Very Light Rail (VLR) Technology - A New, Simple, Safe, Cost-Effective Environmental Solution to Meet Future Transportation Needs

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Introduction

An increasing number of papers (Dearien 1994, Floyd 1990), government programs (FTA 1991), and studies (Johnson 1989), are directed toward the economics of lighter weight vehicles in mass transit. The objectives of these activities are generally directed toward the increased energy efficiency of the lighter vehicles or the benefits to the infrastructure - less wear, repair, or construction cost, or both. Some systems studies of potential magnetic levitation concepts have minimized the size of the vehicles in order to increase the operational flexibility of the system (Johnson 1989).

CyberTran was designed and developed from the ground up as a small vehicle transportation system with the primary objectives of (1) reducing the capital and operating costs of high speed rail and transit systems and (2) maximimizes rider appeal and safety. The potential for significant savings in capital cost with a small vehicle rail system like CyberTran has been evaluated (Morrison Knudsen 1991, Welland 1994). This paper discusses the operational benefits which can be realized with a rail system based on small, light weight, and computer controlled vehicles.

CyberTran was developed at the Idaho National Engineering Laboratory, a U.S. Department of Energy Research and Development Laboratory in Southeastern Idaho.

Vehicle Characteristics

The CyberTran system is based on the use of large numbers (100's) of small (38 feet) and light weight (<10,000 lb) vehicles operating on elevated guideways and under complete computer control (no on board operators). The vehicles are all the same size but can be internally configured for seating of between 6 and 32 passengers, depending on the application. The vehicles are designed for all passengers to be seated in aircraft type seats (6-14 passengers) or bench seats (19-32 passengers).

The vehicles are powered by two electric motors, providing all wheel drive and obtaining their power from a third rail on the elevated guideway. The vehicles are designed to operate at a system speed from 30 mph to 150 mph, depending on application.

Guideway Characteristics

CyberTran is designed to operate on an elevated guideway, at a height sufficient to clear terrain, animals or humans traveling under the guideway, and automotive and truck traffic at intersections. The guideway sections are separate for each lane so that opposing directions of traffic are not capable of derailing and impacting oncoming vehicles. The individual guideway sections have constraining sides so that, in the unlikely event of a derailment, the vehicle would be contained within the guideway section and brought to a stop. The guideway sections can be constructed from a variety of materials in a number of shapes. Figure 1 shows the vehicle sitting on an arch design steel truss. Concrete guideway sections have also been designed as an architectural alternate to steel. The system is designed to operate with a mix of materials and designs, with the final decision being one of cost and aesthetic wishes of the individual customer.

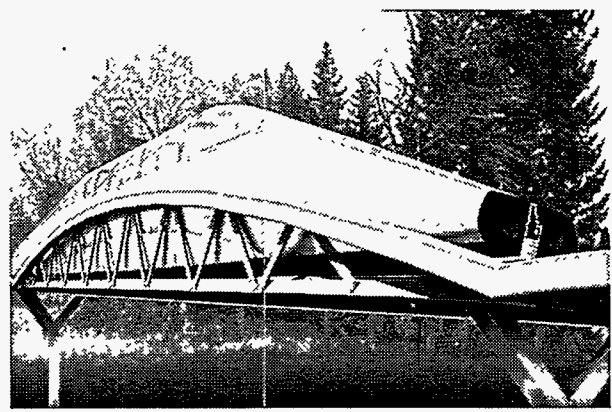**Figure 1. CyberTran Vehicle on Elevated Guideway**

Figure 1 is a composite photograph of the Number 2 test vehicle sitting on the test truss, with a computer graphics simulated column structure and background.

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Carrying Capacity of CyberTran

CyberTran is designed to operate with a vehicle separation of 0.25 miles (1320 feet) at 60 - 75 mph. This compares with a automobile separation of from 100 to 200 feet on a freeway and 2 minute (LA Blue Line) to 7 minute (Portland MAX, TRB 1991b) separation of light rail transit (LRT) vehicles at rush hour. For the above parameters, CyberTran can carry from 3300 to 9600 passengers per hour per direction (pphpd) with the 14 - 32 passenger seating arrangement. A single car consist LRT with 160 passengers (40 seated/120 standing) would carry from 1400 to 4800 pphpd, or 2800 to 9600 pphpd with a double car consist. These numbers are in the capacity range of two to four lanes of a freeway or Interstate Highway (Hall 1993).

For high speed applications (150 mph), operation of a 6 - 14 passenger CyberTran vehicle with a vehicle separation of 1.0 mile provides for a throughput of 900 to 2100 pphpd. This is the numerical equivalent of a 500 passenger 747 or a 500 passenger French TGV (TRB 1991a) leaving every 14 - 33 minutes.

The above comparisons show that for a certain range of passenger flow rates, a transportation system based on small, low occupancy vehicles like CyberTran, can carry the same traffic flow as transportation systems based on large, heavy vehicles.

Figure 2 shows how the transportation modes compare over a range of vehicle capacity and separation times (headway). Decreasing the operating headway is a significant factor in the capability of a small vehicle system to carry large traffic flows (several thousand pphpd). The short operating headway of CyberTran is obtained with a communication based control system.

### Figure 2. Vehicle Capacity, Headway & Flowrate
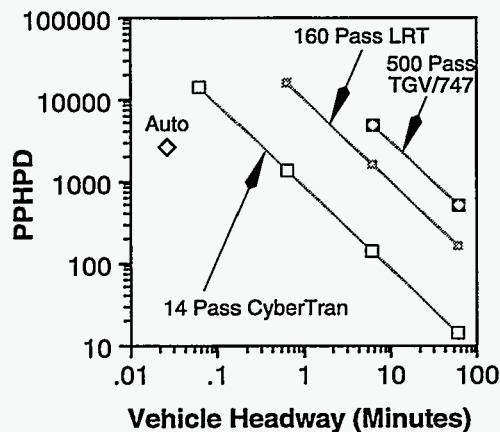
Vehicle Operating Process

CyberTran vehicles are loaded and unloaded off-line and then dispatched direct to their destination. This process results in a much higher average system speed than conventional systems where vehicles stop at each station. Although conventional technology LRT vehicles have a maximum velocity of 55-60 mph, the average velocity of a system can be less than 20 mph (TRB 1989b). Computer simulations of urban transit systems with small vehicles dispatched direct to their destination resulted in system average speeds of over 50 mph, or over 2.5 times the average speed of a LRT system.

Increasing the average system velocity by a factor of 2 - 2.5 has a number of very favorable effects on system operation. From the passenger standpoint, their travel time is cut by a factor of 2 or more. From an operator's standpoint, a higher average system speed allows a corresponding decrease in the number of seats required to handle a given passenger flow rate. Figure 3 illustrates the relationship between system average speed and the number of seats required to provide a given service level.

Figure 3. System Seats Required Vs System Average Speed
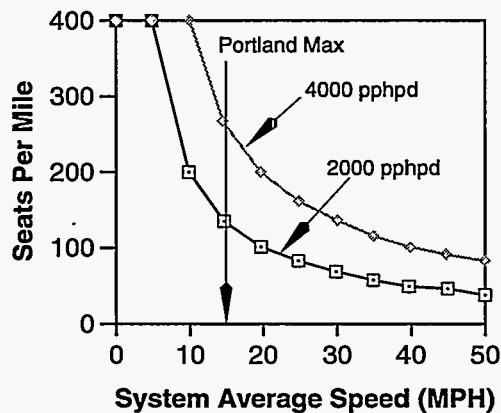
There is an obvious non-linear relationship between equipment requirements and system average speed, with decreasing system speed requiring a non-proportional increase in equipment. From Figure 3, one sees that for a passenger throughput of 4000 pphpd and a system average speed of 20 mph, a supply of 200 seats per mile is required. For a system average speed of 50 mph, only 80 seats per mile are required. With responsive system inventory control and on-line processes to maximize average system speed, a significant reduction can be made in the rolling stock requirements and initial capital cost.

Capital Cost Effects of Higher Average System Speeds

The per seat capital cost of an advanced LRT vehicle capable of carrying 160 passengers is approximately $12,500 per seat ($2M per vehicle, TRB 1989). The projected per seat cost of a 14 passenger CyberTran vehicle is $7000 ($100,000 per vehicle, Welland 1994). For the example described above, a LRT system requiring 200 seats to the mile requires a capital outlay of $2,500,000 per mile to satisfy demand, whereas a high average speed system like CyberTran requires a vehicle capital outlay of only $560,000 to supply the same demand. It is thus an advantage, not only for the satisfaction of the paying passenger, but for the capital cost of the system, to keep the average speed of the system as high as possible.

Passenger Handling in a Computer Controlled, Low Occupancy Vehicle Transportation System

CyberTran is designed to carry passengers from their loading point directly to their destinations. This process decreases the travel time of the passenger and increases utilization of the equipment, but requires special station facilities in order for the system to operate.

Passengers arriving at a departure station will indicate their destination as they pay their fare, either by ticket purchase or use of a debit card. The station computer will direct the passengers to the loading position for their destination.

While the basic design operating mode is direct-to-destination, it is expected that some route and traffic flow situations will require modification to this operating mode. Vehicle dispatch to low passenger flow destinations will be either on a "maximum wait time" (a vehicle will leave within "x" minutes after the first passenger is loaded for that destination) or by combining service to several low flow destinations within one vehicle.

In order to maintain support from the traveling public, passengers must be assured that under any set of circumstances, they will have transportation within a defined set of parameters. The fare structure is projected to cover the direct operating cost of a vehicle with one occupant, therefore single passengers can be transported in low traffic periods without significant impact on costs.

Flexible in vehicle dispatch

For special events such as athletic events, concerts, parades etc., where unusually high numbers of passengers can be anticipated, the system operator has the ability to locate vehicles at stations where they will be most needed to serve inbound and outbound peak loads.

The computer controlled aspect of system operation, specifically the control and flexible dispatch of individual vehicles, allows the system to operate as a 24 hours per day, on-demand system.

Station Operation

CyberTran stations are designed to load and unload passengers off-line in multiple loading/unloading positions. A station with 10 loading positions can dispatch passengers directly to any reasonable number of other stations, depending on the degree to which each loading position is alternated between destinations. The limiting factor of a station throughput is either the rate at which each loading position can be cycled (1 - 2 minutes) or the rate at which vehicles can be processed out of the station and onto the main line (6 per minute per direction). Each loading position can embark from 400 to 800 passengers per hour directly to another station. For flow rates greater than this, multiple loading positions can be allocated to a particular destination. Total station throughput can be on the order of 4000 - 8000 passengers per hour for a 10 slot station.

Stations can be located in or near shopping centers, medical complexes, universities, airports, downtown areas and industrial parks to provide passengers with the travel convenience nearly equal to the automobile.

Extra vehicles are stored in and around each station. This permits rapid availability and dispatch of vehicles under a variety of traffic flow conditions. It also contributes to the flexibility of system operation, being able to move vehicles around the system and store them at stations in anticipation of flow variations.

Passenger Safety

The passenger safety of a small vehicle transportation system such as CyberTran has the potential for being one of the safest modes of transportation in existence (the French TGV has had no fatalities). CyberTran is a steel wheel on rail concept like the TGV, but uses elevated guideways to eliminate at-grade crossings. Each direction of travel is contained within a separate constraining guideway so that if a vehicle should become derailed for any reason, it will stay within the guideway and not impact oncoming vehicles.

In the case of primary power loss, emergency power is available to bring vehicles to the nearest station at a reduced speed. For a condition of total power loss, passengers can leave the vehicle and walk along the guideway.

Passenger Security

Passenger security is the measure of risk to a passenger from acts committed by other passengers, as opposed to passenger safety, which is a measure of risk to the passenger from the system itself. Passenger security in a small vehicle, especially in a computer controlled system like CyberTran must be given special consideration, both for actual passenger security and for perceived security. Passenger security on a small vehicle system which uses large numbers of rapidly deployed vehicles has the potential for providing a higher degree of passenger security than conventional public transportation modes. An individual has the opportunity to survey their fellow passengers prior to getting on a particular vehicle. If there is a perceived risk, the passenger may elect to take the next vehicle which, in a system using large numbers of small vehicles, is dispatched in rapid sequence. Once on a direct-to-destination vehicle, that vehicle does not stop at intermediate stations from which a threat to personal safety could enter the vehicle. Each vehicle is equipped for continuous radio and video contact with the personnel at central control and each vehicle can be immediately redirected to the authorities if a passenger becomes a threat to other passengers.

System Cost

The costs of interest in any transportation system are the up front construction & capital cost and the yearly maintenance & operating costs. CyberTran has been . designed to hold both of these costs to a minimum.

Construction Costs: It has been estimated that a CyberTran system can be constructed for " — 10% to 50% of the cost of conventional rail systems." (Morrison Knudsen 1991). While a more precise value for this quantity must await completion of the test program and construction of the first commercial system, a number of system and component cost evaluations (Welland 1994) provide credence to the assumption that CyberTran can be constructed at a fraction of the cost of conventional technology.

The primary factors accounting for the predicted low construction cost of the CyberTran system are (1) the light weight and low cost of the guideway sections - allowed by the light weight vehicles, (2) mass production of the large numbers of guideway components and vehicles, and

(3) the efficient process for onsite construction of the system.

Figure 4 illustrates the cost of several transportation modes, including the projected cost of CyberTran. CyberTran is expected to also have a wide range of system costs due to a variety of factors such as urban setting, terrain, and traffic flow, but is projected to always be significantly less than convention technology.

Figure 4. Minimum Cost Of Systems
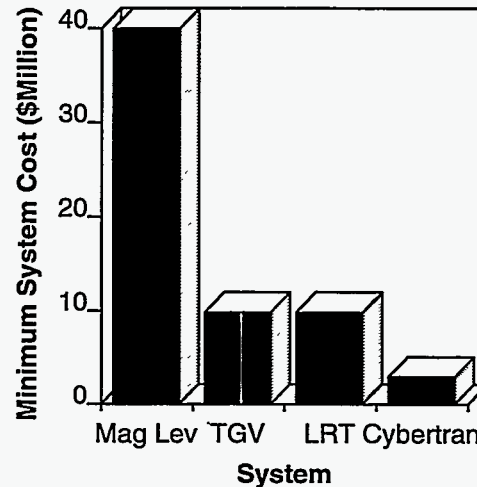
Operating Costs: Operating cost for a CyberTran system is expected to be significantly less than conventional rail and transit systems for several reasons;

- no operator in vehicle
- low direct operating cost of vehicle
- dispatch of vehicles required only for passenger flow rate
- low maintenance guideway
- vehicle designed for low maintenance
- components designed for out-source maintenance
- low debt service as a result of low construction cost

CyberTran Program Status

Two test series have been conducted in which test vehicles were (1) taken to speeds of 55 mph and (2) tested for tracking stability on tangent and curved sections of track. Both test series met their objectives and showed the design of the vehicle to be satisfactory with respect to the physical requirements of a rail transportation system - acceleration, braking, tracking, power & propulsion, etc. The second of these test series showed the single axle propulsion trucks to be stable on both tangents and curves.

These tests were conducted on special trackage (test series 1) and conventional trackage (test series 2) at the INEL. The second test vehicle has been constructed for testing and ergonomic evaluation. Figure 5 shows the interior of the test vehicle in a two-abreast seating configuration.

Figure 5. CyberTran Interior

A computer simulation of the CyberTran vehicle (using the NUCARS Code) at speeds up to 160 mph was conducted by the rail dynamists at the Transportation Test Center in Pueblo, Colorado (Leary 1993) and the vehicle was found to be capable of safe operation at high speed.

Plans are now being developed for a 5 mile long, double line, pinched loop test track on which 4 vehicles would be operated in such a fashion as to prove the commercial operational parameters of the CyberTran system. Partners are being sought for the development of this test track and for the commercialization of this technology in the high speed rail and transit markets of the United States and the world.

Summary

The operation of a rail transportation system, based on the use of large numbers of small, computer controlled vehicles, has been described. It has been shown that the proper application of this technology can result in a rail transportation system that is projected to be not only cheaper to build and operate, but also offers the passenger a much better and less expensive service.

Further testing is required before this technology can be applied in commercial service, and plans are in place to carry out the required testing when funding is obtained.

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