadway, but switch to electric power on the track. These types of vehicles might be necessary for people who live in the countryside far from a TEV Portal, to the drivers of taxis or delivery vehicles, and to anyone else who needs a driving range on the road greater than a pure EV can economically provide (High energy batteries are expensive!).

A nice feature is that efficient, mains electric powered air-conditioning is available on these electric cars while they are on the track. However, in hot climates, a small engine may be required to drive the air conditioner while driving on the open road. Hybrid vehicle designs have already dealt with this issue.

Restricted access

A deliberate constraint on the TEV car design is that the vehicles must be “track compatible.” For example, large vehicles like trucks or buses are simply not acceptable on the track because of the enormous extra cost of the large tunnels and other infrastructure required. Mini-buses built like stretched limousines will be fine, as shown earlier. Vehicle size will also be limited to some degree not discussed here.

Also banned are vehicles with protrusions such as roof racks, strapped-on packages or load-carriers, trailers of all kinds (except, perhaps ones that are specially designed for use on TEV) and all open-bed vehicles such as pickups and anything with less than 4 wheels. Approved vehicles will carry remote radio registration devices that the track computer can read, just like the systems presently used for toll-booths.

Public service vehicles

The design of public service vehicles will follow the same principles as the car design. However, since most Mini-buses, Robo-cabs and Mini-trains will be single-mode vehicles that never leave the track they will be electrically powered almost all the time. A small battery or generator will provide emergency services but in normal operations, they will use NO petroleum based fuels at all.

Rubber tires versus other drive systems

All dual-mode vehicle concepts, TEV or otherwise, must obviously use rubber tires when they travel on normal roads. However, some inventors have been tempted to use a separate support and propulsion system for high-speed travel on the track such as steel-wheels-on-steel-rail or magnetic levitation (Maglev). TEV uses rubber tires for **both road and track** for technical as well as economic reasons.

Steel wheels certainly have the immediate technical appeal of *low rolling resistance* – about 6 times lower than conventional rubber tires. However, the fault of this virtue is that they are also very slippery, which results in several serious problems such as a tendency for wheel-spin during strong acceleration, an inability to climb hills, and, most dangerous of all*, a very poor braking capability*. For example, a modern high speed train can take well over a mile or several kilometers to come to a stop in an emergency, and even more if the track is wet, icy or covered with leaves. This poor performance is completely unacceptable for a high-density people-transporter. In addition, steel wheels are surprisingly noisy, emitting a continuous high-frequency whine caused by slippage between wheel and track

Rubber tires, on the other hand, have *superb traction and braking capability*. What is more, *they already exist* as part of the modern car and are already equipped with incredibly sophisticated technology such as disc brakes and ABS anti-skid systems. **No radical new developments are needed.** Also, modern tire technology has already nearly halved the rolling resistance of conventional rubber tires by using silica based compounds, higher tire pressures, and altering the design of the treads and sidewalls. These new tires run cooler and are ideally suited to high speed travel of 120 miles per hour. What's more, if tire companies were to design tires specifically for the smooth TEV track surface, we could expect even lower rolling resistances.

But the clinching technical argument is that the higher rolling resistance of rubber tires is not as big a drawback as it might seem because, at high speeds, it is **aerodynamic drag,** not rolling resistance that becomes the dominant energy consumer. Calculations show that the rolling resistance to be only about 6% the total drag of a TEV car doing 120 mph (200km/hr), so that further reduction in rolling drag has seriously diminishing returns. (Note: The use of convoys change this calculation a bit but not enough to change the conclusion).

Rubber tires, designed for the present purpose, are also *much quieter* than steel wheels, and "run-flat" rubber tires, essential for the TEV system, are already commercially available. Finally, they are easy to replace when worn.

Maglev (magnetic levitation) may be a technically attractive system for very high speed trains (although even in that application it may now be abandoned). However, it is a tremendously complicated approach for a simple people-mover system like TEV, and would add huge costs to the system. Cars would need to have both a rubber-tire system for road travel and a Maglev system for track travel. The track would require costly embedded coils or magnets, or some other equally expensive arrangement, throughout the entire network, as well as a separate linear induction motor drive arrangement.

And how one would one safely transfer from one support/propulsion system to the other at full cruising speed before exiting the track? It certainly would not be either easy or safe. Then there are the drawback of the huge cost. The Maglev from Pudong airport to Shanghai cost a mind-blowing $50 million per mile. Clearly, Maglev is not a practical option at present. ***In truth, it probably never will be.***

The rubber tire, therefore, is a surprising but worthy winner. It is a thoroughly *practical* solution: reasonably efficient, flexible, simple, inexpensive, reliable, quiet, and *immediately attainable without a major development program.*

One drawback to using rubber tires is that the “road” surfaces might wear out over time and need replacement. However, this drawback can be minimized by the use of mechanized replacement techniques described later.(See Chapter 7).

For the technically inclined, these are some comparative coefficients of rolling resistances – the drag force is expressed simply as a percentage of the vehicle weight. (my apologies to dimensional purists).

- Conventional rubber tires 10.0
- New low-resistance tires 5.0
- Future TEV tires (estimated) 4.0
- Steel wheels on steel rail: 1.5

There may be an exception to the rubber tire rule in due course if we were to build **separate freight vehicles** which would run on their own dedicated track**.** In this case, since the freight vehicles would be a custom design, they could be equipped with steel wheels coaxial with the rubber tires. The steel wheels would support the vehicles between exits where the friction surfaces would rise to form a level crossing surface so the rubber tires would briefly take over. For more details on this potentially important subject see Appendix 1 at the end of this book.

Automated parcel delivery
For companies in the delivery business, like Amazon or the supermarkets - now growing madly due to the influence of the internet - the delivery of physical parcels weighing 5 to 10 pounds directly to the homes of buyers is still a necessity. It is also a process that is very difficult to automate.

TEV can solve this problem too by integrating the “Google car” self-driving software into the TEV Robo-van so that the vehicle can deliver parcels door to door ***with no driver***. The vehicle would call the home owner’s mobile phone, make a delivery appointment and then stop outside of the house at the agreed hour. After receiving the equivalent of a signature, the robot would hand over the package.

4 Computer software

Once a car enters a TEV portal and is accepted for travel on the track, the central computer network takes over the operation of the car. This system controls everything from the initial compatibility-check for the cars, the acceleration up to cruising speed, the grouping into convoys, the exit of the car at its programmed destination, and even the electronic billing of the customer for use of the track and electricity.

This sounds like a huge development task but, remarkably, most of the required computer software has already been developed by the car companies. Their original aim was to develop "automated highways" (AHS) as discussed earlier where cars drive on autopilot on normal highways shared with other vehicles. Most people have seen TV pictures of driverless cars zooming around test circuits in high-speed convoys. See our website at www.TEVproject.com

As already mentioned, despite the brilliant engineering work already done on automated highways, the concept is far too dangerous to be practical given the existence of drunk drivers and ice patches, to mention only two nightmares. But if the vehicles are confined to a restricted track like TEV, especially a covered one, the concept immediately becomes not only practical but very attractive.

The good news is that the engineers' excellent work is not wasted; the software they have developed can easily be transferred to TEV because it is a ***far less demanding application***. Cars driven robotically on normal motorways require complex control in ***two dimensions***: that is both speed control and steering control, the latter being necessary for passing other vehicles. Except for entries and exits, the TEV software requires control in only **one dimension**, speed contro**l,** which is a much simpler task as any engineer would agree. The fact that there is no passing on the track has huge benefits and only a few minor, correctible drawbacks.

The TEV central computer is aware of all traffic conditions on the track network at all times, making it able to redirect traffic away from trouble spots, or bring all cars to a halt in seconds in an emergency. To accommodate the computer controls, each car is modified to have "fly-by-wire" electronic control systems – specifically for brakes, accelerator and the "switch". Again, most of these systems have already been developed by the car industry.

5 Passenger capacity comparisons

The **carrying capacity** any people-mover system is measured by the number of passengers that can be transported each hour past any given point. The TEV capacity calculations involve the following rough assumptions:

- The TEV cars are compact in size having a length of 14 feet (a little more than 4 meters) with four seats and room for luggage. (The shorter the car, the higher the passenger carrying capacity of the track).
- On the TEV track, the cars are grouped into ***convoys*** with about 2 feet (less than 1 meter) between cars during the cruise mode. (The convoy concept is one of the biggest contributors to high capacity).
- The cruise speed on express tracks is 120 mph or 200km/h. (High cruise speed is also a big contributor to capacity).
- The maximum “load factor” is arbitrarily restricted to 75%. That is, convoys of 30 cars are separated by gaps equivalent to at least 10 car spaces (160 feet or 38m).

TEV capacity is huge

If a TEV track were loaded to its full capacity (100% load factor), with all the cars in one continuous convoy traveling at full speed, the number of cars passing a given point would be 39,600 cars per hour. But, since we are assuming that the *practical* maximum track loading is 75%, our practical maximum capacity is **29,700** cars per hour. To show how enormous this capacity is we have to compare it with other transport systems.

Compare with highways

A useful rule in the UK Highway code for spacing of cars on a motorway is to leave two seconds between cars, one second for human reaction time and one more for deceleration. From this we can compute that the capacity of a single lane of expressway is around 1,688 **cars per hour**. (This *is for a dry road; wet roads will be less).*

If you compare this number with the TEV number above, you will be shocked: a single, slim TEV track has the astonishing capacity of more than ***17 lanes of freeway***.

But that is only half of the story. We can stack ***two TEV tracks*** *in the space of a single lane of motorway. In this case, the capacity of a pair of TEV tracks would be about* ***34 times greater than the single lane***

they appropriated. *Clearly, TEV has a capacity advantage of enormous proportions.*

The superior capacity of the TEV format is one of its truly revolutionary aspects. Indeed, it ***irreversibly changes the economics of public transport*****.** The closest parallel is the shift from copper-wire to fiber-optic cable for data transmission. As the technical reader will notice, TEV is a basically packet-switching system for solid objects!

How does the cost per unit capacity compare?
If the construction cost per unit of capacity is compared, the TEV superiority widens even further. A modern interstate highway with 3 lanes each way can easily cost $10 million per mile (we will use American units here) to build even in open countryside. (The cost in town is literally prohibitive). By contrast, a TEV track with one lane each way will likely carry more than ten times the traffic, cost a tenth the money to build ***per unit capacity***, and have a tenth of the environmental impact - both during construction and operation. *That is pretty impressive!*

To be fair, the one great virtue of the traditional road system is its *flexibility*; a road will carry everything from bicycles to huge trucks. But that is what makes it difficult to optimize for capacity – look at web videos of Mumbai roads to see what we mean! The virtue of TEV is exactly the opposite: by focusing on carrying only people and light freight it avoids most of the compromises of flexible road travel. As a result, its capacity is dramatically improved. The road system will continue to exist in a TEV world, but will carry a lower proportion of the traffic as time passes.

Observations confirm the calculations
Author's note: On several occasions, we have stood on bridges that crossed major 6-lane motorways and counted the traffic flow during periods of maximum traffic. In particular, we checked two heavily used roads, the M6 near Manchester in the UK, and the Pennsylvania Turnpike near Philadelphia in the USA. On every occasion, the measured capacity per lane was ***lower than the 1688 vehicles per hour*** *estimated above. In fact, the average capacity was more like 1200 vehicles per hour. One of the reasons for the low capacity was obvious to see. The two "slow lanes" were usually occupied by heavy trucks trying to pass each other, with long empty spaces behind each truck. Other drivers, not wanting to share these lanes with the trucks gravitated to the "fast" lane, which then became clogged with cars driving far too close together for safety. TEV gets it superior capacity*

by closing up the wasteful gaps and having all vehicles maintain the same high speed.

High speed train capacity comparison

But what about advanced trains; how do they compare in passenger carrying capacity?

One of the advanced high-speed train in service today is the French TGV (Train `a Grande Vitesse). This beautiful masterpiece of engineering cruises at over 180 mph (288 km/h) on a network of dedicated high-speed rail tracks. (It also goes more slowly on older, conventional track). It is a successful and popular innovation in France, and not only competes strongly with the airlines, but reportedly paid back its own construction cost in the first 10 years of operation. It is, therefore, a prime yardstick for comparison when future passenger services are discussed.

The capacity of a single high-speed train-track in terms of people carried per hour depends only on *the number of seats per train and the number of trains per hour*. Since the train stops and starts in stations along the track, the maximum cruising speed is not a direct factor in the capacity calculation as it is with the TEV system.

Many TGV trains are single-deck cars with a capacity of under 500 persons. However, there are also double-deck cars that carry 800 persons with yet newer designs coming. We will use the 800 passenger version as our yardstick here.

The published maximum frequency of TGV train service at peak hours is 16 trains per hour which, when multiplied by 800 passenger seats per train, makes the capacity per track equal to *12,800* passengers per hour – or to **3,200 cars per hour**. According to our capacity definition, that is equal to about *two lanes of motorway.*

But that is not the biggest limitation of the high-speed train. There is a much bigger fundamental one, which is that the train stations have to be placed **very far apart** or else the average speed drops precipitously. To illustrate, if a TGV train has to wait 5 minutes at stations that are 30 miles apart, the **average** speed of the TGV train drops to 120mph which is the same as a TEV car that doesn't stop at all. **Stopping on a track is a tremendous waste of capacity**.

For example, in the USA, the Acela train from New York to Washington DC, achieves 150mph in places but ***averages only 84mph*** station to station. TEV would average 120mph. (*In metric units, the Acela has a maximum speed of 240km/h but averages only 134km/h. TEV would average nearly 200km/h).*

This low average speed problem is partly avoided by having long distances between train stations. **Fast trains, therefore, are inter-city expresses** – much like airlines**.** They cannot compete with TEV vehicles anywhere except between major cities. However, since most middle-class people of the world prefer to live in the suburbs or in the countryside outside city centers, we believe that **TEV will be much faster door to door than almost any fixed railway including high speed rail.**

But that is not all. By using new, small tunnels or by reusing old railway lines and tunnels, TEV vehicles can go quickly into the heart of an old, established city as easily as it goes into the countryside. It is a vastly more flexible system for the ordinary person to use than a train. And don't forget, you may be able to stack two TEV tracks in one railway tunnel.

How do commuter trains compare?

Most people would assume that the commuter train, crowded with harassed passengers, has the highest passenger carrying capacity of all. However, they would be wrong. Even though it is cramped, uncivilized and, frankly, unhealthy, the commuter train still can't come close to TEV for capacity. Again, this is because the train must **stop on the line** in a series of stations which ruins its capacity.

Here are the numbers: to match the maximum capacity of a single TEV track, a commuter rail line would have to provide one train, with 500 passengers on board, about **every 15 seconds**. *Obviously, this would be impossible because the train has to stop in each station for much longer than this.* Observation in a London Underground suburban station showed that, at peak travel times, a train rolled by every 10 minutes or so. In that case, the capacity of that rail track will be about

3,000 passengers per hour, the equivalent of 750 cars and only half the capacity of a single lane of highway. This makes the commuter train the **worst** people mover on all counts. **Isn't arithmetic interesting!**

Results and conclusions on capacity
For a fair comparison between train, road cars and TEV cars, we must compare *passengers carried per hour per lane*. With each road car and TEV car having four seats, this is the result:

System	Speed (mph)	Vehicles Per hour	Passengers Per hour	Equivalent road lanes
Highway One lane	70	1688 cars	6,752	1
Commuter train One track	variable	6 trains	3,000	1/2
High Speed Train One track	180	16 trains	12,800	2
TEV One track	**120**	**29,700**	**118,800**	**17**

One surprising result is that the high speed train only has a capacity equivalent to only two lanes of highway traffic. The 16 trains per hour figure corresponds to a rate of one train every 3.75 minutes. **That is, if a train stops in any station for more than this it will hold up the following train.** That seems a bit crazy but it works. However, 3.75 minutes seems to be a bit quick for a handicapped person to find his seat on the train.

Another surprise is that the commuter train is a terrible waste of resources. **The priceless railway right-of-way that it uses into the city could be put to a much better use by TEV**. TEV mini-buses could supply all the peak passenger traffic at a much higher speed while other TEV vehicles, like parcel vans, could use the same track during other times of the day.

But the most remarkable conclusion is that the simple, low-cost, TEV track is the equivalent of 17 lanes of highway, a vastly greater capacity than either freeways or high-speed trains or commuter trains - combined. ***Its combination of speed and capacity truly puts it in a class of its own. It is no contest. TEV wins!***

Critics may quibble with the assumptions of the TEV calculation; that the gaps between cars should be a little more, or the load factor should be a little less, and so on. On the other hand, it equally likely that the cars could be made shorter, the speed could be made higher and the load factor raised to 100% in special circumstances. Further, two TEV tracks can **easily** be stacked in the space of a single highway lane, which would double the capacity to 34 equivalent lanes! Surely that ends the debate. For capacity, there is nothing close to the TEV system.

However, just to be conservative, let us arbitrarily reduce the claimed capacity equivalence of TEV from 17 lanes of highway down to 10 lanes – just to make a nice, round number.

Few would then argue with the conclusion that **one *TEV track is equivalent to at least 10 lanes of highway.*** That is quite enough of an advantage to justify construction of the TEV system.

---

6 Energy consumption of TEV vehicles

Suppose we developed a magic battery that gave electric cars the same performance as conventional gasoline-powered cars. Would that option be as good as TEV? Absolutely not; TEV would still be ***far better.*** Why? Because we would still have the same old traffic jams, traffic lights, intersections, accidents, road repairs, bad drivers, parking problems, bad weather and all the other causes of stoppage. *(Note: By the way, do you know how many people have died on American roads in the last 50 years? The answer is around 2 million. Add to that millions more with serious injuries. Safety matters!)*

TEV's energy efficiency is very high because there is virtually no stopping and starting on the track. It is improved further by the combination of smooth track surfaces, low-resistance tires, streamlined car bodies, banked turns, direct supply of electrical power to the motors, and aerodynamic drag-reducing techniques made possible by the use of convoys.

Modern cars can have very low drag coefficients but still look normal

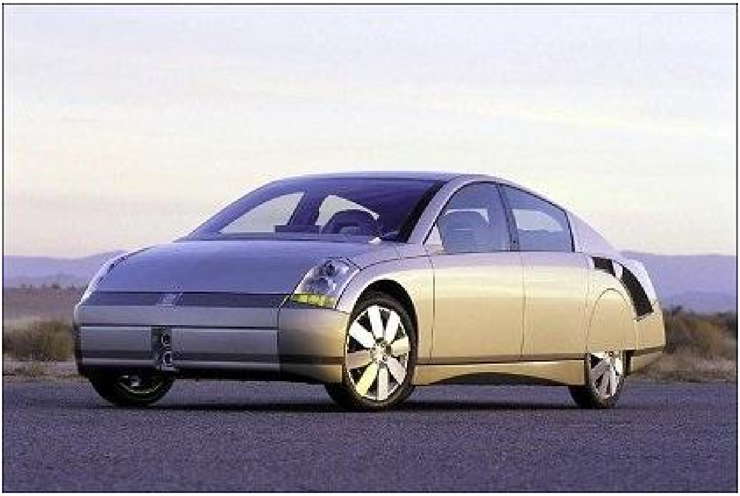
As a result of these "natural" advantages, we would reasonably expect TEV vehicles to consume less energy per passenger-mile than conventional cars on a normal road system – even if these cars had magic batteries. However, we would certainly not expect TEV cars to be competitive with super-streamlined, high-speed trains running on steel wheels, would we? Let's find out.

A Japanese ”Bullet Train” traveling at 160 mph is reported to consume only 55 watt-hours of energy per kilometer per passenger – and that is only counting half the seats as occupied by passengers. The French TGV train is said to consume exactly the same amount of energy per kilometer, but at 180 miles per hour, and with all the seats occupied. In both cases, the consumption figures equate to a ***continuous power draw of 10kW per counted seat*** - which is a very useful comparative measure to have. So now let’s compare TEV with super-trains on that measure.

To match the figure of 10 kW per seat, a four-seat TEV car would have to draw just 40 kW of continuous power at 120 mph. With some simple engineering calculations, we can estimate the approximate power consumption of a TEV vehicle, recognizing that some of the drag forces are difficult to compute, especially (a) the possible ***increase in*** aerodynamic drag of the cars within the partial enclosure of the track and (b) the very substantial ***reduced*** drag from the “drafting” effect of convoys. Therefore, we will ignore both these factors, expecting them, at least partially, to cancel out.

Two drafting NASCAR vehicles doing 200mph. Note that they are only a couple of feet apart.

We will assume that the TEV car is a compact car, weighing a substantial 2000 pounds, having a frontal area of 20 square feet and a ***very streamlined*** shape with a low drag coefficient (Cd) of 0.15 - which is achievable in practice (eg: GM Precept) and, therefore, should be made the target.



The GM Precept experimental car built in 1999 had an aerodynamic coefficient of 1.5 to 1.7. It looks very practical.

The resulting aerodynamic drag force at 120 mph would be 116 pounds force. The rolling drag of the special low resistance tires, is estimated to be only 8 pounds force. Therefore, we get a total drag force of 124 pounds. This drag force of 124 pounds, at 120 mph, equates to 40 brake horse power or about 30 kW. Allowing for some energy conversion losses, the actual power consumed by the vehicle would, therefore, be about 40 kW – an amount identical to the TGV train doing 180mph and double that of the Japanese Bullet Train doing 160mph.

As a result, the total amount of electricity used by the TEV car is very low. For example, a journey of 120 miles could be done in one hour with an energy consumption of just 40 kWh which, even at 10 cents per kWh, would only cost $4.00 in "fuel" costs. *(Note: The actual production cost of electricity can be as low as 2 cents per kWh, as shown later, so it is an exaggerated cost).*

By contrast, a fuel-burning car on a normal road, consuming gasoline at a frugal 30 miles per gallon would use 4 gallons on the trip – going a great deal slower than 120mph. Using American gasoline prices at $3.00 per gallon at the time this report is written, fuel would cost $12.00 - or 3 times more than our clean EV. Using expensive European petrol prices of $6.00 per gallon, it would cost $24.00 – 6 times more. Of course, petroleum prices are largely made up of taxes these days, as are electricity prices. Still, it shows that the cost of TEV is lower than present systems and not inevitably higher, despite faster speeds.

It is an important note that pure EVs will be ***much more energy efficient when driving on the TEV tracks than when driving on roads using their batteries***. The reason is that, on the TEV track, the electricity goes almost directly from the electrical power lines to the drive motors. No energy is wasted going through a charger and battery. A vehicle that drives on its battery loses a substantial amount of energy as it passes through the charger and the battery before reaching the drive motors. The use of fast chargers makes this inefficiency problem even worse.

Note: The weight of the advanced German ICE high-speed train is 2,790 pounds - per seat. A typical compact car, on the other hand, weighs about 2,000 pounds for all 4-seats! Trains are amazingly heavy which is indicative of old technology!

7 Track design

The basic definition of a TEV track is: a single-lane, electrically powered, limited-access, electric roadway with no intersections other than ON ramps and OFF ramps.

A TEV track is quite narrow: just the width of the car plus some extra space necessary to permit passengers to exit their cars in an emergency. To eliminate the possibility of the cars being thrown off the track in any foreseeable event, including terrorist attacks, there are strong crash barriers on each side to keep the vehicles safely contained.

This contrasts with conventional trains which can derail rather easily with truly disastrous consequences. In 1998, the advanced German ICE train damaged a wheel and crashed into a bridge abutment killing over 100 people and injuring hundreds more. It was only doing 120mph. In TEV vehicles, by contrast, occupants are so well protected by advanced, highly developed, safety equipment such as air bags and crush zones that even in a terrorist attack, few people would be injured or killed. ***Cars are much safer in a crash. It is not intuitively obvious, is it?***

Fundamental to the idea of the TEV track is to make travel ***intrinsically safe.*** Therefore, there are no objects on the track that can cause high frontal impact or nasty accidents:

- no trees, telephone poles, walls, ditches
- no head-on crashes, two-way traffic (except as discussed later)
- no intersections, crossroads, railway crossings, traffic lights
- no farm tractors, motorcycles, bicycles, school buses
- no sheep, cattle, pets, wild animals, pedestrians
- no heavy trucks, trailers, flatbed trucks, open pickups
- no drunk drivers, speeding drivers or bad drivers of any kind

All this is possible because TEV is, by design, a highly segregated transport system, concentrating on carrying the most precious cargo of all: ***people*** - plus some light freight to help pay for construction and maintenance.

Stacking of tracks

A pair of TEV tracks can be placed side by side as in a two-lane road. However, they can also be stacked one on top of the each other in double-deck fashion. The double-deck arrangement has benefits of structural strength, useful when making long bridges or other spans, and is perhaps nicer for passengers who, on an elevated track, might enjoy the extra, two-sided visibility. On the other hand, the tracks themselves may not look as nice from the outside in certain locations. Probably, the arrangements will vary according to local needs. Double deck arrangement would make very economical use of existing or new tunnels.

Side-by-side tracks can also be stacked, if there is headroom, to make a quad track. Triple-deck, or even more, tracks are technically feasible but the ample capacity of two or four lanes probably makes such arrangements unlikely unless they were dedicated to freight or low speed local lines.

As mentioned earlier, a double deck track arrangement could be made with freight vehicles running below at a slower speed, say 60 mph, and passenger cars above running at high speed such as 120 mph. This might turn out to be the ideal infrastructure for the future. (See Appendix 1).

The tracks can also be laid down in several ways, as follows:

On old railway tracks, either on the ground or slightly elevated
This is one of the lowest-cost options and has huge potential. In most developed countries, like the UK, there is a large existing network of railway tracks that not only cross the countryside but also drive right in to the centers of major cities. Often these tracks are shockingly underutilized.

(Author's note: For example, we stood on a bridge over railway lines in Putney, London, during the morning rush hour. The road traffic on the M25 ring-road around London was, as usual, choked with traffic and the subway system (the Tube) was also jammed with commuters. But the rails below were completely empty for many minutes before a lone commuter train trundled by. Then nothing happened for another long period. It may have been 10 to 15 minutes. Then another train rolled by, and so on. During non-rush hours, the rails are hardly used at all.

To waste such an ***incredibly valuable asset*** as a fully paid-for right-of-way into the very heart of London for such a crude 19th Century mode of transport as a commuter train is a tragic lack of insight. If the height of each TEV track could be restricted so that a stacked pair could fit inside a regular railway tunnel, TEV could replace each rail line with **double-deck tracks**, and provide a capacity for carrying passengers that could reduce the commuting time for hundreds of thousands of workers, many by an hour or more, each way, each workday. Imagine the time saved.

Cannibalizing underutilized railway tracks outside cities and converting then to TEV tracks is another important resource for the TEV system. Don't mourn the loss of such an archaic system; you will be far better off – especially when you have to travel at some lonely hour of a dark night. Remember this: there is almost nothing a train can do that TEV can't do better, faster, safer, cheaper and in more comfort.

Replace the "fast lane" of a freeway

Here is yet another way of cannibalizing underused assets: a double deck TEV track is placed in the "fast lane" of a 3-lane highway, one track in each direction. A strong crash barrier is installed to protect the TEV track from other road traffic. This option has a big advantage because there are obviously *many existing rights-of-way already* available. The huge capacity of the TEV tracks will not subtract from the capacity of the highway; it will add enormously to it at very low cost. Bridges, tunnels, etc., are not affected. With two tracks replacing single lanes, the yield is the ***equivalent of 10 extra highway lanes each way*** if full speed can be maintained. In practice, the speed of the TEV vehicles might have to be reduced a bit where the freeway is curved too sharply, but the concept itself is an achievable goal. See the construction animation on www.TEV project.com for a conceptual impression.

On elevated tracks

This is the preferred option for new Express Tracks when crossing farms or parkland or passing through low-density suburbs. It provides for minimum environmental impact for both local people and for animals. It also allows the double use of land, like farming, which would be extremely valuable in crowded countries like India, for example. Preferably, the track should be supported on slim pillars which are all that is needed for the relatively lightweight structure. Proper landscaping, including a lot of trees, will be necessary to reduce the visual impact to a minimum, **but that is surely an advantage rather than a drawback**. Once again, the tracks may be either single-deck or double deck, depending on capacity requirements. Elevated tracks also work when used down the center or sides of a multi-lane highway or along a power line corridor. In China, for example, many cities have power line corridors that approach all the way into the city centers. These corridors have plenty of room for track installation.

In "cut and cover" tunnels
If they can't be elevated, TEV tracks can also be placed in relatively economical cut-and-cover tunnels under existing roads for carrying people in and out of cities. This will do wonders to make cities more livable. The same technique can be used for tunnels under public parks or other scenic sites. The tunnels are so small for their carrying capacity that their cost is a tiny fraction of any other tunnel system.

In bored tunnels
One of the most exciting opportunities of all is the creation of ***bored tunnels*** *under our cities.* These would provide an underground network that would virtually eliminate the city's once intractable traffic problems at a stroke. Just imagine the result: elimination of unnecessary road traffic in city centers; absence of traffic jams; absence of road noise; absence of diesel fumes and pollution. What an amazing change that would be. But most importantly, it would not be done by restrictions which say that you can't drive here or you can't park there. But it would be a city of opportunities where you can go where you like and have plenty of parking for both private cars and Robo-cabs and other public transport. Enjoy your visit!

For people who worked in the city, it would be a dream come true. They could zip from the commercial center to the airport in minutes, not hours, whether in the middle of the day or night. They could also live in the suburbs without having a dreadful commute each day. They could also dress up nicely in the evening and drive into town in their own cars or in economical Robo-cabs in civilized comfort, to visit theatres, museums, restaurants or galleries without bothering any of the people who happen to live in areas in between.

Modern tunnel-boring machines are extraordinarily efficient machines and have reduced the cost of tunneling very significantly over the last few years. The cost of a tunnel is closely related to the amount of material – or "muck" as they call it – that is removed, so the larger the tunnel, the more costly it is per mile. However, a very small tunnel also is costly because the muck cannot easily be removed. As a result, the least costly tunnels are ones with a diameter of about 15 to 20 feet, an ideal size for two lanes of TEV – plus some extra room for pipes, cables and other utilities that will **bring in a lot of extra revenue**. Rights of way are extremely valuable assets.

Therefore, the cost of boring these TEV "micro-tunnels" is much cheaper than digging large road tunnels for highways. A bad example of old-fashioned tunneling is the notorious Boston "Big Dig" tunnel that cost nearly $14 billion for 7.5 miles of tunnel, or about $30,000 per inch. By contrast, the 50 mile “ring main” tunnel under London, designed to distribute water around the city, has a mechanically bored tunnel about 8 feet in diameter that cost less than $10 million per mile to dig. TEV tunnels would hopefully have a cost closer to this latter figure, at least for cities with clay soil like London. For the equivalent of a 20 lane highway, that is very cheap!

So, we can bore lots of these “micro-tunnels” under most cities (perhaps not easily through Manhattan’s rock, however!) and bring the TEV system into the heart of most major metropolitan areas without disturbing the people on the surface, all at a relatively small cost. Furthermore, existing tunnels under rivers and channels such as the English Channel Tunnel or the Lincoln Tunnels in New York City could have their capacity **vastly increased** by converting to the TEV format. How much money would that save? Road or rail bridges across large spans would likewise have their capacity transformed at a trivial cost.

Track enclosures
Theoretically, TEV tracks can be made fully open to the sky and that might be a suitable low-cost approach for some long runs in remote areas like the American prairies, for example. However, for most applications, a roof on the track will be a worthwhile enhancement both for the travelers on the track and for the local population.

For travelers, a roof is a great benefit in snowy regions because it keeps the tracks clear. Snow-plowing, which is immensely wasteful of energy, is unnecessary and the tracks are usable under almost all weather conditions – even if their roofs become covered with snowdrifts. Sprinkling salt on roads is very corrosive to steel structures and can be avoided on TEV tracks.

In rainy regions, a roof keeps the track dry, enhancing tire friction and eliminating water spray. In very sunny climates, a roof shelters the cars from solar radiation and reduces air conditioning loads to conserve energy further. It all adds up.

For the local people who live near a TEV track, an enclosure would have the added benefit that it reduces road noise which is mainly tire and wind noise. The use of sound absorbent materials inside the enclosure would trap most of this. In addition, the sides of the enclosure can be partially or completely enclosed with glass windows or even mirrored windows. The latter would not only make the noise disappear but also make the cars “disappear” visually.

In case you thought that high speed trains were nice, quiet, things, you might like to check on the noise made by an ICE train doing 300km per hour in Germany in this YouTube link:

http://www.youtube.com/watch?v=e_mSRb79gOU&feature=related

TEV with its rubber tires will be quieter but I don't know by how much. This is why TEV tracks may be equipped with noise containing side windows when passing through built up areas or sensitive countryside. It will all be up to local planners to decide.

Track construction and repair

The tracks structures have a relatively light construction compared with roadway bridges because they do not have to carry dense, heavy-truck traffic. Ideally, track sections can therefore be mass-produced in factories and brought to the site for installation – a much quicker and less disruptive method than that used in road building, not to mention the greater precision and quality control. The speed of construction for TEV would be breathtaking compared with conventional highways, especially in built-up areas.

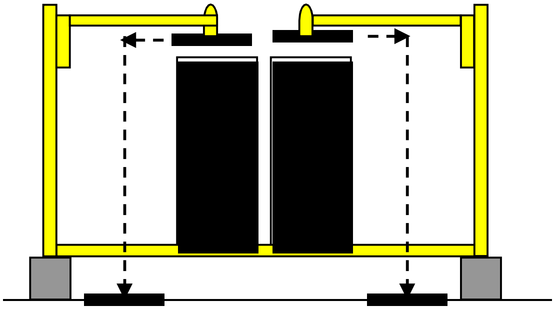
Maintenance and repair of the track roadway, or "friction surfaces" as we call them, is also easier to do than with conventional roadway maintenance. The friction surfaces of the track are twin ribbons of "roadway" on which the tires run. These are not manufactured on-site with the slapdash methods of roadway construction, but in a clean factory with *engineered accuracy*.

The friction surfaces will be designed in conjunction with the vehicle tires to minimize both noise and rolling resistance while still retaining good grip for acceleration and braking. Preferably, they would be delivered to the site from the factory as long strips and attached to the track structure with bolts or other removable attachments. Repair does not involve noisy jackhammers, but is rather a matter of taking up the old friction strips - which are recycled back to the factory, of course - and installing new ones. All this is done "on the fly" with automatic "pick-and-place" machines traveling on the track itself, inside the enclosure. Other procedures are also possible.

Repairs will be few and far between due to the intrinsically low wear-and-tear of the friction surfaces (no heavy trucks, no freezing, and no braking loads) and the development of super-durable, ceramic wear-surfaces. And when it is in need of repair, that repair it will be accomplished far more quickly and efficiently that normal road repair methods. Indeed, one of our calculations suggests that the replacement of a pair of 100 foot strips of friction surface could be achieved in less than a minute, making possible a continuous roadway replacement rate exceeding a *speed of* ***one mile per hour***! The consequent cost reduction potential compared with conventional road repair is obviously huge. Here is one example:

Replacing TEV friction strips: road repair as it should be. Non-techies can skip this part).

In this example, two stacks of 24 friction strips, each strip about 100 feet long, are carried on a special vehicle called V1 (shown below) the wheels of which run on guide-ways outboard of the normal TEV friction strips as shown. V1 has a built in "pick-and-place" machine designed to install the strips on to the road bed. A similar machine can remove the strips.



Schematic of pick and place machine V1

V1 has vacuum cups, magnets, or other means to lift the strips carefully and lower them on to the roadbed where they are located precisely on steel locator pins. Later, another machine on a following vehicle, not shown, will attach the strips to the roadbed with screws, clamps or other reversible attachment means. Let us now calculate the speed of road repair with this arrangement.

The pick and place machine is designed to move as quickly as possible so we can assume that a pair of friction strips can be lifted and laid in 15 seconds. After laying the pair of strips, V1 must move forward 100 feet to repeat the cycle. It repeats this cycle until its cargo of strips is exhausted. If the 100 foot forward motion of the vehicle to its next location takes a further 15 seconds, a single strip-laying cycle is completed in 30 seconds and all 24 pairs of strips are laid in 12 minutes. Given these assumptions, the maximum possible track-laying speed of V1 will be 100 feet in 30 seconds or 2.27mph.

So, the vehicle V1 can lay nearly half a mile of track in only 12 minutes before requiring a recharge of strips. But to keep up a good average, it must be reloaded quickly, preferably from inside the track.

There are many interesting ways of doing this task and finding the best method will keep engineers happy for quite a while. Here is just one method: Reloading is done from a trailing vehicle, a shuttle called V2, which carries identical stacks of strips but has no pick and place machine aboard. During the reload process, V2 engages with V1 and reloads V1 by moving the new stack forward. This might be done in another minute. V1 can then continue its track laying operation for a further 12 minutes. The shuttle V2 can then rush back to the loading depot. The reloading time is not very significant so the average time to lay 24 pairs of strips now becomes 13 minutes, dropping the average speed of track laying to 2.2mph.

This simple arrangement can work indefinitely but, of course, the shuttle's time to base and back will slow the overall process increasingly as V1 moves away from the depot. Several methods may be used to compensate for his time loss as the following examples show but that is an issue for engineers to discuss and not for readers of this booklet.

Obviously, if the track surface is being replaced rather than newly laid, the old friction strips must be detached and removed before new strips can be laid. This would be done by a separate rig, similar to the track laying rig, but focused on the removal process.

Dressing the friction surfaces and other ideas
Another new process is possible, that of "dressing" worn friction strips with, for example, with diamond grinding wheels to recondition the surfaces in situ. This process would be just as fast but without the need for shuttle vehicles. This would be a very low cost way of extending strip life.

Finally, yet another new process is possible, one of removing the strips, flipping them over, and reattaching them again – all automatically. That is, all strips have two identical friction surfaces. No shuttles are required but the speed may be slightly lower.

Yet another method is to make the strips times wider than needed so that the computer can use two or three separate wear surfaces per strip.

Note: Tightening down the strip retention system, for example with bolts, will be done by a separate machine with a built in quality check system.

Diversions

Even though the repairs will not be very frequent, they will have to be done sometime and the question remains: What happens to the traffic on a two lane TEV track - with only one lane each way - during repair periods?

The answer is the same as with any road – a diversion. However, for a TEV track, the diversion procedure is simple, smooth and automatic. One of the lanes is taken out of service for a distance of several miles. The computer then switches the vehicles from this lane to the oncoming lane and then switches them back at the end of the diversion. Special lane-change openings are provided in the dividing barrier for this purpose as part of TEV track construction.

Does this sound like a formula for a head-on collision? Not really, because the TEV computer, with its fail-safe backup, is much too intelligent for that. First, it diverts long distance traffic to alternative TEV tracks to reduce the traffic loads. Then it organizes the remaining traffic from both directions into long convoys, and adjusts their speeds so that the opposing convoys pass through the repair zone in a regular, alternating-convoy pattern. That is, the first approaching convoy switches lanes, goes through at cruising speed, clears the zone and returns to its proper lane. In due course, the second convoy from the opposite direction approaches and goes through the zone in the same way.

Each convoy is timed to arrive at a precise moment in time without the occupants even being aware of it. Such is the capacity of the TEV tracks, there is very little noticeable delay. It is all very seamless and civilized ad there are absolutely **no red plastic cones** involved!

An alternative is to divert the blocked traffic on to the regular highway lanes. That wouldn't be too bad if done at night.

8 Track Safety slots

Normally, the steering of the TEV vehicles over thousands of miles of main track is done by computer. That is, the central computer and the vehicle computer, between them, arrange for the car to be driven safely without touching the crash barriers on either side of the track, this by steering the front wheels. The friction surfaces under the tires are likely to be simple flat roadways.

To make an exit maneuver from the main track to an exit ramp there are many design options. The simplest and preferred option is for the computer to steer the car on to the exit ramp exactly as a human driver would on to a highway exit ramp – that is, by turning the front wheels. However, that raises a safety issue. For example, if ice were to form on the exit ramp and the tires did not respond to the steering input from the computer, there is a ***possibility*** of a crash at the apex point where the track and the exit ramp separate. Therefore, a mechanical safety system may be a prudent investment. One of the simplest is now described recognizing that there are many alternatives which should compete for acceptance. .

As the TEV vehicle approaches an exit ramp, a slot "appears" in the floor preferably on the exit side (say) on the right hand side of the two friction strips and more-or-less flush with them. This is called an "exit slot" and is, in effect, similar to the slot in a model slot-car race track. It could be a steel channel bolted to the floor.

Under the front bumper of the car, and directly above the slot, is an actuator mechanism called a "Switch" which consists mainly of a vertical roller-pin that can be raised or lowered quickly. As the exit slot "appears", the computer instructs the Switch to drop the roller-pin into the exit slot so that the vehicle is locked in mechanically and cannot move more than a few inches either to the left or to the right. Therefore, even in the rare event that the tires were to slip or skid the roller pin will steer the vehicle precisely and safely to the exit.

The safety advantage of this system will be self-evident. The car cannot under any reasonable conditions have a head-on collision with a barrier between the exit ramp and main track. Many variations of this system can be substituted but these will be obvious to any good design engineer and there is no need to explore them further here.

Conversely, when a car merges from an entry ramp on to a main track, the reverse process takes place. The switch mechanism releases the car from the “entry slot” and “sets it free on to the main track. Thus, for instance, an entire transfer of a vehicle from one main track to another main track, via a transfer track, can be achieved with only two stokes of a mechanical actuator on the car. Note that these *exit and entry* actions are ***the only two lane changes possible*** in the TEV network, since there are no level crossings or intersections allowed.

Since the TEV system will probably have exits to the left as well as the right of the main track, a second Switch, interlocked with the first one, will be required on the left side. Thus the Switches will work with either a right or left hand exit ramp and with a right or left hand entry ramp. All four options are possible with the TEV system and are useful because they can lead to reduced construction costs in track interchanges, parking areas, Stations, Stops, and so on.

Note: A “switch” (USA) or “points” (UK) on a conventional railroad causes the rail itself to move, thereby diverting **the entire train** *from the main track and on to the exit track. This is a horribly inefficient approach, and reduces the flexibility of a railway track enormously. TEV is more like a road system where individual vehicles can exit independently at any exit they choose, left or right, at full cruising speed.*

---

9 Automatic parking

Parking in cities anywhere in the world is already almost impossible to find at a reasonable price. High rise parking garages are very expensive, especially if they are near the city center. The cost of *owning* a dedicated parking place in a major city is already beyond the means of most ordinary people – if they are available at all. This makes the TEV concept look impossible for driving private cars into cities: where would all these cars park?

One partial solution, presently coming into operation around the world, is the automated parking garage. Here the car owner drives the vehicle into a “reception” area on the ground floor of a tall building and disembarks. The floor under the car is actually a large pallet. The automatic parking mechanism then lifts the pallet and car up like an elevator and stores it on a rack inside the warehouse building.

This idea is clearly superior to conventional high-rise parking garages because, inside the warehouse, the cars are safe; no one can break into them or drive them away. The building is cheaper because the headroom is only enough for a car, not for a human and the “floors” are just storage racks. When the owner returns to the reception area and pays the parking fee, the car is retrieved automatically and appears quickly on the ground floor. The system is also safer for people because a driver does not have to enter a gloomy building where some criminal might be lurking.

But excellent as these high-rise, active parking garages are, the TEV system can offer a fundamentally superior parking arrangement for solving the parking problem in **cities**.

To begin with, expensive high-rise parking is not the norm for the TEV system because, and this point should be strongly emphasized, ***in many cities, the majority of the TEV tracks in cities will preferably be under ground***. This is for two reasons: first, it allows them to be built initially without the disruption and political squabbles about rights of way on the surface and, second, it is cheaper and more effective in the long run. As a result, it makes sense to build the parking areas with the same technique as the tracks themselves. That is, ***most of the TEV Parks are simple underground tunnels*** and not buildings at all

Parking example..

This is how TEV parking works: a TEV express track splits into several slower branch tracks that go to the different parts of the city. These in turn may split into even slower branch tracks, depending on the circumstances. On each of these branch tracks, there are Stations where the passengers can disembark from their cars (or taxis or minibuses) and make their way to their final destinations on foot or by other normal city means.

The now-driverless cars don't park in the Station at all; that would be too expensive. Instead they move off under automatic control to appropriate TEV-Parks wherever these are available – perhaps nearby or perhaps miles away, out of the city. The computer doesn't have to look for a parking space, of course, because it knows exactly where they all are. The entire exercise is more like storing data on a hard drive than conventional parking. The driver doesn't know or care where his car is parked.

A basic TEV Park might consist of a circular or oval loop of tunnel inside which the cars are parked essentially nose-to-tail. There are several entry and exit points on the loop. As a car arrives though an entry point, it moves forward and stops behind the vehicles already parked. A second arrival stops behind the first one, and so on. When the loop is full, the computer directs any further incoming cars to another parking loop and then to a third loop and so on. This way, the loops are completely full of cars with no waste of space. Note that there are no people in these tunnels, just cars, so there is no need for walkways and the cars can be packed in very tightly. Once again, there are many variations of the theme possible and there is no need to discuss these further here.

Since the system is completely underground, the number of parking loops can be unlimited. On a single track, about 1,000 cars can be stored for every mile of parking track. (*Note: At a tunneling cost of $10 million per mile, the capital cost of each parking place would therefore be about $26,000 each which is **very cheap** indeed by present city parking standards and city dwellers could again be able to buy a reserved space (Note: In some modern cities, like New York you can pay twice that amount – **each year** - just to rent a parking space*).

The truth is, there is plenty of potential parking space in the urban landscape – so long as you go underground. For example, if we stacked four tracks into a single tunnel 22 feet in diameter, about 4,000 cars can be parked in each mile of tunnel. Therefore, a mere 250 miles of tunnel scattered around a city will house **a million cars***,* which is probably far more than is required for the centers of even the world's largest cities. If we need more parking, we just dig some more tunnels, that's all. Apart from getting the money to pay for the tunneling work, there are no major problems involved as there would inevitably be on the surface. And think of the benefits: how much nicer the surface streets will be as a result of the reduction of traffic.

How does the car exit the TEV parking area? When a particular car is recalled by its owner, the computer makes some or all the cars move forward around the loop until the required car reaches an exit point. That car is now free to drive away to meet its owner at a Station. That can be any Station in the network; *it does not have to be the one where the owner disembarked*.

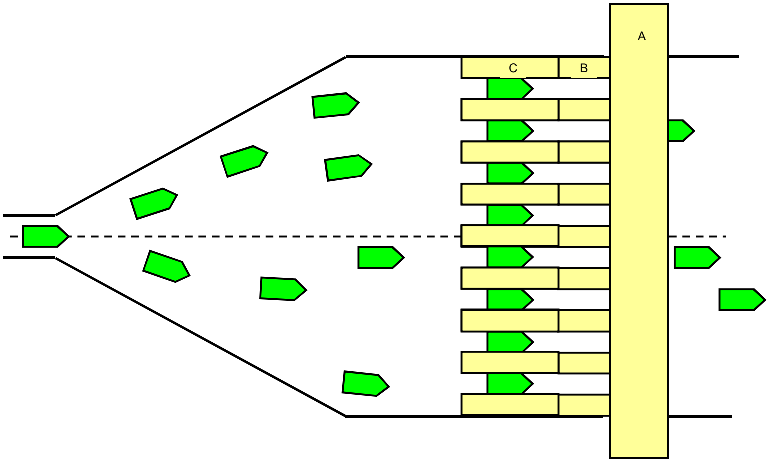
On arrival at the directed Station, the car goes into a short term parking zone and waits – for a fee. To avoid the deliberately high cost of short-term parking, most people will probably wait to recall the car until they are at the Station so there is no real problem with this arrangement. If the owner doesn't turn up, the car will be sent back into long-term storage at a lower cost.

So, the so-called "impossible" problem of city parking is not impossible after all. For TEV, at least, it is not even a difficult problem anymore. The cars never need to come up to the surface. They never take part in any traffic jams. They do not pollute the city air. They occupy no parking space on the surface. They make no noise. They need no fueling stations – or the attendant dangers and smells of tanker trucks. They are not affected by bad weather. They can be used at any time of day or night. They can get in and out of the city at high speed, even in rush hour. In effect, they are completely invisible yet provide a level of convenience and service to their owners that *no other mode of transportation can even hope to match*.

And don't forget, all that private cars can do, so also can cabs and minibuses do. Public transport vehicles will also use the underground tracks, so the surface roads can be free even of the stench of diesel buses. The end result is that the surface streets can largely be returned to pedestrians with a lot more trees, landscaping and room for wildlife. The air will be cleaner and the noise level lower. This is what the future cities should be like.

10 Stations and Stops

A criticism that can be made of some proposed bi-modal transport systems is that the rate of exit of vehicles from the track is too slow, creating a choke point at the exits and, therefore, causing the useful track capacity to be de-rated. That is not true in the case of TEV system, as will now be demonstrated.



Schematic of a TEV station

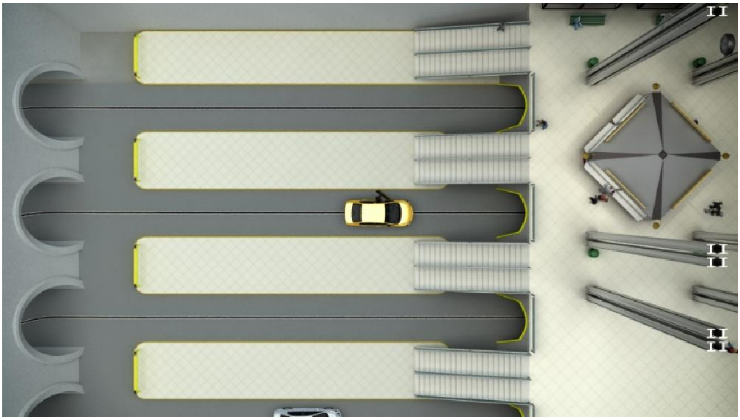
The sketch above shows a medium size TEV Station with eight bays. The same bays can be used either to Embark or to Disembark. In the Disembark mode shown here, cars enter from the left and are automatically directed to one of the eight bays. Passengers step out promptly on to the platforms (C), walk up a small ramp (B), and exit the Station via the low overpass (A). *(Note: People movement can be kept on the same level if the vehicles are made to exit **down** a ramp).*

A standard 15 second free stopping interval is allowed in the bays. This means that the Station can handle 32 cars per minute or 1,920 cars per hour – which is more traffic than one lane of motorway can supply. At this rate, the cars enter the Station continuously at an average speed of 5.4 miles per hour.

Similarly, the bays may be segregated into private passenger cars and cabs in some bays and Robo-buses in others. That is, on one day the traffic may be heavily biased in favor of buses (e.g.: sports fans going to a stadium); on another day, it might be biased in favor of private cars and cabs (theatre or concert fans).

There are many variations on this theme that can add capacity. For example, if batches of two or three cars at a time are allowed into each bay, the capacity is immediately ***doubled or tripled***, and so on. In a very large Station, if such were ever required, there could be 20 bays, serving batches of, say, 6 vehicles at a time. The capacity in that case would be nearly 30,000 cars per hour which, with four people in each car, could theoretically fill a 60,000 seat sports stadium in half an hour. Obviously there is no limit here.

The vehicles shown in the sketch – which can include a mix of Rob-cabs and Robo-buses - leave the Station to the right and can either go back on to the track, or to an automatic TEV park, or anywhere else the owner decides. For example, a private car could drive itself to a TEV park near the car dealer for scheduled maintenance while its owner is at work, or it could run through an automatic car wash before parking itself. The possibilities are endless.



An overhead view of an underground station fromour animation. With multiple bays, multiple vehicles per bay, and automatic parking the capacity can be enormous

The Station is flexible in its response to changing situations. For example, at any one time, the bays may be given completely different assignments such as Embark or Disembark or Handicap Use or Emergency Use and so on. The system lends itself to a degree of flexibility that is unheard of in public transport systems. To minimize human confusion, the bays at one end might be segregated to one mode while the bays at the other to the other mode. The computer would have no problem organizing all of this.

Special cases
The TEV Station can not only handle an enormous amount of traffic, but can do so with a wonderful, disciplined grace; the cars arrive and disappear as if choreographed. This is quite unlike the usual chaos, for example, of the typical airport arrival area. With TEV , there is no traffic noise, no stench of diesel fumes, no ugly parking lots, and no ***dithering drivers*** who are lost or don't know where to park.

A special case for a Station is a city hospital. The TEV system would permit very fast delivery of emergency patients to any hospital, local or distant, saving many lives. Area hospitals could coordinate their services as a result.

Likewise, TEV could initiate another revolution by **connecting together several regional airports** to reduce noise footprints or relieve congestion. For example, a city like London could have Heathrow, Gatwick, Luton and other local airports coupled together with a transport system that could get a passenger from one to the other in a matter 15 or 20 minutes. That would create a single, enormous "virtual" airport. If bad weather or other incident should close one airport, the others could pick up the slack. Even a backup airport 100 miles away would cause less than an hour's delay with a TEV system. In fact, this application might be ideal for a prototype test program for the TEV system.

11 Energy supplies for the future

Where will all the electricity come from?
If we succeed in building **any kind** of electrically powered transport system how do we provide it with the huge amount of electrical energy it requires? The generating capacity of the planet will be far too low, and many more power stations will have to be built especially in the developing countries which need to catch up with the more advanced countries.

What kind of power stations will they be? They can't be coal or oil, or natural gas or ethanol or methanol or any carbon-based fuel, because these all make greenhouse gases. Actually, if we want to avoid burning all hydrocarbon fuels there are only two possibilities – ***wind farms and nuclear energy***.

1. **Wind farms**. The big new wind turbines, now approaching 5 megawatts in size, are impressive machines so wind farms may finally live up to their promise – especially if used on a large scale in remote areas. Cost per kilowatt-hour is dropping slowly **but that is admittedly from a very high base price.** Wind power is by far the most successful of the renewable technologies, mainly due to subsidies, and almost certainly will contribute to energy production in the future. However, the wind is obviously not consistent enough to supply the primary "base load" source of electricity for TEV. We must have backup power generation of some kind and that effectively increases the cost per kilowatt hour.

2. **Nuclear energy**. Whether we like it or not, safe nuclear power is probably the ***only*** option that can presently be guaranteed to produce the vast quantity of energy required by the world on an acceptable schedule – with or without TEV. In any rational energy plan, therefore, nuclear power must be considered as a major contributor. That is bad news in the eyes of some people who class nuclear power as evil. But nuclear isn't evil or good; it is just a means of producing energy. The good news is that it is now safer than ever - even if we use the old-technology pressurized water reactors **(PWRs**) we now have. But the even better news is that there are new ways of producing nuclear energy that are **vast improvements over this old technology**. More on this in a moment. In the meantime we should not forget why nuclear energy is such a strong contender: it makes cheap electricity,

> produces no carbon dioxide and generates around a *million times more energy per gram of fuel than coal or oil.* In other words, it works!

*Authors note**: We are not fans of PWR reactors**. But the dislike is not because they are unsafe but because they are inefficient**:** they waste 99.5% of their uranium fuel. Other designs, discussed later, can use virtually ALL the fuel and are, therefore, a much better choice for the future. .*

Other sources of renewable energy such as solar power are frankly inadequate to make a large contribution to the supply of TEV energy in the short term or medium term, especially in temperate climates. While their development should continue to be encouraged for special duties, they can't be depended on for base loads.

So, whether we like it or not, in the short to medium term most of the energy will have to come from nuclear power. **There really isn't much point in railing against atomic energy because there isn't much of a choice.** In the longer term, we may develop really benign energy sources, perhaps systems based on the ideas of Nicola Tesla. But in our time, we will probably have to compromise and fix one problem at a time. Put it this way: **nuclear power, even from inefficient PWR reactors, is far better than burning 5 billion tons of coal a year.**

I hope that the declining number of anti-nuclear environmentalists will come around to a common sense agreement on this point, because we don't have a time to play politics. This is what James Lovelock, a **revered leader of the environmentalist movement**, has said on the subject:

> *"Only one immediately available source does not cause global warming and that is nuclear energy".*
>
> *"We have no time to experiment with visionary energy sources, civilization is in imminent danger".*
>
> *"Opposition to nuclear power is based on irrational fear led by Hollywood style fiction, the Green lobbies, and the media".*
>
> *".nuclear energy …has proved to be the safest of all energy sources".*

And from Patrick Moore, the co-founder of Greenpeace:

“In the early 1970s when I helped found Greenpeace, I believed that nuclear energy was synonymous with nuclear holocaust….. Thirty years on, my views have changed, and the rest of the environmental movement needs to update its views, too, because nuclear energy may just be the energy source that can save our planet from another possible disaster: catastrophic climate change. Nuclear energy is the only large-scale, cost-effective energy source that can reduce these emissions while continuing to satisfy a growing demand for power. And these days it can do so safely”.

Nuclear power

Are the conventional PWR nuclear power plants, like the present US designs, safe enough to do the job? The answer is yes. The existing plants have worked very well and have proved themselves to be extremely safe. **Not a single person has died from radiation in the entire 50+ years of the US atomic energy program**. Furthermore, a lot has improved in design of plants over the last 25 years. We can proceed at once to scale up nuclear power production.

Just for comparison, over the same 50 year period, over 2 million people have died on US roads. Which is the more dangerous: nuclear power or driving?

However, as mentioned already, PWRs represent **old technology** and there are better types of reactor now available. We should be developing these at full speed. What are these options?

One better option: the Pebble bed reactor

The first alternative to the PWRs is the Pebble Bed reactor (PBR) which was the invention of Dr. Rudolph Schulter of Germany in the 1940s. One feature of this reactor is that it cannot have a core meltdown under any conditions – even if the cooling system is deliberately shut off during full power operation. In that respect, it is “intrinsically safe”. It is also a bit more efficient.

At present, China has the only operating pebble bed reactor in the world. Here is the opinion of Qian Juhui, President of the Nuclear Power Institute of China some time ago:

"Nobody in the mainstream likes novel ideas. But in the international nuclear community, a lot of people believe this is the future. Eventually, these new reactors will compete

strategically, and in the end they will win. When that happens, it will leave traditional nuclear power in ruins."

Energy production is so crucial to our ongoing civilization it is necessary to develop **all practical alternatives** and let them compete. Right now, we may have to go with a few conventional PWRs. Later, when the Pebble Bed Reactor is fully developed, we may switch to that option. .
http://www.answers.com/topic/pebble-bed-reactor.

Probably the best option: the Liquid Fuel Thorium Reactor
However, in the opinion of many experts even the Pebble Bed Reactor is not the best nuclear option for the medium and longer term. One of the most impressive and exciting systems available belongs to a completely different type of reactor called a Liquid Fluoride Thorium Reactor (LFTR) - or "**Lifter**" for short.

This amazing development was the idea of Dr. R.C Bryant and was championed by Dr. Alvin Weinberg in the 1950s and 1960s. Weinberg had earlier invented the PWR but preferred the Lifter design which uses **a liquid fuel - molten thorium salts - instead of the solid fuels used on PWRs.** The US government, on the other hand, preferred to finance uranium reactors, because they could produce plutonium to make atomic bombs. **Lifters do not produce plutonium and this is now**, thankfully, one of its major advantages.

The LFTR design so simple and so safe that it not only makes our present nuclear PWR reactors obsolete, it probably makes **all other large scale energy production methods obsolete too** - including burning coal and natural gas. This reactor can be refueled on the fly and thereby run continuously. It can also be shut down easily.

The LFTR provides one other tremendously important benefit: it is **200 times more efficient than the PWR reactor**. That old PWR technology wastes 99.5% of the uranium fuel. The Lifter, on the other hand, consumes nearly ALL of its fuel. It may not be an exaggeration to say that the Lifter will be the main source of electrical energy for the next century, giving us time to build newer and better technologies.

Thorium is so plentiful in the earth's crust that we will **never** run out of it and thorium reactors are so safe that we could put them inside cites, where the actual power is used and thereby save the 10% loss of energy that is typically wasted with high voltage power lines.

Here are some of its other Lifter advantages:

- It is unpressurized so there can be no explosions
- It uses no water cooling
- It is intrinsically stable and safe
- **It produces no plutonium (bomb material)**
- It is refueled continuously
- If power is lost the fuel drains out by gravity into a safe tank
- (Once again) It is 200 times more efficient than the PWR
- One trainload of thorium (15,000 tons) would be enough to supply the entire world's electricity needs for **one year**.

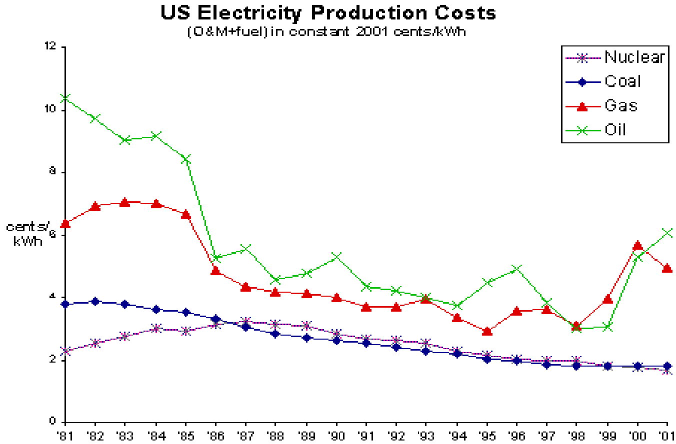
Please take the time to listen to the following YouTube video on the subject. It may change your entire outlook on nuclear energy: :
http://www.youtube.com/watch?v=D3rL08J7fDA

We must start with PWRs

Wonderful though the thorium reactor is, it will take a few years to develop fully. So we must be pragmatic and use what we have. After all, anything is better than burning 5 billion tons of coal a year. So we may well have to rely on PWRs in the short term. If this sounds terrible it is partly because there are many myths about conventional PWR nuclear plants that have been created by its opponents.

The objective truth, based on *actual operations over many decades*, is that the PWR is a very clean, safe and environmentally friendly method for making electricity. So let us expose some of these myths with some more quotes from Patrick Moore:

Myth 1: Nuclear energy is expensive*: It is in fact one of the least expensive energy sources. In 2004, the average cost of producing nuclear energy in the United States was less than two cents per kilowatt hour, comparable with coal and hydroelectric. Advances in technology will bring that down further in the future.*



The cost of nuclear energy is lower than that from oil or gas and doesn't generate greenhouse gases as those do. With mass produced thorium reactors, the cost would be negligible. The cost of the actual fuel is always tiny – even in uranium reactors.

Myth 2: Nuclear plants are not safe. *Three Mile Island was in fact a success story; the concrete containment structure did just what it was designed to do – prevent radiation from escaping into the environment. And although the reactor was crippled, there was no injury or death among the nuclear workers or nearby residents.*

Chernobyl was not (a success story), it was an accident waiting to happen. This early model Soviet reactor had no containment vessel, (and) was an inherently a bad design. The multi-agency U.N. Chernobyl forum reported last year that 56 deaths could be directly attributable to the accident, most of those from radiation and burns suffered while fighting the fire. Tragic as those deaths were, they pale in comparison to the more than 5,000 coal-mining deaths that occur world-wide every year. No one has died of a radiation-related accident in the history of the U.S. civilian nuclear reactor program.

- *Author's note: As already mentioned, over 2 million people have died on US roads in the same 50 year period.*

***Myth 3: Nuclear waste will be dangerous for thousands of years**. Within 40 years, used fuel has less than one-thousandth of the radioactivity it had when it was removed from the PWR reactor. And it is incorrect to call it waste, because 95% of the potential energy is still contained in the used fuel after the first cycle. Now that the U.S. has removed the ban on recycling used fuel, it will be possible to reduce the amount of waste.*

***Myth 4: Nuclear reactors are vulnerable to terrorist attack**. The six-feet-thick reinforced concrete containment vessel protects the contents from the outside as well as the inside. And even if a jumbo jet did crash into a reactor (after breaching) the containment, the reactor would not explode. There are many other types of facilities that are far more vulnerable.*

***Myth 5: There is a shortage of uranium fuel.** On the contrary, there is a glut of uranium in the world, with enough known reserves to last a century or more. With the availability of breeder reactors, there is enough uranium to last many more centuries. Also, scientists have calculated that there is enough uranium is sea water to last billions of years and could be extracted at an economic price. By then, we should have an even better technology.*

- *Author's note: Thorium is even more plentiful in the earth's crust, and thorium reactors are much more efficient, so one small mine, digging up a mere 15 thousand tons of thorium, which is about one train load, could power **the entire world for one year replacing billions of tons** of coal.*

The vast majority of U.S. oil consumption – over 70% -goes to transportation, so the electrification of transportation - cars, trucks, trains, buses, ships, and aircraft - is the single biggest factor in reducing dependency on oil without producing greenhouse gases. *This is where TEV can make a huge contribution, so long as we can get the electricity.*

It is difficult to put a PWR reactor on "idle" at night when the demand for power is low. Therefore, such plants have an enormous "spare" capacity during off-peak hours. This capacity could be sold cheaply to encourage people to use the "off-peak" power available at night. TEV freight vehicles, for example, could use this benefit to reduce delivery costs yet further.

It could also be used to manufacture hydrogen. Using cryogenic (super-cooled) storage, hydrogen might replace carbon fuels in commercial jet aircraft, producing no carbon-dioxide during flight. Remarkably, the economics are quite good, particularly with cheap electricity to make the hydrogen. The technical problems are not as severe as developing fuel cells for cars, for example.

How do we solve the energy problems of the developing nations?
Poorer nations will need help for many years to come. Money subsidies, however, are notoriously inefficient because they can be siphoned off by corrupt officials into secret bank accounts. An energy subsidy using Lifters may be an ideal alternative.

Ideally, by the end of the present century, technology may have advanced enough to allow us to produce energy on a vast scale with a completely different and even better method. But, in the meantime we will do well just to avoid regressing.

Where does the hydrogen economy fit into our future?
A minor cult has developed in the Western world around the concept of a "hydrogen economy". In this scenario, the future lies in burning hydrogen as a fuel instead of fossil fuels. This attractive concept is very misleading because, unlike real fuels, ***hydrogen does not exist naturally.***

Many media people repeat the mantra that hydrogen is the most common element and that we have all we need in water. Of course there is hydrogen in water, but it represents energy that is **already spent**. It is like saying that there is plenty of carbon in the greenhouse gas carbon dioxide. But you can't burn that carbon to make energy *because* ***it has already been burned.*** Likewise, water is the ash that is left over after burning hydrogen.

Simply put, oil, coal, natural gas, uranium and thorium are all *primary fuels*. They are all found in the earth, to be dug up and consumed. The energy they yield to us is *already stored inside their chemical structure* and bursting to get out, so to speak. But there are no natural hydrogen (gas) fields in the world, waiting for us to find them. The fact is that **all hydrogen must be manufactured.** And when it is manufactured, using electricity, it contains less energy than the electricity that was consumed to make it.

The so called "hydrogen economy", therefore, is better described as a "stored hydrogen economy" in which – perhaps - cheap nuclear power **generated** at night is used to extract the hydrogen from water or from some other raw material. Therefore, hydrogen is not the star of the show; electrical power is the star and hydrogen is in a support role as an ***indirect method of storing electrical ene*****rgy.**

Alternately, the hydrogen could be combined with carbon – perhaps from the exhaust of coal fired power plants – to make liquid hydrocarbon fuels for use in diesel engines. Man is an ingenious creature if allowed to exercise his talent.

Clearly, however, there are substantial technical developments involved with storing and using large amounts of hydrogen. It will take years to sort out which solutions work and which do not, but the free market will do that with its usual efficiency in due course.

Hydrogen can be burnt in gasoline engines

Hydrogen can also be used to power conventional car engines directly - in place of gasoline. In fact, several prototypes of hydrogen powered cars are running around at present. They drive much like normal cars and produce no carbon dioxide in their exhaust gases.

So why don't we solve the twin problems of global warming and global oil dependency by converting to hydrogen-burning cars? The answer is that it isn't very efficient. First, hydrogen has to be made from electricity. Then it must be compressed which loses more energy. Then it is piped to its final destination which loses morestill. Then it is burnt in an engine which loses even more. So only a small percentage of the original electrical energy is available to move the car.

Compare this with the high efficiency the TEV system where the electrical energy is distributed very efficiently from the power station to the electric drive motors on the cars. A TEV electric drive system is many times more efficient than an engine that burns hydrogen.

What about hydrogen fuel cells?

The fuel cell car, running on hydrogen is another favorite of idealists, particularly naïve ones. *(Author's note: I ought to know; I wrote a breathlessly positive paper on the concept in my student days over forty years ago).* One advantage is that the fuel cell has over the hydrogen-engine is that the fuel cell is about twice as efficient. This is a useful improvement but still much below the TEV efficiency.

Another advantage is that a fuel cell car could run on a TEV track – even through tunnels – because it doesn't produce fumes – but it is difficult to see how this arrangement would be either necessary or economical.

All the other problems are the same as for the hydrogen engine: the distribution of hydrogen is just as difficult, the storage of hydrogen in the car is just as difficult, the driving range is better but still limited, particularly if the air conditioning or heater is turned on. And the fuel cell does not like cold temperatures. So it is probably true that TEV makes the fuel cell car obsolete.

The bottom line

Let me repeat the major advantages of a TEV based transportation system tied to a clean energy source:

1. TEV will eliminate a huge amount of greenhouse gases, not only because it runs on clean electrical energy but also because it **conserves energy** due to its much higher overall efficiency. This is enough to justify a full scale "Manhattan Project" type of effort to get it into use quickly.
2. TEV will reduce, drastically, the word's dependence on oil, changing the political climate and reducing the risk of wars.
3. TEV will preserve oil supplies to make plastics and other useful products; it is too precious to burn as a cheap fuel.
4. TEV will make life better for ordinary people and not subject them to grim socialist public transport schemes that require them to live in overcrowded cities and travel in inconvenient and unhealthy buses, trams and trains.
5. TEV will reinforce the fundamental concept of freedom to go anywhere, at any time, without unnecessary interference from government agencies.

An final number will make the point about relative costs per mile of different systems. The Maglev that runs from Pudong airport to the outskirts of Shanghai cost $50 million dollars per mile. That is an absurd cost which could never be paid back by ticket fees.

Chapter 12 Management and cost

The problems of startup can be solved..
Like the chicken and egg parable, does the TEV track come first and then the TEV vehicles, or vice versa? The following is a simple plan that makes commercial and developmental sense.

First, build a prototype TEV track between two cities which are fairly close together. For example, in Scotland, it could be between Glasgow and Edinburgh which are 40 miles apart (67km).

At the same time, build some Robo-cabs and Minibuses, single-mode vehicles that can drive on the track but cannot exit. Erect a few TEV Stops along the way, perhaps ending at the airports in each city. All of this construction would have a trivial cost considering its value to the project.

Next, run these vehicles as public transport for an extended period of time, letting members of the public use the services as they will in the future. Start with a slower speed and then raise it step by step until the 120mph target is reached. At this point, the 40 mile trip would take just 20 minutes. Work out all the details of operating the system on this prototype.

After this step, allow the car manufacturers to run their own electric cars on the track in full, dual-mode format. That is, allow the cars to enter from the street, run on the track and leave to the street. By now, everyone would see the sense of the system and how easy it is to operate and use – especially the public who will now want to use electric cars as soon as possible. By now, the car manufacturers would have their own test tracks but this "official track" will give them great publicity.

Finally, and this is quite cunning, allow **petroleum powered, privately owned cars to be converted to run automatically on the track** (which will have to be properly ventilated, of course). These cars would generally be powerful, high end vehicles with the ability to cruise easily at 120 mph.

(Note: Before you object, the intent of this last step was not, initially at least, to allow such vehicles to use the track in the long term, but

*to allow them only **during startup.** An engine powered car might be converted to run on the track for (say) $1,000, so many owners of expensive cars might want to pay for the conversion due to the low risk involved. If the converted cars worked out well, perhaps we should change the rules and **allow engine powered cars to run on TEV**. Except for long tunnels, perhaps there is no good reason to ban engine powered vehicles – at least not until the EVs are well established. Rather it might be a more pragmatic strategy to allow them to compete head to head with the EVs and let the customers find out that the EVs are better because they have unlimited range. The concept is worth exploring).*

This single prototype track, 40 miles long, could become a tremendous educational tool for the TEV system – and for interested parties all over the world. In the meantime, the test track would be racking up miles of usage, allowing engineers to optimize the design of the track, the software, the road repair equipment and so on before the final rollout of the system. In fact, it could even be useful as a practical method of connecting airports: if there were fog in Glasgow, for example, then land the plane in in Edinburgh and take a 20 minute ride back on TEV.

The last step in the process would be to define the standards for TEV tracks formally so that every country in the world could build to that same standard and ensure that they are not left behind in the future.

.

Who pays for commercial construction?

This final section of this booklet is concerned with how such an extensive project as TEV can be implemented in risk-averse world. The answer is the same one it has always been: **make it pay for itself with a good return to investors**. TEV must be a financial success story before it can be a technical, environmental, or political success story.

Most people would think that government subsidies would be essential to bring the TEV system to life. But that concept is out of date and no longer true in many parts of the world. One reason is that many governments are already too indebted and don't have the money to spend anymore. So it is best to work under a public/private arrangement using private capital.

(Note: Having said this, there is no reason to avoid government subsidies during a deep recession. In the 1930s depression, the US

government subsidized the building of road bridges all over the USA. They created lots of jobs and radically improved the road infrastructure. It is probably the BEST form of government spending possible because it increases wealth in the long term).

With respect to the preferred private capital, William Reinhardt, an expert in **Public-Private Partnerships (P3s)** in the transportation construction industry, makes the following optimistic statement:

> *"Two decades of experience have shown that* ***private investment is attracted to large, complex and expensive transportation projects*** *that add new capacity to the US system and can be supported by a new revenue stream, usually tolling".*

Of course, government support in the form of approvals and oversight is necessary so TEV must be developed by using a public-private partnership approach. The government may oversee the project but investors should take the risks - and be fairly recompensed via toll revenue. There is **plenty of investment wealth** available in the world to invest in a company that has a good profit potential. The good news is that TEV could become **one of the most profitable investments in the history of mankind.** In short, we don't need subsides.

We would therefore propose the founding a central joint stock company having several daughter-companies each dedicated to a particular country but joined in a cooperative agreement to share technology and to maintain common standards. Joint stock companies were how the railways and other radical projects of the industrial revolution were developed in nineteenth century in Britain and elsewhere. (Indeed, the East India Company was a joint stock company). It is time we returned to using these strong and innovative entities for large projects such as TEV.

How much would TEV cost?
These are some actual construction costs in dollars per mile for the US Interstate Highway system in 1994 and 1996 dollars. Present values would be about 40% higher than those shown:

- Boston Big Dig — $1000 million/mile
- New York City — $333 million/mile
- Los Angeles — $127 million/mile
- Los Angeles elevated — $20 million/mile
- LA car pool lane — $2.5 million/mile
- Pool lane with tollbooths — $30-50 million/mile

- Rural highway $1 million/mile
- Mountainous $15 million/mile
- Average rural + urban in USA $20 million/mile

It should be obvious that TEV tracks would be far lower in cost for most of these constructions, especially difficult ones like roads into cities, or across mountains, or roads with tollbooths – which TEV replaces directly..

TEV would be funded by tolls paid automatically by the users. The joint stock company would get its return on its investment by taking a percentage of the tolls. The government, likewise, would get its share of tools as revenue. It really isn't a difficult task as the following list indicates:

The plan

1. Set up a parent joint stock company Recruit daughter companies internationally.
2. Set up an international consortium to define a single TEV design standard for word-wide use and to manage the project.
3. Define the project targets and schedule.
4. Delegate the development of hardware and software systems to specific organizations. (For example: vehicle design to the car companies).
5. Select several locations around the world for the building and testing of full-scale prototype tracks, as described already, but complete with Stations, Stops and Portals.
6. Build several full scale systems and test them in the real world before releasing them for public access

The end result will be a clean, efficient, world-class transportation system worthy of the twenty first century, developed and funded by big companies from Europe, China, Japan, the USA and others. The companies might be in the business of automobiles, engineering, electricity production, electric motors, batteries, power systems. Progress on the entire TEV development project would be reported on a continuing basis on an internet website complete with videos, technical performance reports and so on. Everyone in the world would be able to see what was going on directly. So TEV would also be an exercise in open development systems development in democracies.

Appendix 1: What about an additional TEV-based system designed specifically for heavier freight?

The TEV format is very flexible but, if we could afford to have two parallel, separate versions, one optimized for passengers plus parcels and the other one optimized for heavier cargo (and having its own dedicated cargo vehicles) the freight version would be a little different from the passenger/parcel version design presented so far, for these reasons:

1. First, there is no need for TEV **cargo wagons** to drive at high speeds so a slower speed such as 60 mph (100 km/h) is quite adequate. Remember, they never stop for breaks so, in 20 hours, they could travel 1200 miles.
2. This means that they would have to drive on **separate slower tracks** but this offers some great energy cost reductions. .
3. More costs could be saved because there is no need for the cargo wagons to be made in a large number of different shapes, styles and colors as consumer vehicles must. Instead, they can be simple rectangular boxes with minor streamlining, mass produced to a very **standardized design** – essentially **s**mall containers on wheels..
4. With no passengers on board the cargo wagons, there is no need for public escape sidewalks and other safety features on the track so the track enclosures can be made substantially narrower and cheaper. This will reduce costs of tunneling etc.
5. An interesting further cost reduction and energy saving is to equip the wagons with **additional steel wheel/steel rail support** for most of their travel because they will not need the emergency braking performance of the passenger vehicles.

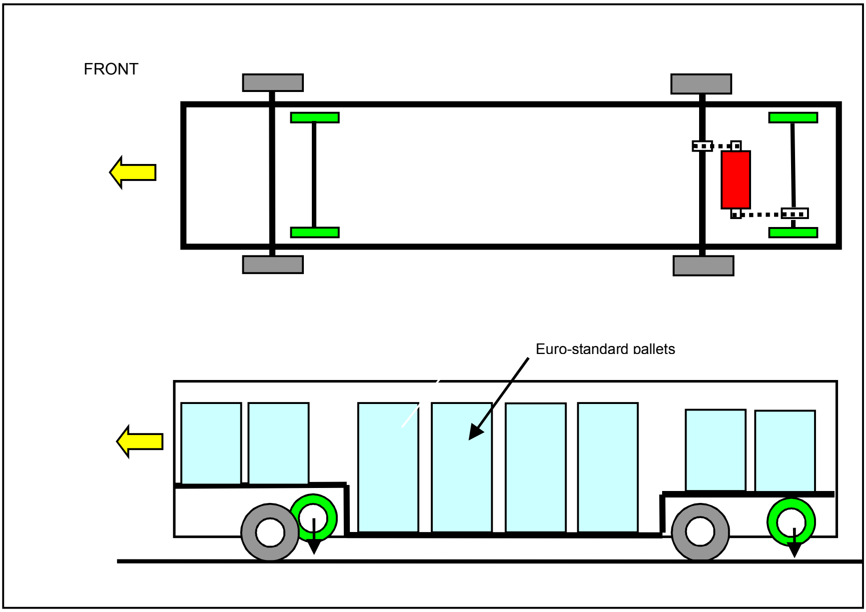
So it may make economic sense to have a **second cargo system**, similar to the normal TEV system but optimized for freight. One possible simple concept is now described. .

A basic proposal

The sketch below shows a straightforward design where the TEV Cargo wagons have separate steel rail wheels and rubber-tired road wheels rotating as one. In practice, the road and rail wheels may be located on the same axles but this is a detail that can be worked out in design review. The wagons would drive continuously on their steel rails until they reach their programmed exit and then easily morph into road vehicles to exit on to the road system on their rubber tires.

For illustration, imagine that on long runs, the vehicle is running on its rail wheels to save energy. As it approaches each exit, the rails taper or slope downward so that the vehicle "lands" on its rubber tires on the friction surfaces. At this point it can either exit the track or continue onwards. If it continues onwards, the rail appears once again, this time tapering upwards slowly so that the rail wheels gently re-engage the rails and the wagon "takes off" from its rubber tires. The wagon is now back to its "cruise" status without any complicated switches or mechanisms on the track whatsoever.

However, if the wagon needs to exit the track at the intersection, it is already on its rubber tires so its computer simply steers it out on to the exit track and from there on to the road system.



Conceptual sketch of a basic TEV Cargo wagon having both road and rail wheels.
The overall height may be as low as an SUV or small van, vastly smaller than a tractor-trailer so that tunnels would be small and cheap to build. The wagons would also be easier to load/unload from the ground - and from the side with standard fork trucks.

Cruising on steel wheels
A Cargo wagon running on steel rails, in a close-coupled convoy, and at a moderate speed, would have an energy consumption per mile that would be astonishingly low, making it a clear contender for the most efficient land-based delivery vehicle ever made.

During cruise, the TEV Cargo wagons would run largely on rail wheels to save energy. The drawbacks of long braking distances and poor hill climb capability of steel wheels are not great liabilities on a freight track. In any case, on a severe incline or an emergency stop, where the steel wheels may not have enough grip, the wagons could be set down on their rubber tires on prepared friction surfaces in place of the rails. After climbing the hill on their rubber tires, they could revert to steel wheels for efficiency on the rail track.

Exits
Having no driver, the wagon could not initially go on public roads so a human driver would tow it the short distance to its destination with a small tractor. In general, the wagon might pull up into the loading area of a large factory, distribution center, supermarket, mall etc., to be unloaded close to the point of use.

Soon, however, new wagon versions would be developed to self-drive on the roads following the example of Sebastian Thrun's Google "driverless cars" and similar systems developed by BMW, Volkswagen and others. This would give us a fully automated, door-to-door delivery system, which could deliver even at night. In the meantime, TEV wagons could be towed to their final destination by a human driving a tug.

One critical requirement of the TEV Cargo system, in our opinion, is that **no switching mechanism with moving parts should be permitted on the track itself.** This is because while vehicles are easy to repair or replace **off the track, the track itself is not easy to repair with traffic on it.** Any fault that happens on the track is going to hold up traffic – an inexcusable sin on the TEV system.

Overall advantages
The great advantage of an arrangement like a separate TEV Cargo system is that the total energy per ton mile used to carry freight will always be tiny compared with **any existing road freight system**. The steel wheel, steel rail combination gives very low rolling resistance and the wagons will form very close coupled convoys to

reduce the aero-dynamic drag. So the system will be both **very efficient and very green.**

Further, the collective carrying capacity of the TEV Cargo wagons on a single TEV Cargo track will be **enormous** compared with that of manually driven trucks on normal roads. So, eventually, the remaining truck traffic on the main roads will be reduced to a small fraction of the present quantity, to the benefit of all. In fact, it would now be possible to use one lane of a motorway as a ground-level TEV track. **The net carrying capacity would be increased not reduced.**

The wagons themselves could be made to several standard lengths that carry multiple standard Euro-pallets. To carry more pallets, users would simply use more wagons; a very flexible option. Physically larger loads, like Caterpillar tractors for example, would go by road as they now do.

The astonishing advantages of the TEV Cargo Wagon system

1. The cost per mile of freight delivery with this system would be a fraction of that of diesel trucks plying the motorway systems of the world, especially when hydrocarbon fuels get too expensive.
2. The flanges on the steel wheels do not have to resemble that of present trains because they do not need to operate with switches (points) and other railway fixtures.
3. Since the TEV Cargo system will not carry passengers, many safety constraints would disappear and the track structure would be made much simpler. For example, we would not need safety "sidewalks" on each side of the cars to allow people to escape in an emergency which would make the freight tracks much narrower and easier to fit in tunnels.
4. Supplying electricity to the vehicles would be easy as well. A simple pair of conductor rails under the vehicles would suffice for electrical supply. Standardization means lower construction cost.
5. The TEV freight track would bring in so much money in user fees that it would probably pay for not only for itself but for the entire TEV passenger track as well.
6. TEV electric wagons could drive on their rubber tires into factories, just like AGVs (Automatic Guided Vehicles) that are already used in big factories, and deliver freight **directly to an assembly line** to complete the supply chain perfectly.

7. If a pair of high-speed TEV passenger tracks were built on top of a pair of TEV Cargo tracks - in double-deck fashion - and that installation could fit inside a typical railway tunnel or railway bridge, we would have a phenomenally low cost way of providing next-generation travel of **both passengers and freight** using last-generation rights of way that are almost universally underused.

   (Note: If you don't believe this last comment, take a look at the enormous gaps between passenger trains in your area, the low speeds of these trains, and how few passengers that are carried, especially in off-peak hours. You will see how incredibly wasteful most commuter trains are).

Will Jones

Conclusion

To the reader we say this: please let's stop **talking** about global warming, oil dependency, pollution and restrictions on our freedom to travel and DO something constructive that will **actually work**.

We need an "**open source**" system like TEV as soon as possible - plus a safe, liquid thorium based, nuclear power program to support it at least for the medium term.

What is the alternative? Trains and buses? They are 19^{th} century concepts now limited by their inflexibility. Do we all really want to live, with our children, in tower blocks in huge cities? No, of course not. With TEV you can live in the suburbs with your own garden, drive your own car, and still be a responsible environmentalist. You can keep your **freedom** to go where you want and still have a clear **conscience**.

Please help make it happen by passing on this information about TEV in any way you can.