ULTRA LIGHT RAIL TRANSPORT (ULRT) from WDC METRO to Atlantic Ocean CITIES via a NEW Chesapeake Bay Tunnel

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ABSTRACT [words 242]

The introduction of a Transit system as part of the Chesapeake Bay Crossing Tier 1 NEPA analysis was not addressed in the Final Report (2). The primary focus of the analysis was a third bridge connecting approximately 20 miles of a 2-mile-wide corridor containing a 4.5-mile Bay crossing. The crossing 7, which utilizes the Rt.50/301 highway was selected by the DoT/FHA as the preferred crossing location at a cost estimate from $5.4 to $8.9B. The Maryland Transportation Authority (MDTA) was authorized to continue to study a third bay bridge span. This analysis is underway. The consideration of a 60-foot diameter tunnel that would include a 150-mile Ultra-Light Rail Transit system should be included in this Tier 2 NEPA analysis. This system would rely on a new autonomous, 10,000 pound, 20-passenger rail car based on a low-drag, efficient battery and Full Self Driving vehicle technology. It would also use the Morgantown, UWV Personal Rail Transit (MPRT) and the London Heathrow airport ULTRA systems that are in current operation. Developing a new high-speed transit system based on this experience should provide a cost-effective system. A June 27, 2023 MTA listening session found that 89% of those in attendance wanted the new bay crossing system to provide a transit system. This paper does a first look at what such a system would include and provides a preliminary cost estimate. Transportation is a system-of-systems, not just a 100-year bridge for trucks and cars.

INTRODUCTION

The Chesapeake Bay Bridge vehicle traffic peaked at 27,140,600 vehicles/year in 2007, Table 1. Excessive queueing delays have limited this operational rate ever since. The current crossing consists of 2 bridges (first bridge constructed in1952 at 2 lanes and the second bridge constructed in 1973 With 3 lanes). The steel bridges are planned to be under extensive refurbishment over the next 50 years due to their deterioration in a salt-water environment. This refurbishment activity adds to the queueing delay problem. It can be argued that there may be at least another 30 (Bridge 1) to 50 (Bridge 2) years to their safe operational life. The future traffic projection is shown in Figure 1 (2). An independent study (3) predicted 82,000 v/d weekday and 105,000 v/d summer weekend in 2040.

TABLE 1. TAKEN FROM (2) PG. A-8, NOTE 2007 TRAFFIC STAGNATION

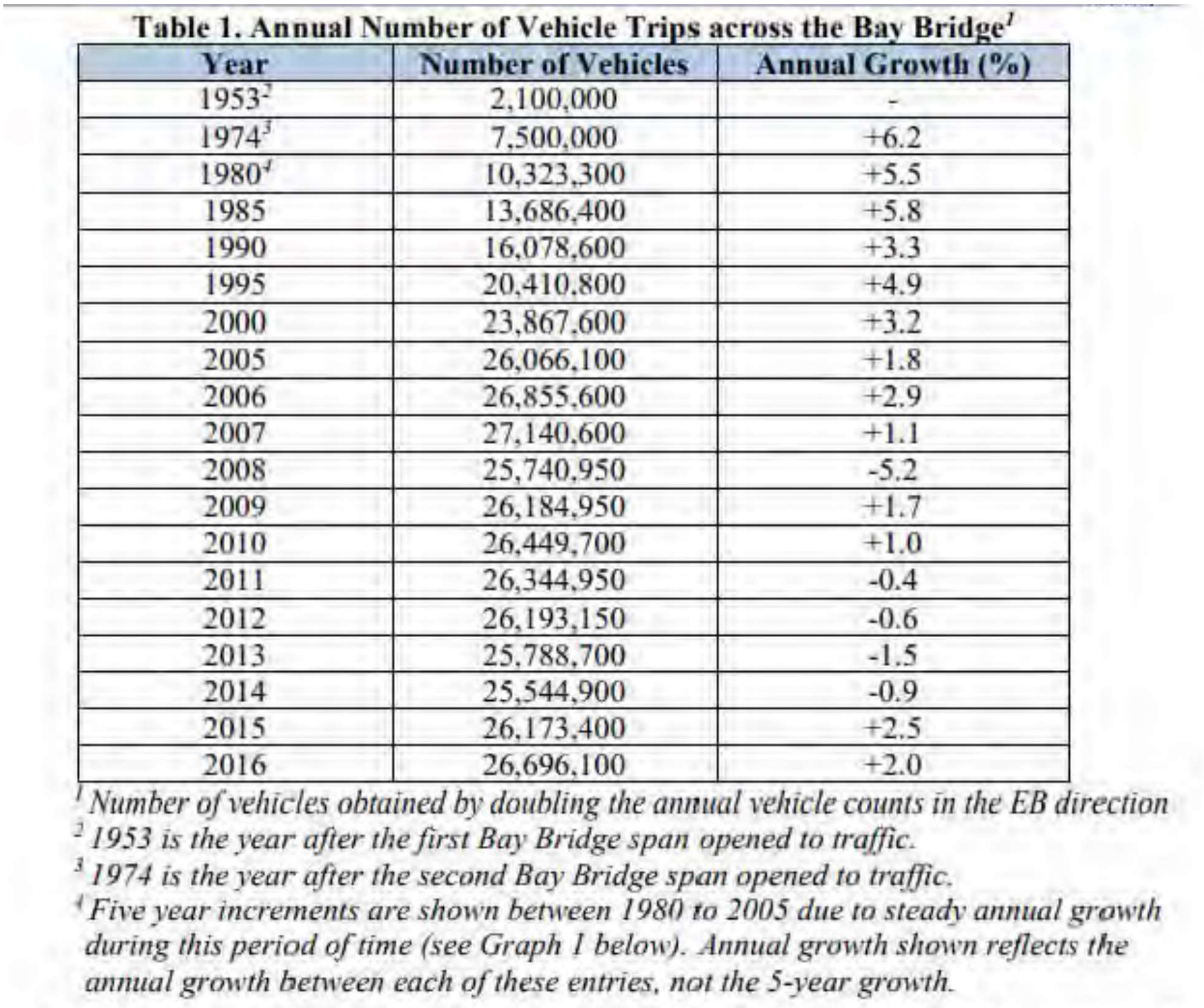


Table 1. Annual Number of Vehicle Trips across the Bay Bridge[1]

Year	Number of Vehicles	Annual Growth (%)
1953[2]	2,100,000	-
1974[3]	7,500,000	+6.2
1980[4]	10,323,300	+5.5
1985	13,686,400	+5.8
1990	16,078,600	+3.3
1995	20,410,800	+4.9
2000	23,867,600	+3.2
2005	26,066,100	+1.8
2006	26,855,600	+2.9
2007	27,140,600	+1.1
2008	25,740,950	-5.2
2009	26,184,950	+1.7
2010	26,449,700	+1.0
2011	26,344,950	-0.4
2012	26,193,150	-0.6
2013	25,788,700	-1.5
2014	25,544,900	-0.9
2015	26,173,400	+2.5
2016	26,696,100	+2.0

[1] *Number of vehicles obtained by doubling the annual vehicle counts in the EB direction*

[2] *1953 is the year after the first Bay Bridge span opened to traffic.*

[3] *1974 is the year after the second Bay Bridge span opened to traffic.*

[4] *Five year increments are shown between 1980 to 2005 due to steady annual growth during this period of time (see Graph 1 below). Annual growth shown reflects the annual growth between each of these entries, not the 5-year growth.*

DACA Chesapeake Bay Bridge Transportation Report December 15, 2020

Figure 1. Comparison Graph of AKRF Realistic Traffic Projections to Previous MDTA Studies, Summer Weekend Daily Traffic in Vehicles Per Day

For the purposes of projecting realistic traffic volumes to 2040, a conservative assumption that the pattern of traffic growth observed using summer weekend daily traffic from 2003, 2006, 2018, and 2019 (years for which adequate data were available to present average summer weekend daily conditions) would continue to 2040 was applied. The best fit for these data was not a linear slope, but a logarithmic curve that smooths out as time goes on. The same curve was also used to estimate summer weekend daily traffic for the interim years between 2003 and 2018 for which data were not available. With a logarithmic curve, certain years of actual data can fall below the curve (such as 2006) or above the curve (such as 2018), but the overall correlation of the fitted curve with the data was found to be strong enough for it to be applied for the traffic volume projections[1]. As shown in **Figure 1**, the Purpose and

Figure 1. AKRF TRAFFIC PROJECTION to 104,219 v/d in Summer Weekend 2040 (3)

The concept of an autonomous Personal Rapid Transit (PRT) system was first funded by the Urban Mass Transportation Administration (UMTA) in the early 1970's (4). Professor Sammy Elias (Chair WVU IE Dept.) obtained a $50,000 UMTA grant to prototype the Alden staRRcar system at UWV. The Jet Propulsion Lab of Cal Tech led the system design with Boeing Vertol as the detail designer. The US Congress approved funding for a demonstration project at the Morgantown campus of the West Virginia University. The system eventually cost $130M for an 8.7-mile System. The system is still in operation today (approx. 1.5 million miles/yr. at 98% availability) using the initial 70 vehicle fleet of 20-passenger cars that weigh less than 10,000 pounds fully loaded. They are powered by 53KW DC motors supplied by a 575 VAC third rail. It has shown the reliability, availability, and cost effectiveness of such a system for almost half a century. This system was the basis for the more recent installation and operation of the London Heathrow airport ULTRA (battery-powered) system in 2011. Both of these systems are proving the advantages of an ULRT system for moving people at under 30 mph based on 1970 and 2010 state-of-the-art technology. Today, we understand that global climate change will require our highway and transit systems to all become electric powered. Development of the automobile high-capacity battery and Full Self Driving (FSD) guidance and control technology will allow for the adoption of this technology to the development of an 80 mph ULRT system that can economically serve a high dynamic range demand system that includes low-density regions previously considered unsuited to a rail transit system. The Origin-Destination (OD pair) with up to 20-passenger packets, Service-on -Demand, is key to its Transit efficiency.

In 2004, John Dearien (6) published a book chapter on a comparison of ground transportation modes based on an energy efficiency analysis. Dearien points out the decreased energy requirement provided by steel wheels on steel rails. He also points out the efficiency advantage of small transportation packets. His Table III (TABLE 2 below) compares four modes of transportation on an energy/passenger mile basis. He concluded that current technology now allows for an ULRT system to be approximately ten time more efficient than automobiles or existing Light Rail Transit (LRT) systems.

TABLE 2: TABLE III ENERGY USAGE OF VARIOUS TRANSPORTATION MODES (6)

	LRT*	**ULR**	**Bus***	**Auto****
Potential	0.04	0.04***	0.14	0.37
Actual	1.14	**0.106********	4.06	**1.4*********

(****kWhr/ pass-mile)

* Data from Portland MAX (Transportation Research Board, SR #221, 1989)
** 4 passenger auto, 27 mpg
*** Estimated based on weight and seats compared to LRT **** Based on dispatching out at 60% occupancy and deadheading back empty

***** Based on 1.05 passenger average occupancy – units of kWhr/passenger mile

What has changed to make this system possible when all previous Chesapeake Bay Crossing studies indicated that rail transit was unaffordable? A good question with several answers:

1. Policy to upgrade our electric power grid and an electric transportation system by 2050 (i.e. < 25 years).
2. The development of Large Tunnel Boring Machines with up to 60-foot diameter capability to provide for up to 4 lanes of cars and trucks and 2 lanes of Ultra-Light Rail Transit.
3. The development of High-Capacity vehicle batteries with up to 400-mile endurance.
4. The development of fully autonomous vehicle guidance and control systems that are suited to rail guidance restrictions. (e.g., Tesla Mod 3 FSD and Chevy Bolt)
5. Vehicle dispatch algorithms to provide optimum utilization of a 20-passenger vehicle transit fleet. These vehicles can be dispatched in 5 to 6 vehicle platoons of up to 120 passengers with 15 second headways at top speeds up to 80mph.

6. The possibility of an 80 mph, 20-pax transit car, based on a Chevy Bolt propulsion system, for less than $50K each. >600,000-mile replacement interval ~ 2,000 round trips/car <$10/passenger for a 100+ mile trip (TBD?)

HISTORY

The Morgantown PRT has demonstrated a number of world "firsts" for a public transport system (3):

1. Fixed guideway transit switching via in-vehicle switching.
2. First "demand mode" fixed guideway transit service.
3. First transit control system whereby central control communicates to vehicles, providing automated vehicle control.
4. First "moving slot" control system.
5. First automated re-distribution of empty vehicles to match projected demand.

About 15,000 people ride the MPRT every day (4) (5). Since it's 1975 opening, the MPRT has travelled approximately 35 million miles along it's tracks. The system's rail cars are based on a Dodge truck chassis, with rubber wheels and travel at speeds up to 30 mph.

The London ULTRA system has built on these features and added the advantage of reducing the need for a third rail for electric propulsion by using modern, high-capacity batteries for vehicle propulsion, further reducing installation and operation costs. The cars travel at speeds up to 25 mph on rubber wheels.

PROPOSED ULRT SYSTEM OVERVIEW

It is proposed that a new ULRT transit system, Figure 2, could be constructed from the Washington DC New Carrolton METRO/MARC station on a 117-mile Main Line to Lewes DE, connecting to a second 36-mile Beach Line connecting the four mid-Atlantic beach cities. Table 3 shows the hypothetical stops, distance between stops and travel time for today's cars and a potential 80 mph ULRT transit system. Since the station stops are designed to be taken on off-main-line spurs, the main-line cars are able to continue at their maximum velocity.

This central design feature, coupled with the ability to customize the car OD pair dispatch rate and low-weight rail foundation design leads to a potential factor of 10 in installation and operating cost savings. The development of high battery capacity and autonomous vehicle collision avoidance systems makes the option of designing high-speed, long-range 20-passenger rail cars possible. The light weight vehicles reduce the cost of each vehicle to further decrease total system acquisition and operations cost.

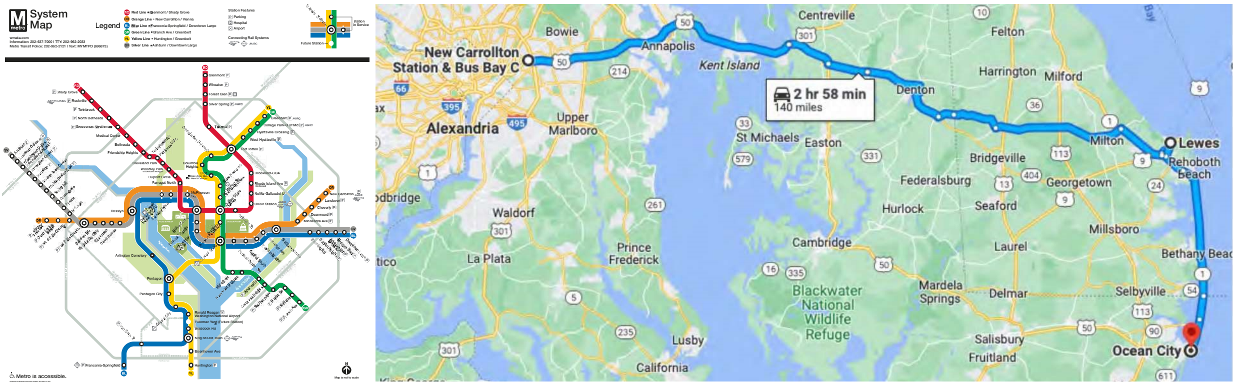


FIGURE 2. WDC METRO WITH MARC LINKS TO BALTIMORE SERVING THE EASTERN SHORE AND ATLANTIC OCEAN BEACH CITIES USING EXISTING HIGHWAY RIGHT OF WAY.

TABLE 3. POTENTIAL 117 MILE MAIN AND 37 MILE BEACH ULRT SYSTEM WITH A TOTAL POTENTIAL OF 110 MINUTES OF PASSANGER TIME SAVINGS

MAIN LINE	New Carrollton Station	USNA Stdium Parking Lot	Stevensville Airport & Parking Lot	Kent Narrows Rest. & Parking Lot	Queenstown Shopping Parking Lot	Chesapeake College Parking Lot	Denton Parking Lot	Greenwood Parking Lot	Lewes Ferry Term. Parking Lot	Charging Terminal Parking Lot	TIME SAVED MINUTES
Mile	0	21.3	14	5.1	7.8	6.6	16.6	16.6	29	117	69
ULRT @ 80 mph Time (minutes)		16.4	10.8	3.9	6.0	5.1	12.8	12.8	22.3	90	
Driving Time est.		22	19	11	10	11	22	21	43	159	

BEACH LINE	Charging Terminal Parking Lot	Rehoboth Beach Parking Lot	Dewey Beach Parking Lot	Bethany Beach Parking Lot	Ocean City Beach Parking Lot	Charging Terminal Parking Lot	TIME SAVED MINUTES			TOTAL ULRT TRACK/TIME	TIME SAVED MINUTES
Mile	0	7.8	2.7	11.2	14.7	36.4	39			153	108
ULRT @ 80 mph Time (minutes)		6.0	2.1	14.7	11.3	34.1				124	
Driving Time est.		19	9	16	29	73.0				232	

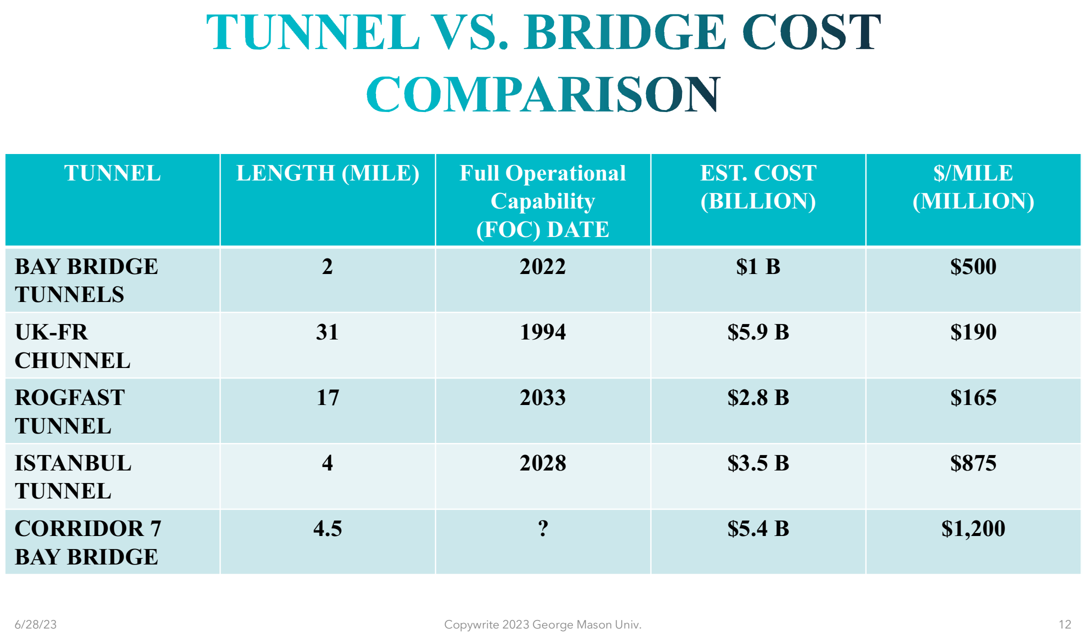
In Virginia, there is a similar 92 mile, highly congested corridor, from The WDC Franconia METRO/VRE Station to Richmond VA. This corridor is 97 miles long and could be served with 80mph ULRT 20-passenger rail cars on existing right-of-way with a potential passenger time savings of over 50 minutes.

For the Maryland line, in order to minimize the onboard battery energy requirements, a new 60 ft. dia. tunnel would be constructed to provide up to 4 lanes of personal car and truck traffic, 2 bicycle lanes and 2 lanes of ULRT rails for cars that average an 80mph speed over the 150-mile-long system. Such a system would reduce commuter and summer beach travel time by a combined 110 minutes (i.e. from a current 240 minute trip to a 130 minute trip). It has been estimated that a modern ULRT system could provide 4,800 persons per hour per day (pphpd) versus a highway estimated 2,500 pphpd/lane of private vehicle car lane (6) at far less expense.

Current LRT construction costs are estimated to be approximately $200M/mile. If the ULRT can achieve the projected costs of $20M/mile that would result in a 150-mile system costing $3B (i.e., 10 times less than the cost of an LRT system). The cars should cost no more than the current price of a Tesla or Chevy car at less than $80,000/car for a 200-vehicle fleet cost of $160M. This would represent a combined cost of about $3.2B.

The construction of a bridge that must provide a 190 ft. clearance over a major shipping lane serving the port of Baltimore should be more expensive to build than a 4.5-mile tunnel that only needs to go under a 50 ft. deep channel. The challenge of constructing a 300 ft. high steel structure with a foundation that must be designed to withstand a Category V hurricane while the major shipping channel must be allowed to continuously operate is no easy feat. TABLE 4 shows a comparison of some significant underwater channel tunnels for comparison. Current under-channel tunnels being constructed in both Europe (i.e., UK to France, Turkey) and the US (i.e., the Chesapeake Bay tunnels in Virginia) are estimated to cost less than $500M/mile (6) (8) for an estimated 4.5-mile tunnel cost of $2.3B.

Table 4. COMPARISONS OF SEVERAL UNDER-CHANNEL TUNNELS AND THE PROPOSED CHESAPEAKE BAY BRIDGES COSTS (various sources)



TUNNEL VS. BRIDGE COST COMPARISON

TUNNEL	LENGTH (MILE)	Full Operational Capability (FOC) DATE	EST. COST (BILLION)	$/MILE (MILLION)
BAY BRIDGE TUNNELS	**2**	**2022**	**$1 B**	**$500**
UK-FR CHUNNEL	**31**	**1994**	**$5.9 B**	**$190**
ROGFAST TUNNEL	**17**	**2033**	**$2.8 B**	**$165**
ISTANBUL TUNNEL	**4**	**2028**	**$3.5 B**	**$875**
CORRIDOR 7 BAY BRIDGE	**4.5**	**?**	**$5.4 B**	**$1,200**

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The Tier 2 NEPA study should evaluate this potential to provide a full new system at an estimated cost of $5.5B. With the current estimated cost of a third bay crossing bridge to be between $5.4 to $8.9B, this would be a much better investment.

POTENTIAL BENEFITS

There would be many benefits of the proposed ULRT system over the mere addition of a third bay bridge:

1. Reduced vehicle queues on both sides of the Bay Crossing.

2. Provide improved transportation equity to low-income urban families that do not have their own personal car transportation options.
3. Per-person transit fares to the beach from Washington DC and Baltimore for less than $10/person?
4. Reduced maintenance cost for exposed steel bridges in a harsh environment.
5. Improved access to and from rural Maryland and Delaware Eastern Shore communities and services to urban employment, medical and education resources.

A NEW DOT/FTA R&D T&E PROJECT NEEDs TO BE AUTHORIZED

Most of the proposed new ULRT system consists of low-risk off-the-shelf technology. The key missing ingredient is the availability of a 20-passenger, lightweight, autonomous, battery-powered rail car. The authors are unaware that any such car either exists or is under development.

TABLE 5. COMPARISONS OF EXISTING AND A POTENTIAL FUTURE ULRT VEHICLE (various sources)

	VEHICLE SPEED MPH	WT. POUNDS	GAUGE FEET	LENGTH FEET	WIDTH FEET	PASSENGERS PER CAR	FOC YEAR
LRT SYSTEMS - RAIL							
BART	80	63,000	5.5	70	10.5	60	1972
WDC METRO	75	79,000	4.69	75	10.15	69	1977
AUTONOMOUS PEOPLE MOVER SYSTEMS - RUBBER TIRES							
MPRT	30	8,750	5.17	15.5	6.67	20	1975
ULTRA	25	800	5?	12	5	4	2011
TESLA FSD	155	4,400	12	15	6	5	2021?
HS AUTONOMOUS, BATTERY-POWERD ULRT POTENTIAL							
	80	7,000	4.69	30	8	20	2030?

Table 5. shows a comparison of 1970 era LRT car systems with current ULRT rubber-wheel, low-speed systems. The Chevy Bolt rubber-wheeled, 12' wide highway autonomously guided vehicles could be the basis for a new 80 mph, autonomous, battery powered ULRT 20-passenger steel-wheeled car today.

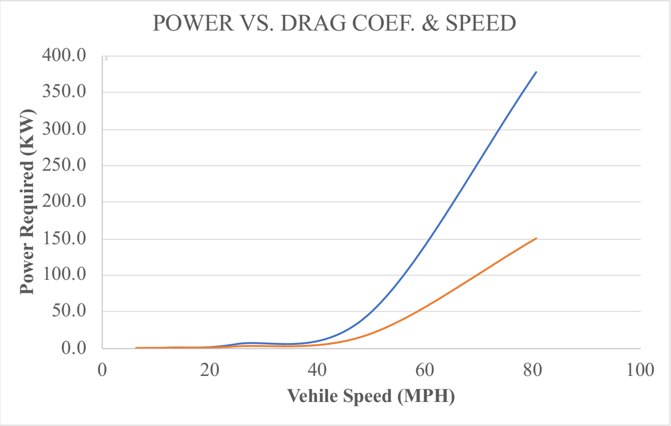

Figure 3. Hypothetical High-Speed vehicle compared to a low-speed vehicle's power requirement. Over a 200KW difference at 80mph.

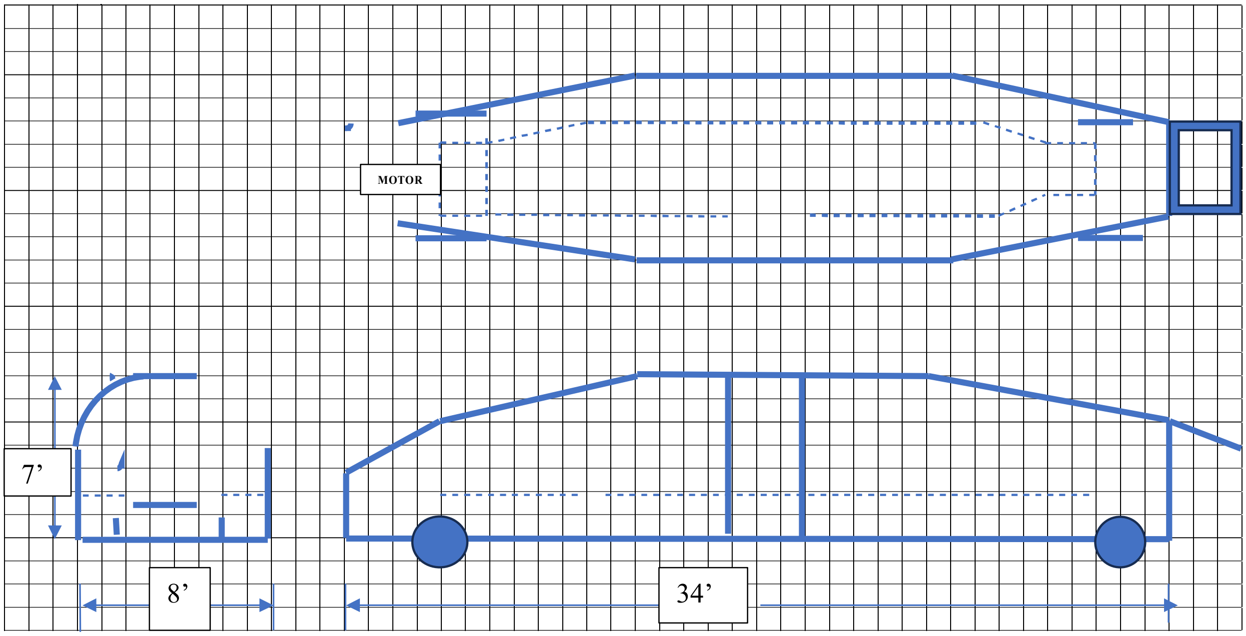

Figure 4. Concept of a High-Speed (80mph) ULRT 20-Passenger Vehicle with a blown-flap for base pressure reduction.

Above speeds of 30 mph, the aerodynamic shaping (L/W~4, Cd~0.4) and light-weight construction techniques are required to achieve efficient steady speeds of up to 80mph. Figure 3 shows a comparison of a low-speed vehicle power requirement designed to provide a 30mph vehicle at 50KW to a vehicle designed to operate at speeds of 80mph. Extensive research on the drag reduction of high prismatic coefficient shapes (10) indicates that a Cd~0.4 may be achieved.

There is little incentive for the private, for-profit sector to develop such a rail car as illustrated in Figure 4. The Morgantown cars are rubber-wheeled, third-rail vehicles based on 1975 truck technology. The guidance and control systems are based on 1975 computer hardware and software. They were developed under DoT funding but operate under state university funding. The London ULTRA system cars were also developed by a UK government funded university/industry partnership and use 2010 battery and computer technology. The DEMVAL test vehicle would use a Chevy Bolt structural frame, collision avoidance and propulsion system (i.e., >150KW) with a low-drag composite outer skin (est. Drag Coefficient <0.4) to keep RDT&E costs to a minimum. This would provide a 2/3rd scale test vehicle for DEMVAL testing at a relatively low risk and low cost. A full-scale system could be based on the GMC 200KWHr, 400V Ultium propulsion platform.

The Maryland Transportation Administration would need to see a real-world technology demonstration program before ever committing to such a transit system investment. A 3-mile (1.2 x 0.3 mile rectangular) testing rail track should be constructed on UMD land. A team of universities led by the George Mason University System Engineering and Operations Research Department could supply such a Demonstration and Validation (DEMVAL) system and test program. The team could consist of the George Mason University SEOR Dept acting as overall System Design and Project Management, the University of Maryland Department of Aeronautical Engineering for vehicle aero design and test track construction, the University of Delaware Department of Civil and Environmental Engineering for rail track design and independent transportation evaluation and Morgan State University School of Engineering for electrical power and vehicle control modifications.

The DEMVAL test and operation facility will provide needed performance, cost and operations data required for the MTA to be able to make an informed deployment decision. The selection of a tunnel instead of a bridge is the first decision to be made in the 2026/27 final Tier 2 NEPA study. Transportation is a system-of-systems, not just a 100-year bridge for trucks and cars. It is estimated that this DEMVAL project could be conducted over a three-to-four-year period of time for less than $3M dollars.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Donohue; data collection: Donohue; analysis and interpretation of results: Donohue, Sherry and Shortle; draft manuscript preparation: Donohue; All authors reviewed the results and approved the final version of the manuscript.

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