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Advanced Low-Floor Vehicle (ALFV) Specification Research

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MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM

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MNTRC Report 12-27

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REPORT 12-27

ADVANCED LOW-FLOOR VEHICLE (ALFV) SPECIFICATION RESEARCH

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16. Abstract

This report details the results of research on market comparison, operational cost efficiencies, and prototype tests conducted on a novel design for an Advanced Low Floor Vehicle (ALFV), flex-route transit bus. Section I describes how the need for such a bus arises from a combination of diminishing transit funding from the federal government and demographic and transportation factors. Section II describes the unique features of this bus design that render it suitable for rural and urban operation, including improved transit passenger and wheelchair accessibility, reduced maintenance, structural design features, safety provisions, and the technical specifications of this design. Section III details the potential differences in capital and operational costs of procuring and operating this bus in a fleet. Potential cost reductions due to the long-life vehicle concept, maneuverability, operational savings (from APTA Bus Roadeo tests), and reserve fleet savings are explored. Section IV refers to the Federal Transit Administration (FTA) new model bus tests ("Altoona Testing"). However, at the this time, the Altoona Bus Test Report for these tests is not yet released by the bus manufacturer, Ride Solution, Inc., as is its right under the Bus Testing Regulation. The report must be released to the public before this bus can be purchased by a transit agency using FTA funds. In addition to the standard Altoona Bus Test, additional research was conducted to determine the turning ability, suspension travel, ramp travel index, field of view for the driver, compliance to Americans with Disabilities Act (ADA) requirements, and timed assessment of wheelchair securement. Section IV also presents the results of these tests. Section V presents results from a market comparison that included the buses in this mid-size category that were tested at Altoona and are expected to be available for FTA grantees to purchase. The specifications and performance of the ALFV bus are compared with these buses. Section VI presents a flex-route utilization plan, and Section VII provides the results from a survey of transit professionals about their interest in the features of this bus design. Section VIII gives Ride Solution's experience in developing the concept for ALFV. Conclusions of this report are presented in Section IX, followed by the references and appendices.

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- The U.S. House Transportation Committee
- The Putnam County Chamber of Commerce
- The Small Business Development Center at Putnam County
- Putnam County Board of County Commissioners

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EXECUTIVE SUMMARY

The Pennsylvania State University's Thomas D. Larson Pennsylvania Transportation Institute (Larson Institute) Altoona Bus Research and Testing Center, and Ride Solution, Inc., Florida prepared this report on a prototype Advanced Low-Floor Vehicle (ALFV), a purpose-built, low floor, diesel-powered, 25-seat (including the driver), 26-foot (7.92 meter) bus. This bus was developed by Ride Solution, Inc., of Putnam County, Florida, for the United States Department of Transportation (USDOT) Federal Transit Administration (FTA) Advanced Low-Floor Vehicle Specifications Research project. Tests conducted at the Altoona Bus Research and Testing Center included a 10-year, 350,000-mile (560,273-kilometer) STURAA (Altoona) test. Supplemental tests to determine the turning radius of the vehicle (curb-to-curb and wall-to-wall), suspension travel and ramp travel index, and ADA conformance were also performed at the Larson Institute. Research was conducted by Ride Solution, Inc. to provide a market analysis and comparison of available mid-sized vehicles with this prototype bus, as well as the operational cost efficiencies for this design.

There is a need for such a bus, based on the potential for diminishing transit funding, as well as demographic, socio-economic, and transportation factors. This bus design has unique features that render it suitable for rural and urban operation. They include a low floor with no steps and the ability to carry 25 passengers, or 5 wheelchairs, or 6 gurneys, or a combination of the above. The shortest rear overhang in its category renders it capable of operation on rural, unpaved roads. The manufacturer predicts that the welded steel structure will improve the shell life to 20 years or more. Locating the engine/transmission in a cradle aids in low replacement time for the power unit. There is also Internet connectivity, both for passengers and to help with maintenance.

Ride Solution projects that the potential savings offered by this ALFV bus is a significant fraction of its purchase price, if one assumes a 20-year service life and the purchase price of $350,000. The basis is a conventional 10-year mid-size bus costing $285,050. Potential savings of up to 63% from its long life, up to 13% from improved maneuverability (based on APTA bus Roadeo tests), and up to 11% from reduction in reserve fleet ratio are possible. This results in a total potential savings of up to 87% of the purchase price. It should be noted that the bus tested in Altoona was a conventional diesel under the 10-year service life category.

Data from test reports of the Altoona Bus Research and testing Center shows that a large number of buses tested at Altoona between January 2009 and December 2013 had a gross vehicle weight that exceeded their gross vehicle weight rating, and that 20% of the buses exceeded that limit by more than 1,000 pounds (454 kilos). The ALFV bus was well within its limits, with a margin of more than 5,000 pounds (2,268 kilos). It had an above-average number of passenger seats and number of wheelchair positions. It was one of the few vehicles with no interior steps, and it had one of the smallest fuel tanks with an adequate driving range.

Test findings indicated that the ALFV required a high number of scheduled and unscheduled repairs and work hours. This is primarily due to its development as a research project built by non-profit transit agency personnel rather than by commercial manufacturing professionals. This also accounted for its large number of subsystem failures during the structural integrity tests. It performed well after being repaired.

Recommendations from prototype tests of the ALFV include improvement of workmanship, better quality control (welding quality in particular), improvement of reliability, reduction of time to replace Additional Replacement Components, reduction of wet friction stopping distance, conformance to all ADA requirements, and reduction of interior and exterior noise and particulate emissions.

When operating costs were compared for 100 passenger seat miles (psm) on a basis of diesel gallon equivalent (DGE), the ALFV cost $2.386 per psm, only 5.5 cents above the $2.331 average cost psm for all 31 mid-size buses tested during the time period above. When compared with the other 24-passenger low-floor buses in the study, the AMPV's operating costs were very similar.

This report presents to the current market a "view of the future" in mid-sized transit buses, and a comparative study of the current market. This comes in light of what is required by federal mandate, what is available now, and what may be needed in the future. It is also intended to extend the way manufacturing and procurement can be advanced to meet the increasing requirements of the transit industry in serving the public.

I. INTRODUCTION

There is a need for a multi-purpose, flex route, low-floor transit bus that is economical to purchase and operate because of diminishing transit funding available in the near future and beyond, along with demographic, socioeconomic, and transportation factors. These are examined in detail, and a novel design that meets the requirements of such a bus is presented in this section.

DIMINISHING TRANSIT FUNDING

The Congressional Budget Office (CBO) noted in April 2013 that, "The current trajectory of the Highway Trust Fund is unsustainable. Starting in fiscal year 2015, the trust fund will have insufficient amounts to meet all of its obligations, resulting in steadily accumulating shortfalls"[1] The CBO testified that "by substantially reducing spending for surface transportation programs, by boosting revenues, or by adopting some combination of the two," lawmakers could address the shortfall. As seen in Table 1, the Highway Trust Fund Transit Account shows a $1 billion deficit in 2015, which grows to $5 billion in 2016.[1]

Table 1. Projections of Highway Trust Fund Accounts Under CBO's February 2013 Baseline

Projections of Highway Trust Fund Accounts Under CBO's February 2013 baseline												
Billions of $	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Highway Account												
Start-of-Year Balance	14	10	5	5	-	-	-	-	-	-	-	-
Plus: Revenues, interest	35	33	33	34	35	35	36	36	36	36	36	36
Plus: Intra-govt transfers	2	6	10	0	0	0	0	0	0	0	0	0
Minus: Outlays	42	44	44	45	45	45	46	46	46	47	48	48
End-of-year balance	10	5	5	-	-	-	-	-	-	-	-	-
Cumulative shortfall	n.a	n.a	n.a	-6	-16	-26	-36	-46	-56	-67	-79	-91
Transit Account												
Start-of-Year Balance	7	5	3	2	-	-	-	-	-	-	-	-
Plus: Revenues, interest	5	5	5	5	5	5	5	5	5	5	5	5
Plus: Intra-govt. transfers	0	0	2	0	0	0	0	0	0	0	0	0
Minus: Outlays	7	7	8	8	8	8	9	9	9	9	10	10
End-of-year balance	5	3	2	-	-	-	-	-	-	-	-	-
Cumulative shortfall	n.a	n.a	n.a	-1	-4	-7	-11	-15	-19	-23	-28	-33

Source: Congressional Budget Office.

Further, the Government Accountability Office (GAO), in November 2013, stated that, "Total federal spending on transportation services for the transportation disadvantaged remains unknown because federal departments did not track spending for roughly two-thirds of the programs identified in 2012."[2] Neither the CBO nor the GAO reports convey a sense of the pivotal role that coordination of human service transportation has in supporting rural transit or the fundamental role that rural transit will play in regionalization.[2]

There is also the great economic potential inherent in regional transit. The massive economic inefficiency of our daily, single-occupant vehicle (SOV) commute was not considered by the CBO, whereas the potential savings could be used to address the transportation budget shortfall. Moreover, the GAO report, in its focus on elderly and disabled populations, does not convey the scale of the transportation disadvantaged (TD) population, which in Florida is estimated to be 40.64% of the state, or that the working poor might constitute the largest segment of the TD population.

Reducing the SOV commute to four-passenger carpools and/or integrating rural and urban transit operations has the potential to put more than $200 billion back into local economies, increase Highway Trust Fund revenues by 30%, create more than 8 million job equivalents, and cut consumption of gasoline in half.[1] Transportation coordination can play a significant role in achieving these targets. Transportation coordination can reduce federal transportation program costs by clustering passengers, utilizing fewer one-way trips, and sharing the use of transportation personnel, equipment, and facilities. In addition, people who need transportation often benefit from the greater and higher-quality transportation services available when transportation providers coordinate their operations.

The extent to which commuter logistics run counter to urban-centric regional transit models can be appreciated when it is recognized that the biggest and most pressing need for regional transit stems from the daily SOV commute, which overwhelmingly flows from the rural perimeter to the urban core. Transit logistics would dictate that, to minimize deadhead, commuter routes begin in the rural perimeter—counties surrounding urban employment centers. Responding to those logistics begins, then, in the rural areas with operational strategies based on coordinating existing but non-traditional rural transit resources, which include rural human service transportation funding and rural-to-urban SOV commuter expenses. The need for a purpose-built, flex-route vehicle with the agility, capacity, and ruggedness necessary to span both rural and urban coordinated transit operations comes from the necessity to coordinate trips in those two key rural funding sources to access the funding needed for the regionalization of transit and budgetary relief for the Highway Trust Fund. The capability to carry 25 passengers or 5 wheelchair passengers, or a combination in between, will increase the utility of this design. Further, a low floor eliminates the need for a wheelchair lift. The Advanced Low-Floor Vehicle (ALFV) described in this report includes all these features.

DEMOGRAPHICS

Demographic and geographic data are presented at the national and state levels to provide a comprehensive picture of the market at this particular time in the history of our country and transportation policy. Data from the State of Florida are used for this illustration. The place of transit vehicles in providing mobility for our current population—commuters, the elderly, the disabled, and all non-drivers—has become an increasingly important matter for federal, state, and local policy makers. As light rail costs rise into the billions of dollars and the Congressional Budget Office projects huge deficits for the Highway Trust Fund, effective and efficient means of daily transportation must be a primary concern for those who are making transportation policy at all levels of government. The few funds currently available must be allocated to the most cost-effective, long-term solutions possible.

The US Census Bureau estimated the resident population for the United States in December 2012 to be about 315 million. This is an increase of about 6 million people over the officially reported census figure of December 2007, which was 309 million when the research project to develop this vehicle was originally funded. The estimated population of Florida in 2012 was about 19 million, and in 2007 it was about 18 million, an increase of 1 million. During this period, the United States had a 2% increase and the Florida increase was 5.84%. Florida accounted for 17.27% of the entire national population increase for this period. In recent years, this trend shifted. Between 2010 and 2012, the state gain slowed to 2.7%. Putnam County, home of Ride Solution, Inc. and the ALFV, recorded a loss of 1.5% of its population during this time.

The exodus of the rural population to urban areas is due to a number of factors, but the major one is jobs. This is an unfortunate event; some would suggest that the job market can be better accommodated in smaller communities, providing labor at less cost, with fewer regulations, a better quality environment, less congestion, a more stable work force, and a more relaxed lifestyle than in large urban areas. (This view is supported by the location of major auto manufacturing plants in North Carolina, Tennessee, and Alabama outside major urban areas). Improved rural transit could be a factor in overcoming this problem on a national scale. Transportation policy can be a means of addressing this migration and economic loss due to the high cost of labor in urban areas.

The rural-to-urban shift in the 21st century is more pronounced. The rural population increased from 44.8 million in 2000 to 46.2 million by 2013. This was an increase of 3.2%. The urban population data for this same time period was 236.6 million at the beginning of the century and rose to 269.9 million by 2013, a 14.1% gain, according to the State Fact Sheets for the combined United States published by the US Department of Agriculture, Economic Research Service in 2014. The Florida State Fact Sheet, from the same series, indicated rural growth of 8.9%, from 645,159 to 702,636 during the same time period. Urban areas increased 22.9% from 15.3 million to 18.9 million during these early years of the century. These facts indicate a growing population and a shift from rural to urban areas. In Florida's case, there is a migration into the state from within and outside the United States as well.

The effects of these demographics are causing an increased burden on transportation systems across the nation. Traffic delays are becoming longer and more frequent. The high cost of fuel increases commuting costs and reduces the remaining spending power of the average working citizen. All these add to the state and federal transportation requirements and challenges to keep up with demand in the various transportation sectors.

TRANSPORTATION FACTORS

The 17th edition of the *Transportation Statistics Annual Report* (2011-2012), compiled by the Bureau of Transportation Statistics (BTS) in the Research and Innovative Technology Administration (RITA) of the US Department of Transportation (USDOT), states that 729 urban transit agencies and nearly 1,580 rural and tribal government transit agencies reported data to the National Transit Database (NTD) of the Federal Transit Administration in 2010. Nearly 10 billion unlinked transit trips were reported on these systems in 2010.

This represents an increase of one-third over the 7.5 billion unlinked transit trips reported in 1995. Buses accounted for the vast majority of transit routes and passengers. Unlinked trips are the number of trips on transit vehicles. Transferring from one vehicle to another would be two unlinked trips. The report goes on to state that the findings of a US Census Bureau survey in 2011 covering the trip from home to work were as follows, indicating a large potential for public transit:

- 76.4% of commuters drove to work alone;
- 9.7% carpooled;
- 5.0% took public transportation to work, chiefly the bus;
- 3.4% walked or biked to work; and
- 4.3% worked at home.

In a section reporting data for transportation of elderly and disabled people, the FTA indicated that demand response trips increased from 77 million in 2001 to 93 million in 2010 and suggested additional increases will probably occur as the large number of Baby Boomers begin entering retirement age. The report also addresses the impact of congestion and delay. Quoting a study by the Texas Transportation Institute (TTI), the estimated time the average commuter spent sitting in traffic in 2010 was 34 hours, about 4 work days, wasting about 14 gallons of fuel. The estimated cost of delay per car commuter was set at $713. The cost for Washington, DC was $1,495 and for the Chicago metro area, $1,568. The effects on air quality are in addition to these figures.

These data indicate that, when considered with the demographic and socioeconomic data above, it would be logical to assume there may be a progressive increase in transit ridership that could continue for years into the future.

The annual cost of owning and operating a car may soon be a factor in the growth of public transportation. The *Insurance Journal* published an article, based on a study by Bankrate.com, which estimated the annual cost of car ownership for each state in the United States based mainly on 2012 prices. The findings may be surprising to many. The cheapest state was Oregon, at $3,201. The most expensive was Georgia, at $4,233. The article pointed to a “lack of public transportation” as an item contributing to this high cost. The top five (in descending order) were Georgia, California ($3,966), Wyoming ($3,938), Rhode Island ($3,913), and Nevada ($3,886). At the median of the states were Oklahoma and South Carolina. The least expensive states in which to own and operate a car were Indiana ($2,698), Montana ($2,660), South Dakota ($2,343), Alaska ($2,227), and Oregon ($2,203). The average cost to own and operate a vehicle in the United States was $3,201.

When considered as a part of the Social Security Administration’s reported median wage of wage earners, which is $27,519, this amounts to 11.6% of the earnings for those at the very top of this scale. For those at the 24th percentile, making $10,000 or less, this would be at least 32% or more of their annual earnings. This was the case for more than 37 million workers in 2012. From this perspective, public transportation appears to be an attractive option to the American workers who are on the low end of the wage distribution scale.

A NOVEL DESIGN FOR A FLEX ROUTE TRANSIT BUS

These demographic and transportation data have an impact on public transportation and the mid-sized vehicles reviewed in this study. The current commercial transit bus industry offers primarily two types of vehicles: Large, heavy-duty buses, and bus bodies added to “cutaway” chassis available in a variety of lengths. These choices are not suitable for the requirements of small, non-urban, and rural transit agencies. The smaller transit agency needs a multi-purpose vehicle that can be used to provide fixed-route service when needed and also serve as a paratransit vehicle when necessary. This type of “flex-route” system, described in more detail in Section 6 of this report, is currently being developed by Ride Solution, Inc. in northeastern Florida. It will be used to provide a plan for use of the new Advanced Low-Floor Vehicle, which is designed as a prototype, purpose-built vehicle to serve the transit needs of small rural and urban communities. Rural and small urban vehicles must negotiate all types of road networks, including small streets with tight corners, and do so with a minimum of maintenance. The small rural and urban transit agencies operate under very frugal budget restrictions that require low operating, maintenance, and life-cycle costs for their vehicles.

The Advanced Low-Floor Vehicle was developed to provide a vehicle that can meet the above requirements and is not currently available from the commercial market. As it was being developed, a number of design concepts were introduced to address various problems identified with available buses. These included eliminating the need for a wheelchair lift, better access to the engine for easier maintenance, space for more wheelchairs, improved ground clearance, a “good ride,” good traction and stability, a service life potentially longer than seven, ten, or even twelve years, and a low lifetime cost.

Ride Solution, a transit operator in rural Putnam County in northeastern Florida, built two prototypes of the ALFV design with federal grant money. This is believed to be the first time that federal funds had been approved for a rural transit operator to design and build a vehicle. The grants were in the amounts of $742,000 (Project number FL-04-7526) for preparation and tooling, and $1,857,500 (FL-03-7527) for vehicle construction. This was a total of $2.6 million allocated for the research work.

On Ride Solution’s routes, cutaway vans lasted only a few years before they required replacement due to the rugged condition of the roads of Putnam County, over 50% of which are unpaved. Replacement funds are scarce for rural transit. The best solution appeared to be to build the type of vehicle that could operate reliably and efficiently under these conditions because the marketplace had no such vehicle. The prototypes were developed based on the observed transportation needs and road conditions of Putnam County riders and Ride Solution.

In an environment of federal capital subsidies, diminishing Highway Trust Funds would tend to favor lower-priced vehicles unless the life-cycle costs of a more costly vehicle were significantly lower. Ride Solution designed the ALFV to operate at significantly lower costs on rural transit routes.

II. THE ADVANCED LOW-FLOOR VEHICLE'S UNIQUE FEATURES

The Advanced Low-Floor Vehicle was designed from the ground up to provide a vehicle that was not currently available from the commercial market. As it was being developed, a number of design concepts were introduced to address various limitations perceived with the available buses. These included eliminating the need for a wheelchair lift, better access to the engine for easier maintenance, space for more wheelchairs, improved ground clearance, good ride quality, good traction and stability, a service life potentially longer than seven, ten, or even twelve years, and a low lifetime cost. The goal of the design was to provide a vehicle that was well-adapted for flex-route operation. The specific design features for the ALFV are detailed in this section.

DESIGN FOR RURAL AND URBAN OPERATION

The ALFV length is 26 feet 8 inches (about 8 meters) and the width is 96 inches (2.44 meters). It is 124 inches high (3.15 meters) overall and has a 206-inch (5.23 meters) wheelbase, which provides a good quality ride. The front overhang is 56 inches with a 58-inch (1.42 meters) rear overhang, one of the shortest on the market. One of the major features is the short rear overhang of the vehicle, necessary to avoid "hang ups" in large dips and potholes that occur on the unpaved rural roads. This was achieved by the use of a transverse engine mounting over the rear axle. This also provided the added benefit of better traction for the rear wheels due to the placement of the weight of the power system. The road clearance and break-over angles, plus the reduced rear overhang, allow the ALFV to enter private driveways and operate where other mid-sized vehicles have limited access. This combination of dimensions permits using the ALFV in narrow streets, such as those in older sections of urban and suburban areas where many larger transit vehicles cannot operate.

TRANSIT PASSENGER ACCESSIBILITY

The low-floor design of this unique vehicle extends the entire distance between the front and rear axle and has numerous advantages when combined with other features. The automatic hydraulic ramp is superior to a wheelchair lift, can be operated manually, if required, and has a shallow incline (conforming to ADA specifications), making it easier for passengers in wheelchairs or with other mobility impairments to board. The passenger seats in the vehicle, except those across the back, fold up and stow against the side of the vehicle, requiring less stow space than the typical convertible seat. These seats were specially designed to provide standard-size seating, but on a smaller folding frame. Seating is provided for 24 passengers plus the driver within a 26-feet-long (7.92 meters) vehicle. When the fold-away seats are stowed, seven ambulatory passengers and five wheelchairs can be transported. In a vehicle of this size, the ability to transport five wheelchairs is not typical.

Due to both the low floor and the tubular stainless steel frame, the option of installing floor-to-ceiling belts, similar to wheelchair ties, makes it possible to attach six to eight regulation US Army canvas stretchers for disaster relief, including evacuations of hospitals, nursing homes, or other bedridden individuals who need transportation. Regular emergency gurneys can also be used because there is no slope to the low floor. This potential feature has been well received by transit agencies serving nursing homes and veterans' hospitals.

EASE OF MAINTENANCE

Easier maintenance in less time has long been a goal of mechanics and fiscal officers. To this end, the entire power system, including the engine, transmission, gas tank, battery, and everything required to run the engine, was mounted on a removable frame that would allow complete diagnosis and testing of the power system components outside the vehicle. This engine mount is connected to the structure of the vehicle by only four bolts, which allows removal in just 60 minutes. Replacement can be done in the same amount of time. A rear engine compartment door that opens hydraulically permits access to the entire engine compartment. All hoses have quick disconnect, no-drip fittings to facilitate easy removal. It is also possible to totally change power systems as new ones come on the market and become cost effective. This is possible with very little, if any, reconfiguration of the engine compartment. Several new systems currently under development will be available within the next decade. The cost of upgrading should be less than the cost of a new vehicle. This feature not only serves to ensure easy maintenance, but also reduces the number of back-up vehicles required to support the fleet and provides the ability for the design to adapt to state-of-the-art components. This produces savings in manufacturing costs and in operating and capital costs for the transit agency.

Additional features were incorporated into the vehicle design to improve longevity and minimize repair and maintenance costs. The sidewall skin is composed of aluminum composite materials that permit easy fabrication of rounded corners and facilitates cost-effective repairs of external damages. All hoses traversing the length underneath the vehicle are encased in a stainless steel tunnel than can be easily accessed from below. This feature not only protects the hoses, thereby extending the service life, but also provides quick access for repairs.

ALFV multiplex electrical systems are of the latest design and conform to J-1939 standards. The central electrical panel is configured for diagnostics by a laptop computer and will permit connection to the manufacturer over the Internet directly from the vehicle, if required, for advanced troubleshooting and repair. All electrical wiring is contained in an overhead tunnel that is hinged and accessible the full length of the vehicle. Internet can also be made available for passenger seats.

OTHER FEATURES

The space-frame chassis, made of stainless steel tubing and electrically welded, provides a safe and stable vehicle. The concept of the similar chassis has been proven in use on larger buses. The stability of this chassis adds to the safety for passengers. The design also provides protection to the various sub-components of the vehicle, including the plumbing tube channels beneath the floor and the electrical channels in the ceiling. All hoses going front to back under the vehicle are encased in a stainless steel tunnel than can be easily accessed from below. This feature not only protects the hoses, but also provides quick access for repairs.

The use of a transverse engine mounting over the rear axle improved balance of the weight distribution and added to the vehicle's stability. The rear wheel track, measured to the inside edge of the tires, is 72.1 inches (1.83 meters) and the front is 84 inches (2.13 meters), also providing stability on rough rural and bumpy city roads.

TECHNICAL SPECIFICATIONS

The ALFV has a space-frame 1003 + 304 stainless steel, seamless, square tubing chassis that is electrically welded. The power train is a patented H-drive configuration and is cradle mounted at the rear. Additional specifications are included in Table 2.

Table 2. Specifications of the Advanced Low-Floor Vehicle

Overall Length:	25'-6" (7.77m)			Seating capacity:	25
Overall Heigth	100" (2.54m)			Forward facing seats:	23
Overall Width:	96" (2.44m)			Wheelchair positions:	5, in lieu of 17 seats
Wheel Base:	206" (5.23m)			Break over angle, degrees:	7
Overhang Front:	43" (1.09m)			Approach angle, degrees:	15
Overhand Rear:	54" (1.37)			Departure angle, degrees:	15
Continuous Low floor area:	7'6x12' (2.29mx3.66m)			Inside headroom/center of vehicle:	83" (2.11m)
Step, ground to floor:	11.5" (3.5m)			Inside headroom/side (min.):	77" (1.96m)
Door frame height:	78" (1.98m)			Ramp at front door, ADA compliant:	32.5"x48" (0.83mx1.22m)
Door frame width:	40" (1.02m)				
Weights	Front axle, lb	Rear axle, lb	Gross vehicle, lb	Engine: Cummins ISB 6.7 L	
Rating	8,000	17,500	25,000	Horse Power: 200 Hp at rated speed: 2,400 Rpm	
Curb	4,990	10,960	15,950		
Seated	6,940	13,140	20,080	Peak Torque: 520 lb-ft at rated speed: 1,600 Rpm	
Gross	6,940	13,140	20,080		
Engine: 2010 EPA/CARB Emission Certification w/ SCR and DEF					
Transmission:	Allison 2100			5-speed Automatic Overdrive	
		Patented Drive System:	Transfer Case: Aluminum body with 3 gears, 1:1 ratio		
			Right Angle Transfer Box: Steel, spiral bevel gear, with 1:1 ration		
			Drive axle ratio: 4.56		
Drive axle brakes:	15x6, Q+cam, automatic slack adjuster with ABS				
Front Axle				Single drop:	3.75" (0.1m)
Front axle brakes:	Air, 15x5, Q+ cam, automatic slack adjuster with ABS				
Rear Air Ride Suspension:	Ridewel Rad 238			Nominal weight rating:	17,000 lbs
Front Air Ride Suspension:	Ridewel Ras 238			Nominal weight rating:	8,000 lbs
Tires:	245/75R19.5			Steering:	Trw-Thp-60
Steering:				Gear-driven power steering with constant flow valve, with stainless steel hydraulic lines. Hydraulic power assists the steering system.	
Steering Column:				18" (0.46m) – 4 spoke, Tilt and telescoping, with turn signal, head light switches and horn button	
Fuel Tank:	30 gallons			Rectangular, aluminum, road side fill	
A/C Roof:	Thermo-King			63,000 BTU rating, ultra-low profile and weight	

Driver Seat:	Bostrom Talladega 910	High-back air suspension seat
ADA Ramp:	Braun Ra 400	12V operation, hydraulic up, gravity drift down, manual override
Door:	Bode 40"x78" (1.02mx1.98m)	12V operation, swing out, manual override
Windows:	ArowGlobal (Stormtite)	Clamp in, smooth glass, emergency exit
Flooring:	SMI	RCA-type rubber flooring
Sidewall Skin:	Alucabond/Dibond-Alcan	VHB 3M tape-bonded to frame, 3 mm thick
Electrical System:	J 1939 Multiplex	Alternator: Leece Neville 270 amp

III. FINANCIAL EFFICIENCY – LIFE CYCLE OPERATIONAL COST SAVINGS

Several factors determine the overall financial efficiency of transit service vehicles including, but not limited to, the costs associated with the acquisition of fleet vehicles, maintenance and repair costs, and operating expenses. The life-cycle cost analysis contained herein is based on the operation of a 17-vehicle fleet on the coordinated flex-route plan in Putnam County, Florida, consisting of 17 routes. To estimate the operational costs and compare them with the operational costs of a conventional 10-year service life vehicle, the purchase price of the ALFV is estimated to be $350,000 with a diesel engine. A conventional 10-year service life mid-size bus is the vehicle against which the ALFV is compared, and the purchase price of $285,050 is used for the purpose of the following comparisons and cost saving calculations.

LONG-LIFE VEHICLE SAVINGS

The Long-Life Vehicle (LLV) concept, while perhaps new to transit, has been employed in transportation for a number of decades, most notably by the US Postal Service and UPS (which operates 20-year vehicles). Ride Solution has operated mild steel chassis full-size buses, which were purchased new in 1989, over a 24-year, 1-million-mile (1,609,344-km) service life per unit, much of which has occurred on the dirt roads of Putnam County. What became evident in Ride Solution's life-cycle cost analysis was that repairs on these old units never exceeded the depreciation inherent in a replacement vehicle. After these buses were fully depreciated at 10 years, they constituted an operational savings over a new vehicle.

Ride Solution's most successful "Dirt Bus" conversions were of two stainless steel Rapid Transit Series (RTS) buses, both of which had about 400,000 miles (643,738 km) when they were surplused at 12 years by urban transit agencies. Ride Solution has driven these units in daily service for an additional 12 years. Their stainless construction has given them a decided edge over the mild steel buses in terms of chassis maintenance, though their two-cycle Detroit Diesel engines do not have the longevity of the four-cycle engines.

Ride Solution, thus, has developed an appreciation for vehicles that can be operated for 20 years. This perspective is particularly relevant when it comes to the maintenance of van cutaways, the predominant rural transit vehicle due to its low acquisition cost. Van cutaways have a very difficult time coping with the wear and tear of dirt roads and the most Ride Solution have ever gotten out of one is about 7 years and 400,000 miles. Nevertheless, the van cutaway purchase cycle is very difficult to break, due to the capital grant dollars available in any one year and the inability for rural properties in Florida to bundle capital grants across multiple years.

When given the opportunity to construct the ALFV, Ride Solution chose a stainless chassis construction. While the difficulties of welding stainless became evident during the Altoona testing of the ALFV, Ride Solution knows this is a challenge that can be overcome under proper production conditions. The ALFV suspension bushings were also an issue during the Altoona test. Again, this is a challenge that can be overcome in production models. As the construction issues encountered at Altoona did not also involve design issues, Ride Solution is confident that the production ALFV, which will use the same stainless alloy as the RTS buses, will be a 20-year chassis.

Currently the Federal Transit Administration limits testing at the Altoona Bus Research and Test Center (ABRTC) to a maximum of a 12-year life-cycle test program of 15,000 test miles (24,140 km). Ride Solution Inc. would like to see an additional category to include a 20-year service life within the FTA Bus Testing Program. Based on Ride Solution's experience mentioned above, a long-life (20-year) analysis of costs for the ALFV to indicate the best possible economics of such a program is included in this document. It is noted that the cost savings are calculated on a 20-year life of this bus, although the ALFV was tested in Altoona under the 10-year category. The acquisition cost savings associated with the estimated longer life of the ALFV bus is projected in Table 3. It is assumed that both buses reach their advertised service life, with no more or less time in service that could change the analysis.

Table 3. Average Annual Vehicle Purchase Price Cost Analysis

Item	Per Item Cost	Total
Cost of a 20-year AMPV bus	$350,000	$350,000
Cost of two 10-year buses	$285,050	$570,100
Savings		$220,100
Percent of AMPV cost	62.9%	

*Prices are the median cost for 10-year buses from the Florida DOT Vehicle Procurement Website (TRIPS), http://www.tripsflorida.org/md10.html, as of August 2013.

For a 17-vehicle fleet, the total capital savings would be $3,741,700.

MANEUVERABILITY OPERATIONAL SAVINGS (APTA ROADEO STUDY)

The International Bus Roadeo is an annual competition for bus operators and maintenance personnel. It includes a set of driving courses intended to test and rate one driver's expertise against another's. Ride Solution used the same set of driving tasks to compare the ALFV against a 31-foot (9.45-meter) bus using the same driver in order to compare the agility of the ALFV bus against another low floor bus with a similar seating capacity. The rodeo tests were conducted by Ride Solution in Palatka, Florida, not at the Altoona test track.

That a 26-foot (7.92-meter), 25-passenger bus can be more productive throughout its workday than a 31-foot (9.45-meter), 25-passenger bus, is rarely considered during the purchase of buses. The ALFV Roadeo study shows that vehicle agility can translate into significant operational savings. To gauge vehicle agility against a known standard, Ride Solution utilized eight of the twelve events in the APTA National Bus Roadeo 2013 Standardized course (Appendix 1). This course, which is normally used to test drivers, was used by Ride Solution to compare the agility of the AMPV with a typical cutaway low-floor alternative. The competing low-floor bus model used for comparison also had a 25-passenger capacity and was selected as representative of the vehicle length necessary to transport 25 passengers when that vehicle is a low-floor cutaway. The competing vehicle measured 31 feet (9.45 meters) long and 102 inches (2.59 meters) wide and was at a clear disadvantage in the bus Roadeo obstacles. It is the low-floor ALFV's unique ability to accommodate 25 passengers in 26 feet (7.92 meters) of vehicle length that gives it a time advantage both in the rodeo and in flex route services, which place a premium on route deviation. Vehicle agility can translate to savings due to reduced time in the operating budget and, by faciliating the flex-route format, can yield increased productivity. Photographs of the ALFV operating during one of the Bus Roadeo events and the competing vehicle are shown in Figure 1.

The APTA Bus Roadeo course dimensions utilized were for the 35-foot long, 96-inch wide bus (10.67-meter long, 2.44-meter wide). The AMPV is 26 feet long and 96 inches wide (7.92 meters long, 2.44 meters wide), while the alternative bus was 31 feet long and 102 inches wide (9.45 meters long, 2.59 meters wide). While the alternative's 102-inch width was a disadvantage in some events, it was impossible, and therefore irrelevant, to perform some of the events with the 102-inch width. Events that were precluded by the 102-inch width were Event 4, the "Rear Duals Clearance," and Event 11, the "Diminishing Clearance." In both cases, minimum clearance widths for these two events equaled or were less than 102 inches. Event 1, the "Pre-Trip Inspection" and Event 12, the "Judgment Stop" were also not used in this comparison due to the difficulty in extrapolating a meaningful time and physical characteristic from these events that could be coded into the bus routes. Details of the events are given in the APTA Roadeo Handbook.[3] The remaining eight events were used in this study.

Figure 1. ALFV Operating through Two Bus Roadeo Events, and Competing Bus

The experimental methodology consisted of coding Ride Solution's existing flex routes for the frequency per hour of the physical characteristics of each APTA Roadeo event. Ride Solution operates 26 routes or services, of which 17 were sufficiently defined or regular enough to lend themselves to this coding process. Routes were evaluated and coded, for instance, for how many left and right turns per hour occurred on the route. The roadeo time difference for left and right turns was then calculated on a per-hour basis for each of the 17 routes. As the 26-foot (7.92-meter) AMPV ran all roadeo events faster than the 31-foot (9.45-meter) competitor vehicle, the time difference per hour can translate to a time savings per hour provided by the ALFV in service.

APTA Roadeo time savings per hour per route were then accumulated over the projected AMPV 20-year lifetime for a 17-vehicle fleet. From these time savings, per hour and total cost savings for the 17-vehicle fleet were calculated using Ride Solution's cost allocation methodology employed to manage the overall system. This methodology establishes three cost centers in the operating line item budget: Miles Cost, Hours Cost, and Fixed Cost. Miles Cost is defined as fuel, oil, tires, and maintenance. Hours Cost is driver salary plus fringe, while Fixed Costs are all other budget line items. It is Hours Cost that is amenable to vehicle agility. The resulting calculated maximum savings based on Roadeo performance assuming 20-year service life are shown in Figure 2.

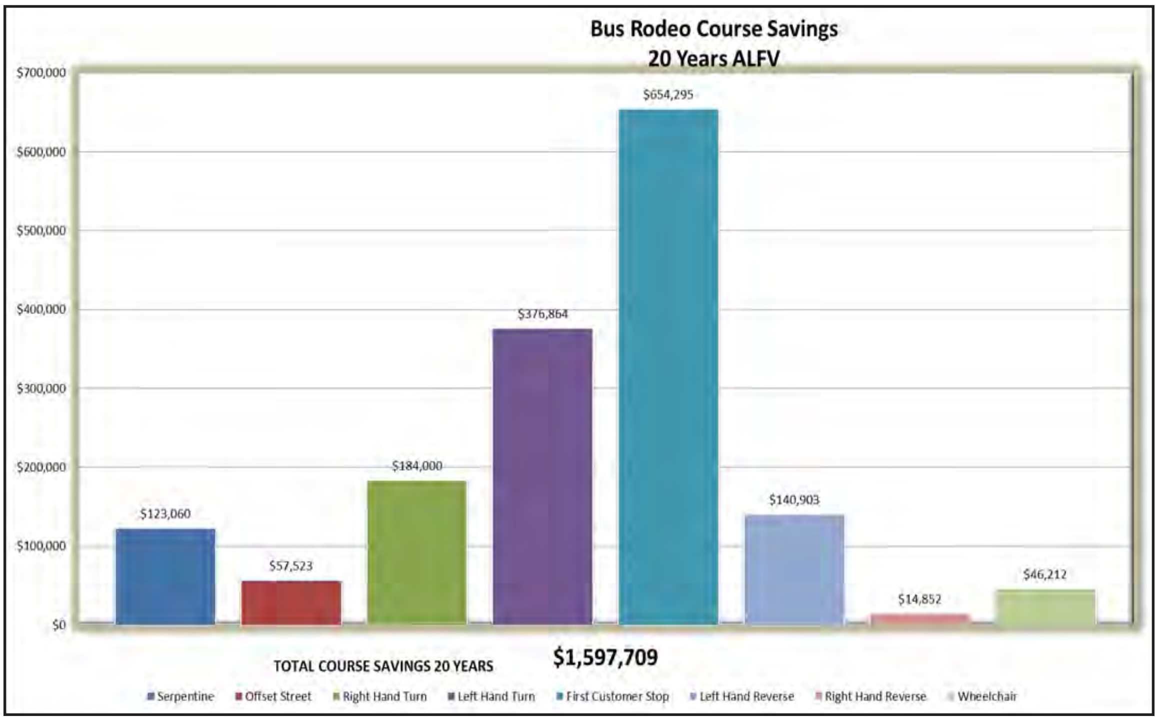


Figure 2. Maximum Maneuverability Operational Cost Savings Based on Roadeo Performance (Assuming a 20-Year Service Life)

As shown in Figure 1, due to the better agility of the ALFV, the agility savings could add to $1,597,709 for the 17 routes utilizing 17 vehicles over 20 years, if all the time saved during the roadeo were converted to time savings in service.

The Roadeo is practically a race, and all time savings above are unlikely to be realized in revenue service. Therefore, assuming that 50% can be converted to revenue savings, this translates to 13.5% of the purchase price.

RESERVE FLEET SAVINGS

With a quicker remove-and-replace, fully self-contained power module, it should be feasible to substantially reduce reserve fleet ratios, perhaps from 20% to 10%. Lowering the reserve fleet ratio reduces capital costs as well as ongoing vehicle insurance costs. Average insurance costs per vehicle at Ride Solution are $5,501 annually. A 10% reduction in reserves for the 17-vehicle fleet equals 1.7 (rounded of to 2) vehicles, or $11,002 per year, which, over a 20-year period, equals $220,040. This savings equals 3.7% of the total AMPV 17-vehicle fleet purchase price of $5,950,000.

Using a $285,050, 10-year, low-floor mid-sized vehicle to compute the capital savings resulting from the 10% reserve fleet reduction would also result in two vehicles that would not have to be purchased over the 20-year ALFV 17-vehicle fleet life cycle, or a vehicle purchase savings of $570,100 ($285,050x2). This vehicle purchase savings would be offset by the purchase of two ALFV power modules at $75,000 each, for a total of $150,000 in power module capital expenditure. This offset would result in a total reduction in reserve fleet capital expenditure of $420,100 ($570,100 - $150,000), or 7.1% of the total 17-vehicle purchase price of $5,950,000.

Total reserve fleet savings, achieved by reducing reserve vehicles from 20% to 10% of total fleet, then, equals $640,140 ($420,100 + $220,040) or 10.8% of the 17-vehicle fleet of the AMPV's purchase price of $5,950,000.

TOTAL POTENTIAL SAVINGS

The ALFV, based on a 20-year life, is potentially capable of delivering operational savings that offset the purchase price, as shown in Table 4.

Table 4. Potential Operational Savings of the ALFV

Long-Life Vehicle Capital Savings (as tested)	62.9%
Maneuverability Operational Savings (as tested, 50%)	13.5%
Reserve Fleet Operational Savings (as tested)	10.8%
Total Projected Savings based on Purchase Price	87.2%

This same information is shown graphically in Figure 3.

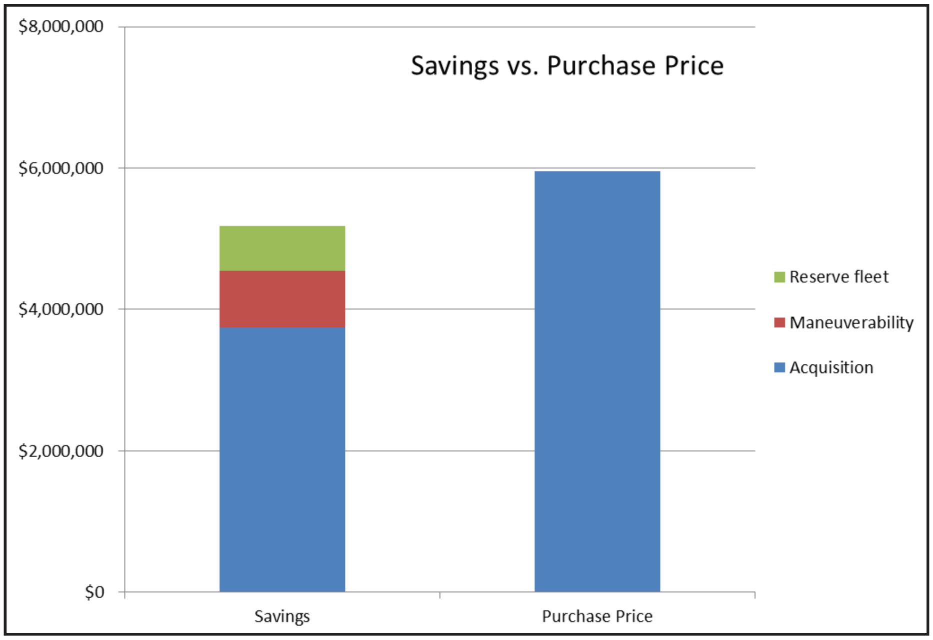


Figure 3. ALFV Savings versus Purchase Price

IV. PROTOTYPE TESTING

THE FTA NEW BUS MODEL TEST

One of the goals of this project was to measure the performance and reliability characteristics of a prototype ALFV bus in a standard testing environment. This was achieved by testing the prototype bus for the standard FTA ("Altoona") 10-year/350,000-mile (563,270-km) service life test. The prototype bus completed the test in June 2013. At the time of writing this report, Ride Solution, Inc. had not yet released the official Federal Transit Administration's Altoona bus test report. This report, when released, will contain results of tests conducted on the prototype. However, some of the test results relevant to this report are presented and compared to other bus models in Appendix 2. The procedures and tests conducted under the Altoona Bus Testing program are:

- Bus Check In
- Maintainability
- Reliability
- Safety
- Performance
- Structural Integrity
- Fuel Economy
- Noise
- Emissions

The details of the test methodology and test reports are available at the Bus Testing Program's website: www.altoonabustest.com

ADDITIONAL RESEARCH TESTS (ALFV)

In addition to the FTA New Model Test above, supplemental tests were conducted at the Penn State Bus Research and Testing Facility of the Larson Institute to investigate the design features that bear on intended performance and costing of the ALFV. These include measurement of the turning radius of the vehicle, the suspension travel and ramp travel index, determination of the driver's field of view, ground clearance, and compliance of the bus to ADA requirements. These tests and the results are included in this section.

Turning Ability

The objective of this test is to determine the turning radius (curb-to-curb and wall-to-wall) of the bus. In this test, the field test procedure as specified in SAE J695, 2011, "Turning Ability and Off Tracking-Motor Vehicles," is followed. The vehicle is run on dry ground in both directions in low gear at engine idle speed with wheels turned to the maximum cut angle. The path of the outside front wheel is marked on the ground by spraying marker paint over the wheels. The turning diameter is found by measuring the distance between the mid-points of tire contact trace on the ground to a similar point diametrically opposite on the traced circular path.

The test consisted of running the vehicle in both clockwise and counter-clockwise directions and tracing the path of the outer front tire in each case by spraying marker paint on it. The path of the outer edge of the tire is traced on the ground. The diameter of these circles (left and right turning circles) is measured, and the tire width is subtracted from it to obtain the turning diameter (TD). The data from the test are found in Table 5.

To obtain the curb clearance increment, a straight edge was placed horizontally across the outside face of the tire at a height of 150 mm (5.91 inches) above the ground. From the foremost point of contact of this surface with the tire, a point was located on the ground that is vertically beneath it. The distance of this point from the midpoint of the tire's width gave the curb clearance increment (CCI). TD (Curb-to-Curb) = TD + 2 x (CCI).

To obtain the wall-to-wall turning diameter, a point directly beneath the extreme radial extension of the vehicle (in this case, the wing mirrors) was located on the ground. The distance of this point from the midpoint of the tire's width was measured, and twice this distance was added to the turning diameter to obtain wall-to-wall turning diameter. TD (Wall-to-Wall) = TD + 2 x (Measured distance from tire midpoint to extreme radial extension).

Table 5. ALFV Turning Radius Data Form

Parameter	Right Turn	Left Turn
Turning Radius	32 ft 7 in (9.91m)	28 ft (8.53m)
Turning Radius (Curb-to-Curb)	33 ft (10.06m)	28 ft 5.5 in (8.69m)
Turning Radius (Wall-to-Wall)	34 ft (10.36m)	29 ft. 4.5 in (8.92m)

Suspension Travel and Ramp Travel Index

The objective of this test is to find the total travel of the suspension and ramp travel index of the vehicle to give a quantitative analysis of the off-roading capability of the bus.

Suspension Travel: The bus is lifted off the ground using a vehicle lifting arrangement and supported on hoisting pillars. The bus is supported on its chassis so the tires are free to hang down. This way, there is no load on the suspension system, and this position is the maximum extension position of the suspensions (which is reached in driving conditions if the bus becomes airborne). The maximum compressed position in the suspensions is obtained dynamically when the tires hit the bump stops. The total suspension travel is obtained by measuring the distance between maximum compressed position and maximum extended position.

Ramp Travel Index: Ramp travel index (RTI) is used to measure the vehicle's ability to flex its suspension. RTI rating gives a measure of the off-roading capability of the vehicle. The RTI rating is measured without a ramp, using basic trigonometric relation as shown in Figure 4.

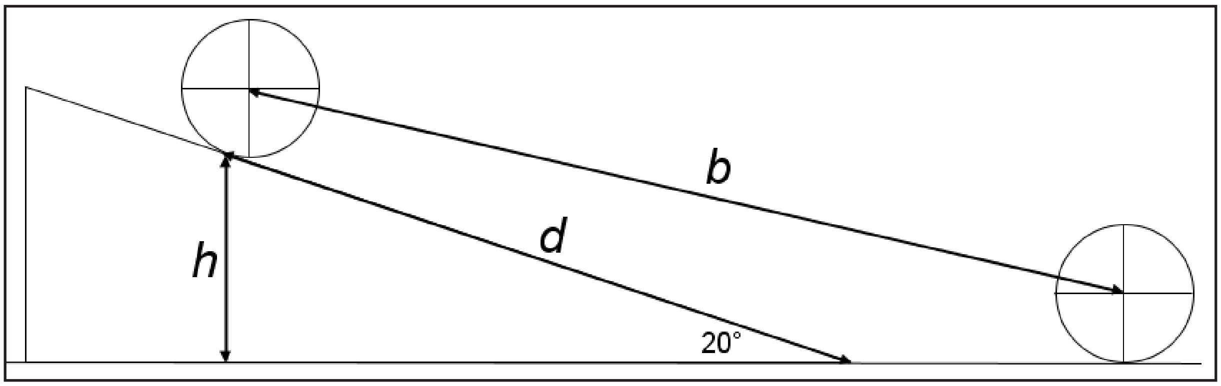


Figure 4. Ramp Travel Index Schematic (Wikipedia)

The right front tire of the vehicle is lifted up using a forklift, and the distance '*h*' is measured, which is the maximum distance from the bottom of the tire to the ground without allowing any other wheel to leave the ground (in this case, just before the right rear tire left the ground). Referring to Figure 4, for a 20° ramp, the following relation is obtained:

$$\sin 20^o = \frac{h}{d} \Rightarrow d = \frac{h}{\sin 20^o}$$

RTI is defined as:

$$r = \frac{d}{b} \times 1000$$

Where '*b*' is the wheelbase of the vehicle, '*d*' is the distance travelled along a ramp (usually 20°) before any of the other wheels leave the ground, and '*r*' is the calculated ramp travel index. Substituting the value of '*d*' from the above expression, the RTI for a 20° ramp can be calculated as:

$$r = RTI_{20} = \frac{h}{b} \times \frac{1000}{\sin 20^o}$$

The total suspension travel for all four suspensions is summarized in Table 6.

Table 6. Suspension Travel Data

Suspension	Total Travel (in)	Suspension	Total Travel (in)
Front Left	$8\frac{3}{4}$	Rear Left	$8\frac{3}{8}$
Front Right	$8\frac{1}{2}$	Rear Right	$8\frac{3}{8}$

Ramp Travel Index: The calculated Ramp Travel Index is:

Height from bottom of tire to ground, *h* = 14.25 inches (0.36 meter)

Wheel Base, *b* = 205.75 inches (5.23 meters)

Ramp Travel Index value is: $r = RTI_{20} = \frac{h}{b} \times \frac{1000}{\sin 20°}$ = 202 (rounded)

To compare this value, it should be noted that the RTI of most SUVs is in the range of 400-550.

Field of View

The objective of this test is to determine the (direct) front and (indirect) rear field of view of the driver while seated in the normal driving position.

Eyellipse is the contraction of the words eye and ellipse, which is used to describe the statistical distribution of eye locations in three-dimensional space located relative to defined vehicle interior reference points. A 2-D CAD model of the bus is created in both side view and top view to determine the vertical and horizontal range of the field of view. The range of front field of view of the vehicle is determined by methods described in SAE J1050 (2009), “Describing and Measuring the Driver’s Field of View” and SAE J941 (2010), “Motor Vehicle Drivers’ Eye Locations.” The centroid of the drivers’ eyellipses is located using procedures mentioned in Appendix E of SAE J941, “Eyellipses for class B vehicles.”[4,5] Sight lines are constructed from aperture limits to the closest side of the farthest eyellipse. Wherever necessary, the eyepoints on the eyellipses are rotated about a corresponding neck pivot point to construct sight lines passing through aperture limits and within allowable eye and head movement. Using this procedure, the range of direct field of view is obtained as a sum of angular field of view to the right and left (or up and down) as determined from the CAD model. Figure 5 shows the total horizontal and vertical field of view of the driver.

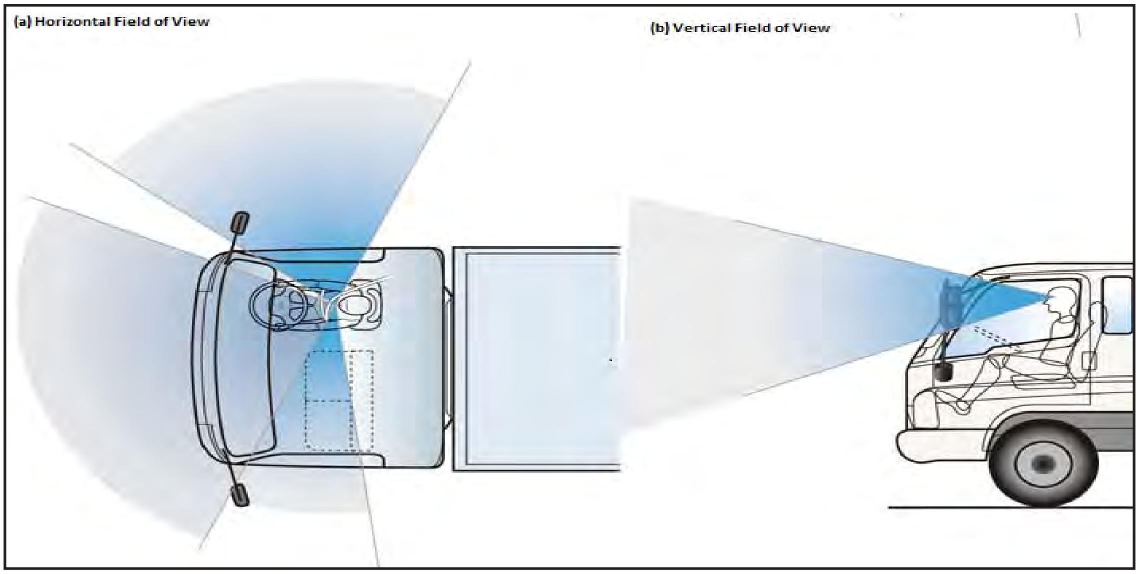


Figure 5. Front Field of View

http://www.hyundai.com.au/Images/UserUploadedImages/91/Excellent-field-of-view.jpg

The shaded region in Figure 5 (a) and (b) represents the total field of view in horizontal and vertical directions, respectively. The figure presented here is for pictorial reference of field of view and doesn't represent the actual vehicle tested.

A grid with a length of 70 feet (21.34 meters) and breadth of 50 feet (15.24 meters) is created on a clear level ground. The bus is positioned such that the rearmost point on the longitudinal centerline of the bus is positioned exactly at the origin of the grid, as shown in Figure 6. At this position, a square grid of size 50 feet by 50 feet is available to the rear of the bus. Grid points are marked at distances of 1 foot (0.3 meter) along the length and breadth of the rectangular grid. With the driver sitting in a normal driving position wearing the seat belt, a traffic cone 1 foot high is placed at every grid point. The driver is then asked to find out if he can spot the cone using either the side view mirrors or the cameras installed in the bus. The side view mirrors are located within the bounds of maximum head and eye turning angle of the driver, as specified in SAE J1050. Using this procedure, the grid points that are visible using either mirror or camera and the grid points that are not visible using either are marked.

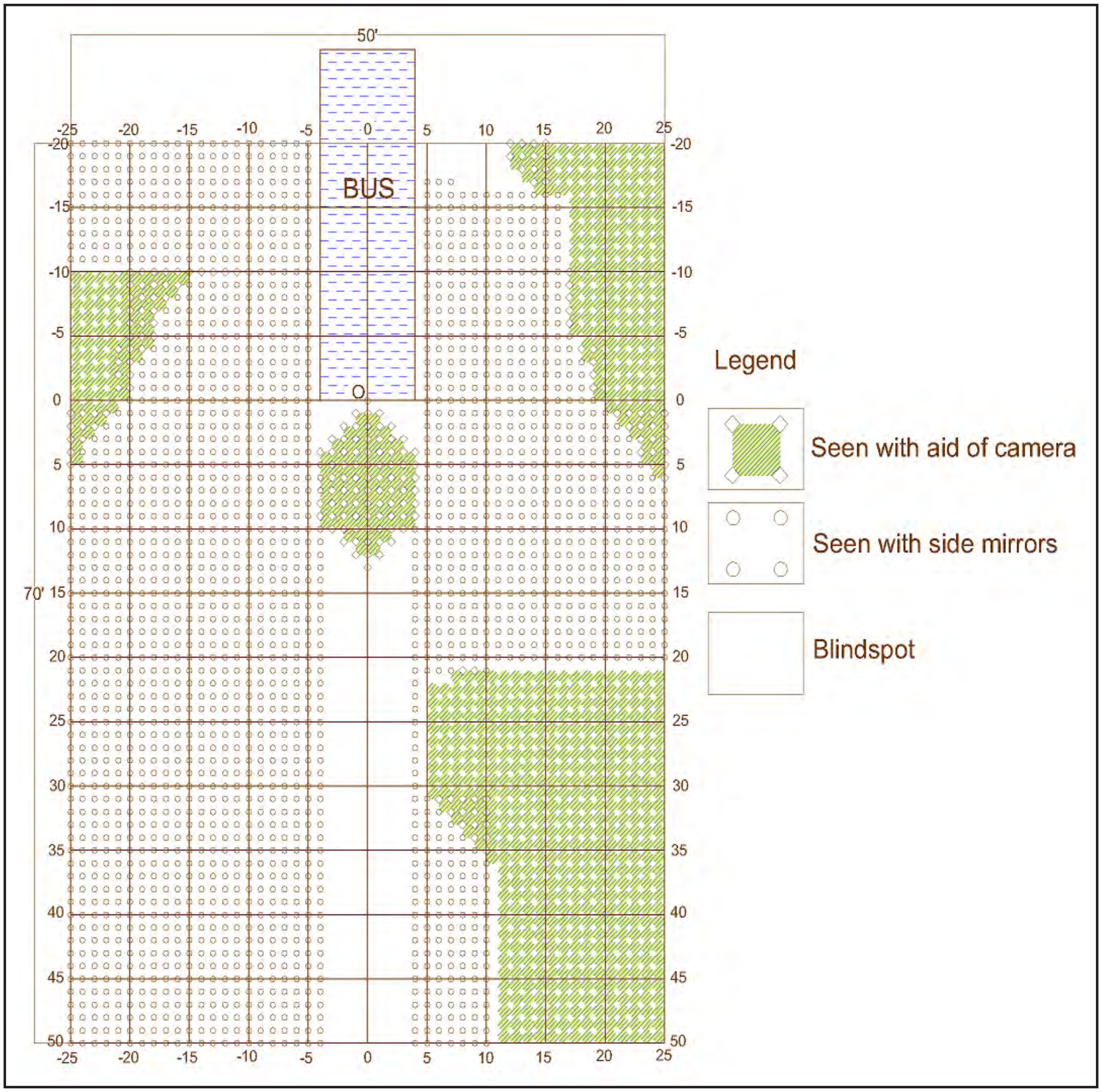


Figure 6. Rear Field of View of ALFV

For the front field of view, the eyellipses' centroid location is found with reference to the Accommodation Tool Reference Point (ATRP). As per a drawing provided by the manufacturer, the height of the H-point (H30) above accommodation heel reference point is z = 468.22 mm. SAE J1516 defines Accommodation Tool Reference line equation as: $x = 798.74 - 0.446z = 589.91$, for a 50:50 male-to-female ratio, where x is the horizontal reference location in millimeters aft of the accommodation heel reference, and z = H30 mentioned above. Using these values and the vehicle drawing, the X and Z coordinate of the ATRP are found as X(ATRP) = 1415.29 mm and Z(ATRP) = 1219.45 mm.

For a 50:50 male/female ratio, the centroid location is given in SAE J941 as:

$$\mathrm{X} = \mathrm{X(ATRP)} - 175.26 + 12.68 \times (\mathrm{A40})$$
$$\mathrm{Z} = \mathrm{Z(ATRP)} + 691.09 - 3.57 \times (\mathrm{A40})$$

in which A40 is the design torso angle with value 18°. Thus we obtain:

X = 1468.27 mm = 57.80 inches and Z = 1846.28 mm = 72.69 inches.

The Y coordinate of the eyellipses are given by:

YL = W20 – 32.5 = - 1903.72 mm = - 74.95 inches

YR = W20 + 32.5 = - 1838.72 mm = - 72.39 inches

in which W20 = -1871.22 mm is Y(ATRP) and origin of the coordinate system is located at the front right corner of the vehicle.

Assuming a 95th percentile ellipse, the axes lengths are given as X-axis = 173.8 mm, Y-axis = 105.0 mm, and Z-axis = 86.0 mm. With the above configuration and using the CAD model, the vertical direct field of view range is found to be 33° in total, which is within maximum limits of maximum eye rotation.

While defining the horizontal range, it is seen that the left edge of the windshield can be viewed with an eye rotation of 21°, while its right edge can be seen with a head rotation of 17° followed by an eye rotation of 30°. The widest points that are visible on the right and left sides are respectively obtained by head rotation of 60° followed by eye rotation of 30°, and by head rotation of 50° followed by eye rotation of 24°.

Figure 7, Figure 8, and Figure 9 show the side, top, and 3D view of the vehicle, respectively.

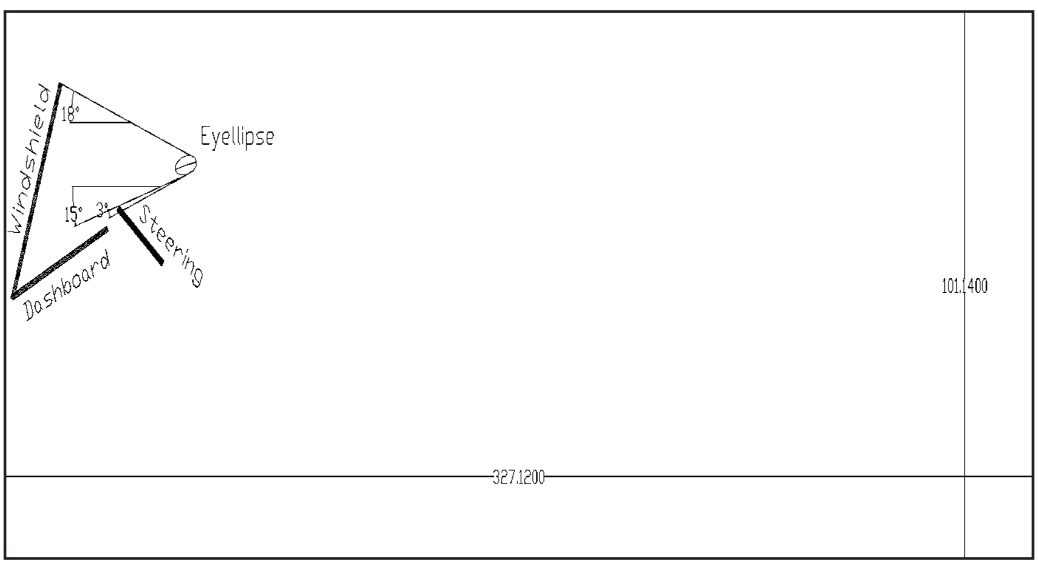


Figure 7. Side View of Vehicle Indicating Vertical Range of Field of View

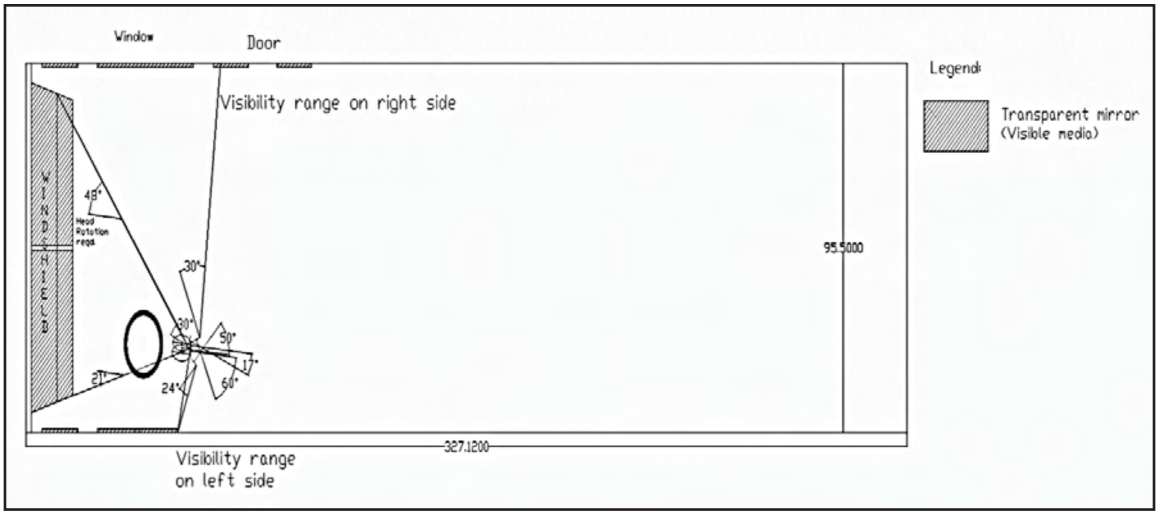


Figure 8. Top View of Vehicle Indicating Horizontal Range of Field of View

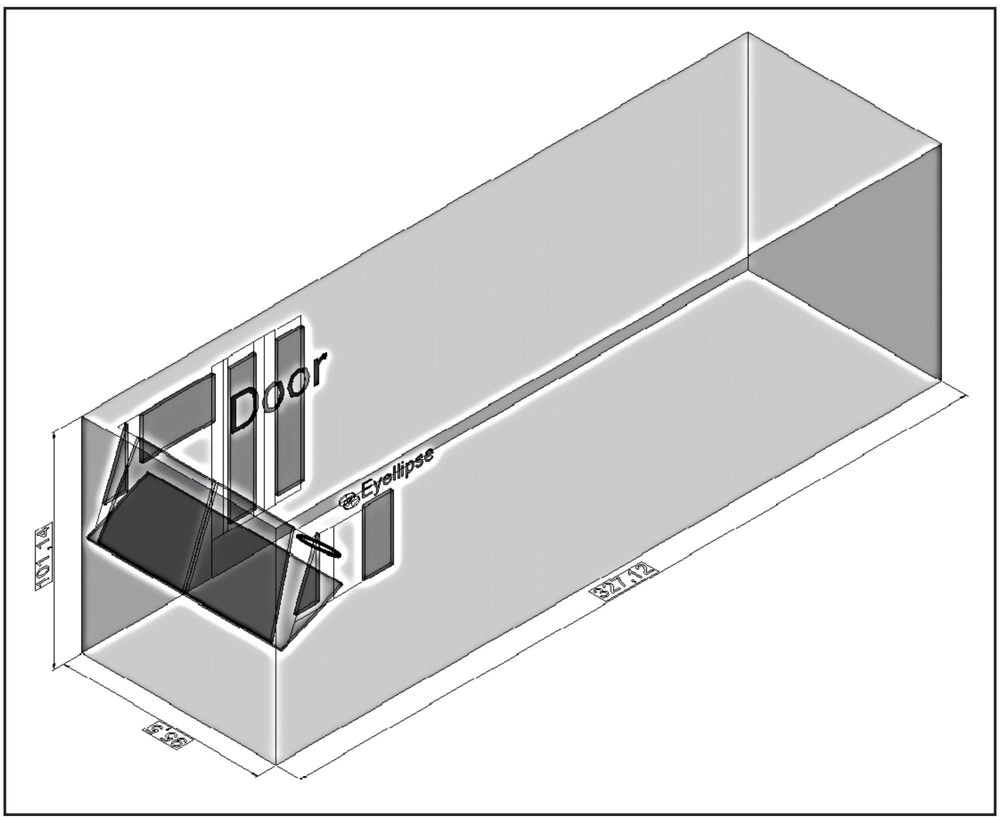


Figure 9. 3D Model of the Vehicle

Figure 9 shows the demarcation of the various areas in the tested grid: area seen with aid of camera, area seen with mirror, and blind spot. Due to constraints on the availability of equipment for a more rigorous field-of-view test, the test was conducted in a subjective manner. However, the visibility of grid points was determined by two different drivers by repeating the test on two separate days to eliminate strict subjectivity from the test. This practical procedure of determining the rear field of view of the vehicle is taken from National

Highway Traffic Safety Administration's paper (Mazzae & Barickman, 2009), "Direct Rear Visibility of Passenger Cars: Laser-Based Measurement Development and Findings for Late Model Vehicles."[6] Due to equipment constraint, the laser-based measurement technique had to be changed to human observations, which made the tests somewhat subjective.

In the front field of view of the vehicle, it is seen that the driver can see the edges of the windshield within maximum limits of head and eye rotation. With the aid of a camera, the vehicle's rear field of view is substantially increased, which is evident from Figure 6. The vertical field of view on the right side is partially obstructed by two passenger seats. However, the obstruction is partially mitigated by providing a rear-view mirror and cameras to widen the field of view.

Compliance to ADA Requirements

The objective of this part is to assess whether the bus meets the requirements of the ADA.

A checklist was prepared based on CFR 2005, Title 49, Vol 1, Part 38 (2005), "Americans With Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles."[7] Subpart B of the document lists specifications for buses, vans, and systems. The ALFV vehicle specifications were compared with the stated requirements. The checklist used and the notations for the ALFV are found in Table 7.

Table 7. ADA Compliant Checklist for the ALFV

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
§ 38.23 Mobility aid accessibility (a) General	All vehicles covered by this subpart shall provide a level change mechanism or boarding device(e.g., lift or ramp) complying with point (b) or (c) of this section and sufficient clearances to permit a wheelchair or other mobility aid user to reach a securement location. At least two securement locations and devices, complying with point (d) of this section, shall be provided on vehicles in excess of 22 feet in length; at least one securement location and device, complying with point (d) of this section, shall be provided on vehicles 22 feet in length or less.	Wheelchair ramp provided
(b) Vehicle Lift		

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
1. Design Load		
2. Controls		
3. Emergency operation		
4. Power or equipment failure		
5. Platform Barriers		
6. Platform Surface		
7. Platform gaps	Vehicle is not equipped with a lift	Not Applicable
8. Platform Entrance ramp		
9. Platform deflection		
10. Platform Movement		
11. Boarding Direction		
12. Use by Standees		
13. Handrails		
(c) Vehicle Ramp		
1. Design Load	Ramps 30 inches or longer shall support a load of 600 pounds, placed at the centroid of the ramp distributed over an area of 26 inches by 26 inches, with a safety factor of at least 3 based on the ultimate strength of the material. Ramps shorter than 30 inches shall support a load of 300 pounds.	Ramp of dimension 48 inch X 32 ½ inch. Checked with 600 lbs for deformation. No deformation observed.
2. Ramp Surface	The ramp surface shall be continuous and slip resistant; shall not have protrusions from the surface greater than ¼ inch high; shall have a clear width of 30 inches; and shall accommodate both four-wheel and three-wheel mobility aids.	Compliant
3. Ramp Threshold	The transition from roadway (or sidewalk) or from vehicle floor to ramp may be vertical without edge treatment upto ¼ inch. Changes in level between ¼ inch to ½ inch shall be beveled with a slope no greater than 1:2.	Compliant
4. Ramp Barriers	Each side of the ramp shall have barriers at least 2 inches in high to prevent mobility aid wheels from slipping off.	Compliant

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
5. Slope	Ramps shall have the least slope practicable and shall not exceed 1:4 when deployed to ground level. If the height of the vehicle floor from which the ramp is deployed is 3 inches or less above a 6-inch curb, a maximum slope of 1:4 is permitted; if the height of the vehicle floor from which the ramp is deployed is 6 inches or less, but greater than 3 inches, above a 6-inchcurb, a maximum slope of 1:6 is permitted; if the height of the vehicle floor from which the ramp is deployed is 9 inches or less, but greater than 6inches, above a 6-inch curb, a maximum slope of 1:8 is permitted; if the height of the vehicle floor from which the ramp is deployed is greater than 9 inches above a 6-inch curb, a slope of 1:12 shall be achieved. Folding or telescoping ramps are permitted provided they meet all structural requirements of this section.	Height of vehicle floor is 4.5 inches above a 6-inch curb. Slope of 0.09 is calculated, which is lesser than 1:6. Compliant
6. Attachment	When in use for boarding or alighting, the ramp shall be firmly attached to the vehicle so that it is not subject to displacement when loading or unloading a heavy power mobility aid and that no gap between vehicle and ramp exceeds ⅝ inch.	Compliant
7. Stowage	A compartment, securement system, or other appropriate method shall be provided to ensure that stowed ramps, including portable ramps stowed in the passenger area, do not impinge on a passenger's wheelchair or mobility aid or pose any hazard to passengers in the event of a sudden stop or maneuver.	Compliant

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
8. Handrails	If provided, handrails shall allow persons with disabilities to grasp them from outside the vehicle while starting to board, and to continue to use them throughout the boarding process, and shall have the top between 30 inches and 38 inches above the ramp surface. The handrails shall be capable of withstanding a force of 100 pounds concentrated at any point on the handrail without permanent deformation of the rail or its supporting structure. The handrail shall have across-sectional diameter between 1 ¼ inches and 1 ½ inches or shall provide an equivalent grasping surface, and have eased edges with corner radii of not less than ⅛ inch. Handrails shall not interfere with wheelchair or mobility aid maneuverability when entering or leaving the vehicle.	Compliant
(d) Securement Devices		
1. Design Load	Securement systems on vehicles with GVWRs of 30,000 pounds or above, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,000 pounds per securement leg or clamping mechanism and a minimum of 4,000 pounds for each mobility aid. Securement systems on vehicles with GVWRs of up to 30,000 pounds, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,500 pounds per securement leg or clamping mechanism and a minimum of 5,000 pounds for each mobility aid.	Anchor points are not bolted to the vehicle frame, but to the floorboard. It was determined not to perform this test because of safety considerations. Although the design load of the securement system was not tested, it is believed that **the bus is not compliant with this requirement**.
2. Location and size	The securement system shall be placed as near to the accessible entrance as practicable and shall have a clear floor area of 30 inches by 48 inches. Such space shall adjoin, and may overlap, an access path. Not more than 6 inches of the required clear floor space may be accommodated or footrests under another seat provided there is a minimum of 9 inches from the floor to the lowest part of the seat overhanging the space. Securement areas may have fold-down seats to accommodate other passengers when a wheelchair or mobility aid is not occupying the area, provided the seats, when folded up, do not obstruct the clear floor space required.	Tested wheelchair occupied a floor space of 24”X48”, which is accommodated well within each securement location’s solo anchor points on the bus floor. Compliant
3. Mobility aids accommodated	The securement system shall secure common wheelchairs and mobility aids and shall either be automatic or easily attached by a person familiar with the system and mobility aid and having average dexterity.	Compliant (Checked with a typical wheelchair)

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
4. Orientation	In vehicles in excess of 22 feet in length, at least one securement device or system required by point (a) of this section shall secure the wheelchair or mobility aid facing toward the front of the vehicle. Additional securement devices or systems shall secure the wheelchair or mobility aid facing forward, or rearward with a padded barrier, extending from a height of 38 inches from the vehicle floor to a height of 56 inches from the vehicle floor with a width of 18 inches, laterally centered immediately in back of the seated individual. In vehicles 22 feet in length or less, the required securement device may secure the wheelchair or mobility aid either facing toward the front of the vehicle or facing rearward, with a padded barrier as described. Additional securement locations shall be either forward or rearward facing with a padded barrier. Such barriers need not be solid provided equivalent protection is afforded.	This bus has 5 wheelchair positions. Padded barrier not provided behind securement locations. **The bus is not compliant with this requirement**.
5. Movement	When the wheelchair or mobility aid is secured in accordance with manufacturer’s instructions, the securement system shall limit the movement of an occupied wheelchair or mobility aid to no more than 2 inches in any direction under normal vehicle operating conditions.	Compliant
6. Stowage	When not being used for securement, or when the securement area can be used by standees, the securement system shall not interfere with passenger movement, shall not present any hazardous condition, shall be reasonably protected from vandalism, and shall be readily accessed when needed for use.	Compliant
7. Seat belt and shoulder harness	For each wheelchair or mobility aid securement device provided, a passenger seatbelt and shoulder harness, complying with all applicable provisions of part 571 of this title, shall also be provided for use by wheel-chair or mobility aid users. Such seat belts and shoulder harnesses shall not be used in lieu of a device which secures the wheelchair or mobility aid itself.	Not provided. **The bus is not compliant with this requirement**.
§ 38.25 Door, steps and thresholds		
a. Slip resistance	All aisles, steps, floor areas where people walk and floors in securement locations shall have slip-resistant surfaces.	Compliant
b. Contrast	All step edges, thresholds, and the boarding edge of ramps or lift platforms shall have a band of color(s) running the full width of the step or edge which contrasts from the step tread and riser, or lift or ramp surface, either light-on-dark or dark-on-light.	Compliant

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
c. Door height	For vehicles in excess of 22 feet in length, the overhead clearance between the top of the door opening and the raised lift platform, or highest point of a ramp, shall be a minimum of 68 inches. For vehicles of 22 feet in length or less, the overhead clearance between the top of the door opening and the raised lift platform, or highest point of a ramp, shall be a minimum of 56 inches.	Compliant (Overhead clearance of 77 ¼ inches)
§ 38.27 Priority Seating Signs		
	Each vehicle shall contain sign(s) which indicate that seats in the front of the vehicle are priority seats for persons with disabilities, and that other passengers should make such seats available to those who wish to use them. At least one set of forward-facing seats shall be so designated.	Not compliant. No indication signs provided.
	Each securement location shall have a sign designating it as such.	Not compliant. No indication signs provided.
	Characters on signs required by paragraphs (a) and (b) of this section shall have a width-to-height ratio between 3:5 and 1:1 and a stroke width-to-height ratio between 1:5 and 1:10, with a minimum character height (using an upper case "X") of 5/8 inch, with "wide" spacing (generally, the space between letters shall be 1/16 the height of upper case letters), and shall contrast with the background either light-on-dark or dark-on-light.	Not compliant. No indication signs provided.
§ 38.29 Interior Circulation, handrails and stanchions		
	Interior handrails and stanchions shall permit sufficient turning and maneuvering space for wheelchairs and other mobility aids to reach a securement location from the lift or ramp.	Compliant

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
	Handrails and stanchions shall be provided in the entrance to the vehicle in a configuration which allows persons with disabilities to grasp such assists from outside the vehicle while starting to board, and to continue using such assists throughout the boarding and fare collection process. Handrails shall have a cross-sectional diameter between 1 ¼ inches and 1 ½ inches or shall provide an equivalent grasping surface, and have eased edges with corner radii of not less than 1/8 inch. Handrails shall be placed to provide a minimum 1 ½ inches knuckle clearance from the nearest adjacent surface. Where onboard fare collection devices are used on vehicles in excess of 22 feet in length, a horizontal passenger assist shall be located across the front of the vehicle and shall prevent passengers from sustaining injuries on the fare collection device or windshield in the event of a sudden deceleration. Without restricting the vestibule space, the assist shall provide support for a boarding passenger from the front door through the boarding procedure. Passengers shall be able to lean against the assist for security while paying fares.	Compliant.
	For vehicles in excess of 22 feet in length, overhead handrail(s) shall be provided which shall be continuous except for a gap at the rear doorway.	Compliant
	Handrails and stanchions shall be sufficient to permit safe boarding, on-board circulation, seating and standing assistance, and alighting by persons with disabilities.	Compliant
	For vehicles in excess of 22 feet in length with front-door lifts or ramps, vertical stanchions immediately behind the driver shall either terminate at the lower edge of the aisle-facing seats, if applicable, or be ‘‘dog-legged’’ so that the floor attachment does not impede or interfere with wheelchair footrests. If the driver seat platform must be passed by a wheelchair or mobility aid user entering the vehicle, the platform, to the maximum extent practicable, shall not extend into the aisle or vestibule beyond the wheel housing.	No vertical stanchion behind driver. Driver seat platform needn’t be passed by a wheelchair or mobility aid user. Compliant
	For vehicles in excess of 22 feet in length, the minimum interior height along the path from the lift to the securement location shall be 68 inches. For vehicles of 22 feet in length or less, the minimum interior height from lift to securement location shall be 56 inches.	Compliant (82 ¼ inches)
§ 38.31 Lighting	** The amount of illumination at different points are measured using Extech HD400 Light Meter, Serial # 10082852.	

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
	Any step well or doorway immediately adjacent to the driver shall have, when the door is open, at least 2 foot-candles of illumination measured on the step tread or lift platform.	7.5 Foot-candles. Compliant
	Other step wells and doorways, including doorways in which lifts or ramps are installed, shall have, at all times, at least 2 foot-candles of illumination measured on the step tread, or lift or ramp, when deployed at the vehicle floor level.	10.5 Foot-candles. Compliant
	The vehicle doorways, including doorways in which lifts or ramps are installed, shall have outside light(s) which, when the door is open, provide at least 1 foot-candle of illumination on the street surface for a distance of 3 feet perpendicular to the bottom step tread or lift outer edge. Such light(s) shall be shielded to protect the eyes of entering and exiting passengers.	1.05 Foot-candles. Compliant
§ 38.33 Fare Box	Where provided, the fare-box shall be located as far forward as practicable and shall not obstruct traffic in the vestibule, especially wheelchairs or mobility aids.	Fare box not provided
§ 38.35 Public Information System	Vehicles in excess of 22 feet in length, used in multiple-stop, fixed-route service, shall be equipped with a public address system permitting the driver, or recorded or digitized human speech messages, to announce stops and provide other passenger information within the vehicle.	**Not compliant**
§ 38.37 Stop Request		
	Where passengers may board or alight at multiple stops at their option, vehicles in excess of 22 feet in length shall provide controls adjacent to the securement location for requesting tops and which alerts the driver that a mobility aid user wishes to disembark. Such a system shall provide auditory and visual indications that the request has been made.	Not provided
	Controls required by paragraph(a) of this section shall be mounted no higher than 48 inches and no lower than 15 inches above the floor, shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls shall be no greater than 5 lbf (22.2 N).	**Not compliant**
§ 38.39 Destination and Route Signs		
	Where destination or route information is displayed on the exterior of a vehicle, each vehicle shall have illuminated signs on the front and boarding side of the vehicle.	Compliant

Table 7, continued

Checklist for ADA compliance as per (CFR 2005, Title 49, Vol 1, Part 38, 2005) Americans with Disabilities Act (ADA) accessibility specifications for transportation vehicles.		
Items in Subpart B	**Description**	**Status**
	Characters on signs required by paragraph (a) of this section shall have a width-to-height ratio between 3:5 and 1:1 and a stroke width-to-height ratio between 1:5 and 1:10, with a minimum character height (using an upper case "X") of 1 inch for signs on the boarding side and a minimum character height of 2 inches for front "head signs", with "wide" spacing (generally, the space between letters shall be 1/16 the height of upper case letters), and shall contrast with the background, either dark-on-light or light-on-dark.	Compliant

The vehicle in its present condition does not meet the requirements for ADA compliance because of shortcomings in the above checklist. They are summarized below:

38.23 Mobility aid accessibility, (d) Securement Devices, 7. Seat belts and shoulder harness;

38.27 Priority Seating Signs, a, b, c;

38.35 Public Information System, a; and

38.37 Stop Request, a, b.

The remedies to these shortcomings would be affordable and easy to implement.

Timed Assessment of Wheelchair Securement in the Bus and Wheelchair Ramp Angle

The objective of this test is to qualitatively assess the time required to secure common wheelchairs to securement locations by a person with average dexterity, and to find the wheelchair ramp angle.

The process for determining the amount of time required to secure a wheelchair in the vehicle is as follows. First, the wheelchair ramp is deployed. Second, a wheelchair is taken inside the bus and secured to a securement location. Finally, the wheelchair ramp is retracted. The time taken is measured using a stopwatch. The time required for the various actions in the process is summarized in Table 8. The time required to load, secure, and remove a wheelchair from the ALFV is comparable to similar buses.

Table 8. Time Data for Wheelchair Securement Process

Step	Actions Taken	Time Required
1.	Time taken from opening the door, deploying ramp, securing wheelchair, retracting ramp, to closing the door	3 min 25 secs
2.	Time taken from opening the door to deploying ramp	15 secs
3.	Time taken for converting seats to wheelchair position and back	31 secs
4.	Time taken for positioning wheelchair at a securement location and securing it	2 min 24 secs
5.	Time taken for retracting ramp to closing the door	15 secs

To find the wheelchair ramp angle, the ramp is deployed with the bus in kneeling position. The height of the top position of the ramp from the ground is measured and the length of the ramp is measured. Wheelchair ramp angle is calculated using basic trigonometric relation. All measurements are taken at curb weight.

For the ALFV, the height of the top position of the ramp from the ground is 10.5 inches (0.27 meter). The length of the ramp is 48 inches (1.22 meters). With this information, the ramp angle is:

$$\sin^{-1}\frac{10.5}{48} = 12.63°$$

V. COMPARISON OF VEHICLES SIMILAR TO THE ALFV

The ALFV was assigned the identification of “Bus 1301” by the Altoona Bus Research and Testing Center and was used as the base vehicle for the comparison. A review of the reports generated by the Center identified 30 mid-sized vehicles, in addition to the ALFV, between 20 and 35 feet long (6.1 and 10.67 meters) that were tested during the past five years. Twenty vehicles underwent the full test program, and 11 vehicles underwent a partial test program; both were included in the analysis. January 2009 through December 2013 was selected as the time period representative of vehicles that would be on the market during the 2014 federal fiscal year. Data from the reports on the buses identified above were analyzed and assembled into the tables. Detailed tables and related discussion are included in Appendix 2. The ALFV specifications that make it an attractive vehicle for rural and urban flex route operation are discussed below.

LOW FLOOR

The low-floor transit bus increases productivity, along with ambulatory and wheelchair passenger safety, as it does not require a subfloor baggage area. From Ride Solution’s perspective, flex-route service, being a blend of demand response/subscription door-to-door service interspersed with fixed-route stops, is sensitive to passenger load times due to the time constraints of the route deviations. Reduced ambulatory passenger load times, reduced wheelchair passenger load times, and reduced chances for tripping and falling are key advantages of a low-floor bus. As seen from Table 9, only 7 out of 30 vehicles in the study had a low floor. In this table, B denotes a conventional bus, while C denotes a cutaway.

VEHICLE LENGTH

Flex routing requires a nimble vehicle due to the door-to-door demand-response component of the service. Ride Solution’s perspective is that 25-foot (7.62-meter) cutaways lacked capacity and longevity, and the 35-foot (10.67-meter) buses were too long to easily navigate the route deviations. Ride Solution projects that a 25- to 27-foot (7.62–8.23-meter) bus can strike the necessary balance between length and capacity. From Table 8, it is seen that only 10 buses other than the ALFV had more than 20 seats, and all but one of them were 30 feet or more in length.

SEATING CAPACITY

Table 9 shows the seating capacities of the buses in this study. The range of seating capacities for the buses in this study is large, but the ALFV has a seating capacity that is close to the average. The ALFV also has the highest ambulatory passenger seats per vehicle length and the highest number of wheelchair positions per vehicle length among similar buses. It is Ride Solution’s recommendation that a minimum seating capacity of 20 ambulatory passengers is required, and that standee passengers are a hazard in rural service.

Table 9. Low-Floor Buses

Bus No.	Partial Test?	Type	Low Floor?	Bus Length, ft	# of Seats	# of Wheel-chairs	# of Seats with Wheel-chairs	# of Stow-away Seats
1301		B	Y	27	24	5	8	17
1304	Y	C	N	26	9	2	7	2
1214		C	N	25	16	2	16	0
1212		C	N	24	12	2	12	0
1207	Y	C	Y	25	14	0	X	X
1204		C	N	25	18	2	16	2
1203		C	Y	28	14	2	14	0
1201		C	N	27	8	4	4	4
1120		C	Y	28	10	0	X	X
1116	Y	C	N	30	22	2	20	2
1114		C	N	33	28	2	26	4
1113		C	N	33	28	1	26	2
1112		C	N	33	24	2	24	0
1111		C	N	26	16	2	16	0
1109		B	Y	31	25	2	18	7
1106	Y	C	N	23	12	2	14	0
1012	Y	C	N	33	33	0	X	X
1009	Y	C	Y	24	11	2	9	2
1008		C	N	26	16	2	16	0
1005		C	N	23	14	2	12	2
1004		C	N	34	18	2	18	0
1002		C	Y	27	19	3	10	9
1001		C	N	27	16	2	16	2
0920		C	N	24	8	1	8	0
0916	Y	C	Y	23	14	0	X	X
0912		C	N	29	21	1	21	0
0910	Y	C	N	26	25	0	X	X
0909	Y	C	N	26	20	2	18	4
0908	Y	C	N	26	16	1	14	2
0907		B	N	34	26	2	26	0
0903	Y	C	N	24	9	1	7	2

FRONT APPROACH ANGLE, REAR APPROACH ANGLE, RAMP CLEARANCE ANGLE

Rural roads require appropriate vehicle approach, break-over, and departure angles. While the approach and break-over angles of one of the buses (Bus 1002) are appropriate for rural roads, the departure angle (rear approach angle) is not (Appendix 2, Table 14) and will result in repeated damage to the rear of the bus, as well as increased incidents of the vehicle getting stuck on dirt roads. Therefore, Ride Solution's experience suggests that Bus 1002, a low-floor cutaway, has close to the semi-low-floor capacity necessary for flex routing, but it will be restricted in its rural flex-route applications as a 35-foot (10.67-meter) standard floor bus. It should also be noted that the interior entrance ramp typical of the low-floor cutaway increases both load time and chances of passenger tripping and falling.

DURABILITY AND OPERATING COST

Durability issues with van cutaways prompted the start of Ride Solution's "Dirt Bus Project" in 1990, four years after the purchase of Ride Solution's 1986 van cutaways. The 1986 cutaways, fully occupied, were over their Gross Vehicle Weight Rating (GVWR). Examples of more recent buses are shown in Appendix A, Table 13. The ALFV is designed with a 20-year life for the bus body in rural environments. It has an operating cost of $2.386 per 100 passenger miles, close to the group average (Appendix A, Table 30).

SUMMARY

Specific vehicle requirements of individual transit agencies vary greatly according to the population, nature of the routes they serve, and socio-economic factors. No single set of specifications can address the requirements of all agencies. However, the requirements of items 1 through 5 above are not fulfilled by any one vehicle available on the market today, and this prompted the development of the ALFV. Ride Solution's intent in addressing this niche was to position the rural operator to move into the flex-route format, thereby supporting the growth of regional public transportation. The results from prototype testing indicate that improvements are needed in workmanship, quality control (welding quality in particular), reliability, time required to replace "additional replacement components," wet friction stopping distance, conformance to all ADA requirements, interior and exterior noise, and particulate emissions. The ALFV performed "less than average" for these items. Details can be found in Appendix 2.

VI. FLEX ROUTE UTILIZATION PLAN

Ride Solution perceives that the coordination of human service transportation funding can result in a fully developed and integrated rural public transit system in rural counties utilizing the flex-route service format, and this strategy of regional transit development warrants full exploration. It is also Ride Solution's opinion that the recent NCTR "Flexible Public Transportation Services In Florida, 2013" misses the pivotal role of the flex-route format in establishing rural public transit via the coordination of human service funding because it focuses exclusively on FTA's Section 5307 grant recipients.[8]

Ride Solution's development of the ALFV was the result of vehicle requirements identified over many years of coordinated flex-route deployment in Putnam County, Florida. Putnam flex-route service began in 1988 with the Palatka City Route. By 1996, all Putnam County out-of-county routes were flex, and by 1997 all in-county human service transport had been converted to flex. Figure 10 shows one of the flex-route shelters in use in Putnam County. The feasibility of flex-route operation is illustrated below using the example of Putnam County's experience from data gathered by Ride Solution in Putnam County.

Figure 10. An Example of a Flex Route Bus Stop Shelter

Flex routing is a blend of demand response and fixed-route service formats created by inserting suffiient time in a fixed-route schedule to allow the bus to deviate from the route to pick up human service demand-response and subscription passengers at their door, thereby pulling the human service agency revenue into the publicly accessible route. While the route deviation reduces the productivity of the fixed-route section of the service, the human service transportation revenue that the deviation captures is what produces the publically accessible fixed route service. Putnam County would not have a routed, scheduled public transit system were it not for flex routing.

The coordination of the human service transportation funding within the flex-route format allows general public access to what has previously been agency-only transport. By pulling the human service transportation revenue into the route structure, which contains general public stops, flex routing establishes public transportation in rural counties at a level that is impossible to achieve utilizing the traditional demand-response and subscription formats. Ride Solution obtains a 50% boost in productivity, above the core agency trips, with the flex-route public walk-ons, while Putnam County benefits as a whole from a public transit service that would not exist otherwise. As can be seen in the “Trips” pie chart of Figure 11, the flex-route, walk-on passenger who boards at a general public bus stop (in blue) adds a 50% boost in productivity, against the core agency trips (in red), to what is essentially an agency-funded transit system. The blue “flex ride” trips are value-added trips that do not substaintially increase the overall cost of the service. As the scheduled service also does a good job of coordinating the agency trips (two-thirds of the Medicaid trips are shared rides), the system saves the agencies money as well. For the agencies and the public, flex routing is a win-win.

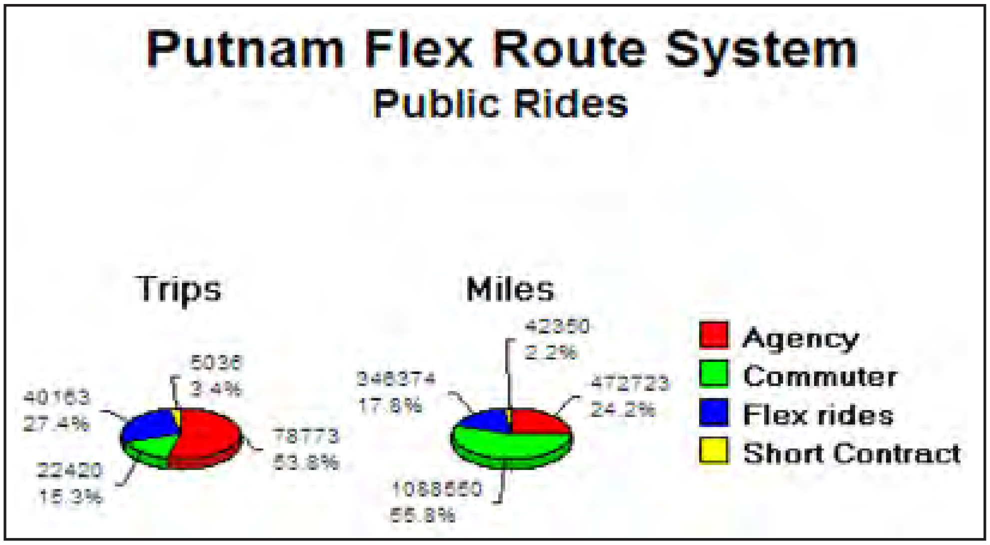


Figure 11. Productivity Increase for Flex Route Systems

A flex-route bus, therefore, requires more capacity than a demand-response vehicle and more agility than a fixed-route vehicle. Coordinating human service transportation funding within the flex-route format offers rural counties the potential of a general public, fixed-route transportation system where there would not otherwise be sufficient funding to create a public bus service. Given that over 50% of the road mileage in Putnam County is dirt, Ride Solution’s flex-route buses also had to be more rugged than the typical van cutaway. While the ALFV had an excessive number of durability issues during the Altoona test, those issues stemmed primarily from the fact that Ride Solution is not a professional bus manufacturer and the ALFV, as tested, was a first-generation prototype. Ride Solution, which operates both ALFV prototytpes in daily service, remains confident that the initial durability issues will be overcome by better weld quality control in the production process and a strengthening of certain suspension components.

The ALFV, therefore, evolved out of the specific needs of the rural flex-route format. Ride Solution believes that facilitation of this format, through vehicle and routing-scheduling software development, will provide a good return to both the taxpayer and the general public transit rider. Ride Solution’s projection of potential savings for its operation is shown in Table 10.

Table 10. Projection of Cost Allocation for Bus Roadeo Routes

Route	Mile /run	Hours/run	Days/year	miles/ year	% miles	Hours/ year	% hours	Mile Cost	Hour cost	Fixed cost	Total cost
B1	47	3.5	252	11,844	1.4	882	2.3	10,609.11	13,498.60	17,170.64	41,278.36
B1m	16	1	252	4,032	0.5	252	0.7	3,611.61	3,856.74	4,905.90	12,374.25
B1m	16	1	252	4,032	0.5	252	0.7	3,611.61	3,856.74	4,905.90	12,374.25
G-commu	184.8	7	251	46,384.80	5.6	1,757	4.6	41,548.60	26,890.07	34,205.01	102,643.68
JTA-PC50	180	7	251	45,180	5.5	1,757	4.6	40,469.42	26,890.07	34,205.01	101,564.50
C	209	5	252	52,668	6.4	1,260	3.3	47,176.70	19,283.71	24,529.49	90,989.91
C	209	2	252	52,668	6.4	504	1.3	47,176.70	7,713.49	9,811.90	64,701.98
T-feeder	150	6.5	311	46,650	5.6	2,022	5.3	41,786.15	30,939.12	29,354.26	112,078.53
E1	164	8	252	41,328	5	2,016	5.2	37,019.04	30,953.94	39,354.26	107,120.17
E2	93.3	5.75	252	23,512	2.8	1,449	3.8	21,060.22	22,176.27	28,208.91	71,445.41
E2m	46.6	2.75	252	11,743	1.4	693	1.8	10,518.92	10,606.04	13,491.22	34,616.09
G Grhnd	226.9	10.85	364	82,591.60	10	3,949	10.3	73,980.39	60,443.73	76,886.32	211,310.45
JaxGrhnd	214	8.5	364	77,896	9.4	3,094	8	69,774.37	47,352.32	60,233.52	177,360.12
D1	89	7.5	311	27,679	3.3	2,333	6.1	24,793.12	35,697.83	45,408.76	105,899.70
D3	63	7.5	311	19,593	2.4	2,333	6.1	17,550.18	35,697.83	45,408.76	98,656.77
RTE 10	19	2.75	246	4,674	0.6	677	1.8	4,186.68	10,353.52	13,170.00	27,710.20
RTE 12	56	3.75	246	13,776	1.7	923	2.4	12,339.68	14,118.43	17,959.09	44,417.20
RTE 14	37	2.5	246	9,102	1.1	615	1.6	8,153.00	9,412.29	11,972.73	29,538.02
RTE 16	32	3	246	7,872	1	738	1.9	7,051.25	11,294.75	14,367.27	32,713.27
RTE 18	21	3.5	246	5,166	0.6	861	2.2	4,627.38	13,177.21	16,761.82	34,566.40
RTE 20	25	2.75	246	6,150	0.7	677	1.8	5,508.79	10,353.52	13,170.00	29,032.30
RTE 22	129	4	246	31,734	3.8	984	2.6	28,425.33	15,059.66	19,156.36	62,641.36
Annual 17 route total				626,275		30,028					1,605,032.92
20 Year 17 route total				12,525,504		600,508					21,340,549
20 year Flex route value added with 50% walk-on				6,262,752		300,254					10,670,275
20 year flex route savings as a % of 17-AMPV purchase @ 5,950,000											179%

VII. SURVEY RESULTS FROM TRANSIT PROFESSIONALS

A survey was conducted through Survey Monkey to learn the relative interest in the features of an ALFV among transit operators. The survey is included in Appendix 3. The level of interest in certain design features of the ALFV, including the long-life concept, mechanic friendliness, rugged construction, ability to cater to flex routes, commuter services, and disaster relief operations, were surveyed. Results from the survey are shown in Figure 12.

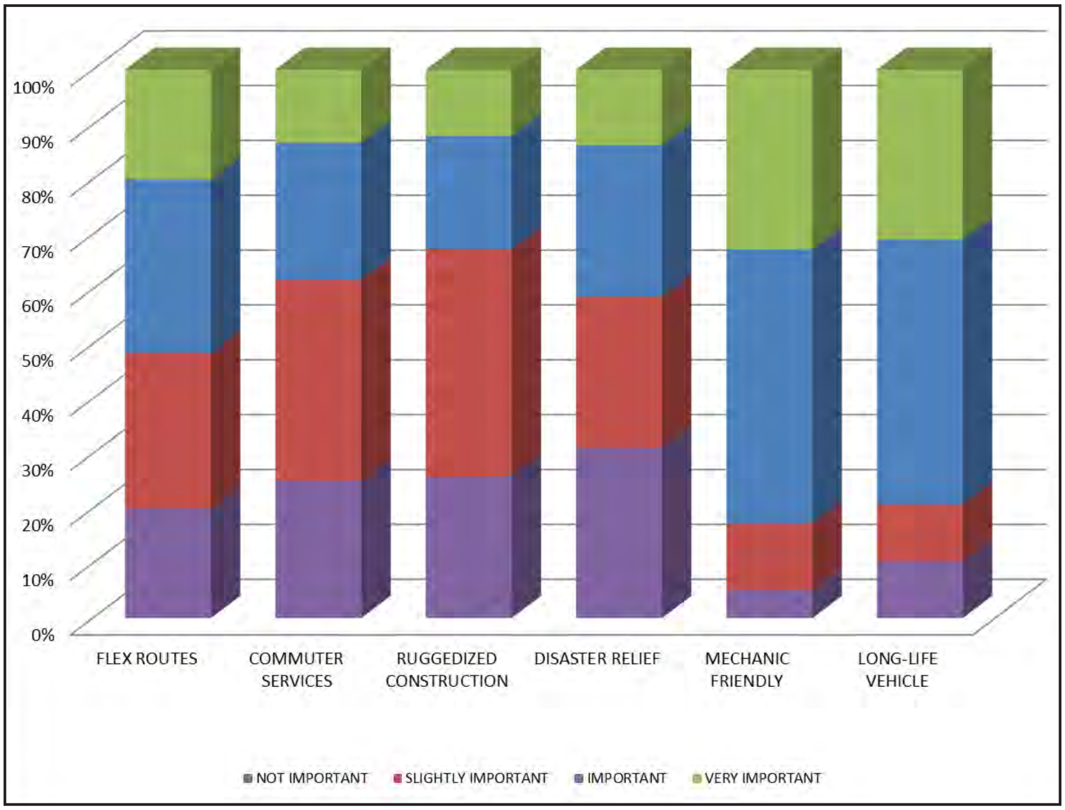


Figure 12. Survey Results for the Features of a Flex Route Vehicle (2013)

The ALFV attributes most valued by the predominantly urban respondents were the mechanic-friendly and long-life vehicle characteristics. Least valued were the more rural-focused commuter capability, dirt-road ruggedized construction, and disaster relief capabilities. The ALFV's ability to facilitate a flex-route was an intermediate value. It is interesting to note that the maintainability and life span of the vehicle ranked higher than any potential efficiency based on service format. This is a logical starting point in ranking a vehicle, as the mechanicals must be sound if the vehicle is to be viable, and is perhaps indicative of a good level of respondent expertise. As noted in "Flexible Public Transportation Services in Florida," 45% of Florida's urban systems are now operating some form of flexible service. Ride Solution's first flex route began in 1988.[9] Jacksonville Transit Authority (JTA) was the first Florida urban system to employ the flex format. JTA's flex service began in the mid 2000s. The emergence of the flex service format in urban systems and the ranking of flex route as the third most important ALFV characteristic indicate a trend in urban systems to extend services into low-density areas.

VIII. THE RIDE SOLUTION PERSPECTIVE

For most urban, fixed-route public transportation systems in the US, there are several peripheral rural counties that contribute daily to the urban commute. Integration of the transit needs of these peripheral rural counties into the urban transit perspective can help produce an encompassing regional transit alternative for the largely single-occupant vehicle (SOV) urban commute. Rural transit, however, is a relatively small market and, to date, neither economic nor environmental considerations have been sufficient to sell the need for regional transit at a level sufficient to produce purpose-built rural transit vehicles. Software development specific to the rural transit market has also lagged for much the same reasons.

These were the technical limitations faced by Ride Solution, operating in Putnam County, Florida, when it began operations in 1986 that compelled both an in-house vehicle and a software development effort. The in-house software product, created through the collaborative efforts of Dr. Carl Thornblad and Ms. Myra Strange, was a DOS-based, flex-route slot scheduler that allowed transfers between up to three routes. The ability to schedule trips across connecting routes allowed the management of trips, and human service revenues, within the route system. At the conclusion of this software effort in the late 1990s, the scheduler was integrated with Automatic Vehicle Locator/ Mobile Data Terminals (AVL/MDTs) that supported driver payroll, driver pre-checks, and on-vehicle trip billing, as well as the real-time position of the vehicle. It was the development of this software that allowed Ride Solution to begin its first flex route, the Palatka City Route, in 1988, and to complete the rollout of the county-wide flex-route system by 1995. The result was a highly productive rural transit system. The increased productivity is largely due to the walk-ons that board at the flex-route public stops.

The software effort, then, enabled the flex-route system, which in turn produced a need for vehicle seating capacity that exceeded that of a typical demand-response, raised-roof van. The rural dirt roads were devastating to the van cutaways that met the capacity requirement. The cutaways were also becoming stuck on a regular basis in the “sugar sand” of the rural dirt roads.

School buses were also tried, but their entry steps were difficult for elderly people and for people with disabilities and, at less than 30 feet long (9.14 meters), the school bus ride was too harsh for many human service agency passengers. Buses over 30 feet long had difficulty negotiating the “pig trails,” the long rural dirt tracks down which many of the human service passengers lived.

The types of vehicles that were available off-the-shelf ended up shaping the execution of the flex-route system. Cutaways, which handled the bulk of the route deviations, were stationed on the system’s feeder routes. The feeder routes were then connected to cross-county express routes, which were run with 35-foot (10.67-meter) school buses. While this vehicle arrangement worked well enough to produce a high level of productivity in the flex-route system overall, it was obvious that there was a lot of room for improvement.

The need for a maneuverable, high-capacity, durable vehicle resulted in Ride Solution's "Dirt Bus Project." A series of 30-foot, two-door, city transits were purchased, used, and adapted to life in the dirt. Transportation Manufacturing Corporation's, and General Motors' Rapid Transit Series buses (RTS), and Blue Bird City Birds were modified with platform wheelchair lifts, Recreational Vehicle's roof air conditioning (with limb guards), cyclone separator engine air pre-filters, and Mesabi radiators in an attempt to arrive at a heavy-duty vehicle that could exist in this rural environment. The final iteration of the two-door transit project resulted in a 25-foot GM RTS that was cut down in-house from its original 35-foot length. All of the two-door transits, however, had the same issues with approach and departure angles and were no better than the van cutaways when it came to towing fees. The Dirt Bus Project went on for 14 years, from 1990 until 2004.

In 2004, Ride Solution was awarded congressional earmarks sufficient to replace much of its aging fleet. Also in 2004, Ride Solution was introduced to a 22-foot-long (6.71-meter), 22-passenger, low-floor, proof-of-concept bus with short overhangs, short wheelbase, and transverse rear engine. Due to the experience gained in the Dirt Bus Project, Ride Solution grasped the advantages of the basic design within the rural flex-route environment and opted to commit its FTA 5309 Bus and Bus Facility Earmarks to the development of the vehicle. After passing the 5309 funds back through Congress for re-designation as 5312 research funding, a three-year process, the funding re-emerged as FTA Advanced Rural Low-Floor Vehicle Project. Construction of the two ALFV prototypes began in 2008.

The two prototypes were constructed over 2 ½ years, concluding in 2011. Many changes to the basic design were made, not the least of which was the use of stainless steel for the chassis, in order to improve the life expectancy of the vehicle. The project expended all funds before the third prototype, which was to have been the Altoona test bus, was completed. Prototype bus #1 was deployed in field tests and daily service, and bus #2 was held back for eventual Altoona tests, should funding for the tests be acquired. In 2012, with the assistance of the Florida Department of Transportation, the funds necessary to send bus #2 to Altoona for the 10-year test were available.

Bus #2 arrived at Altoona in December 2012 and was assigned test #1301. The results of this test, and a comparison with similar buses tested at Altoona are the subject of this report.

IX. CONCLUSIONS

This study is based on only 31 mid-sized vehicles, including the ALFV, 20 feet or longer but less than 35 feet long (6.10–10.67 meters), and tested at the Altoona Bus Testing Center between January 2009 and December 2013. These vehicle models will comprise the majority of the mid-sized transit and para-transit bus market available for public transit purchases during financial years 2014 and 2015.

The comparisons and conclusions presented in this study are for the purpose of reference and advancing knowledge for those involved in developing, manufacturing, purchasing, financing, or selling public transit vehicles. This includes local transit agency administrators, State Department of Transportation (DOT) administrators, federal regional transit administrators, university research groups, the Federal Transit Administration, the US Department of Transportation, the US House of Representatives Transportation Committee, the US Senate Transportation Committee, and the private sector of transit vehicle manufacturers and distributors.

It is observed that for many of the vehicles considered in this category, the gross vehicle weight exceeded the gross vehicle weight rating; this can lead to unsafe operating conditions for the bus. This was true for almost half of the vehicles in the study, with 20% of the buses exceeding the GVWR by more than 1,000 pounds. The ALFV, on the other hand, has a safety margin of more than 1,000 pounds (450 kilos) for the front axle, more than 4,000 pounds (1,814 kilos) for the rear axle, and more than 5,000 pounds (2,268 kilos) for the total vehicle weight when carrying a full passenger load.

Structural design of the ALFV was close to or above average in dimensions and clearances, with the minimum rear overhang of any of the study group vehicles. The wide front wheel track provides good stability. Passenger seating capacity of the ALFV was above average, and the ALFV had the greatest number of wheelchair positions. It was one of the few vehicles with no steps inside the vehicle. The size of the fuel tank was among the smallest, as were the heating and cooling Btu values.

Both scheduled and unscheduled maintenance work hours were high due to the nature of the ALFV bus as a “research” vehicle and having been built outside a commercial vehicle manufacturing facility. This was also true of the various subsystem failures. The ALFV bus was close to average for the braking tests except the Low Friction Test, in which it reported the longest stopping distance. On the Static Loading Tests, the measured deflection was better than average for eight of the twelve loading reference points, at average for three, and slightly above average for one. Total Deviation was only 0.001 inches above the minimum reported. The Jacking Test Frame Clearance data were less than the average for all items. The ALFV bus’ fuel economy was below average compared with all the gasoline, diesel, and propane-fueled vehicles. Noise levels for the Interior Noise tests were all below average for the non-moving test and were the maximum or near it for the acceleration (0 to 30 mph, or 48.28 kmh) tests. There were no abnormal vibrations or other abnormal noises reported for any of the vehicles in the study. The External Noise test results for this bus were at or near maximum for the group.

In the three cycles tested for the ALFV bus, emissions were above average for CO_2, low or near low for CO, low or near low for THC, below average for NMHC, below average in two of the tests for NOx, and high in all three test cycles for diesel particulates.

Vehicle weight has a direct relationship to the amount of fuel used. For this reason, this study has presented vehicle weight in terms of Seated Load Weight (SLW) per foot of length of the vehicle and SLW per passenger seat. The less weight for these items, the better the mileage data will be in most circumstances, regardless of the fuel used. The passenger seat vehicle weight data appear to have more of a direct relationship to true return on investment than per foot of vehicle weight. All Fuel Costs at SLW (for DGEs) are compared in terms of cost per diesel gallon equivalents (DGEs) as taken from the US Department of Energy, Clean Cities Alternative Fuel Price Report, October 2013, Table 2, page 3. These data convert all prices to the common DGE basis and are for the same October 4-18, 2013 dates.

Recommendations from prototype tests of the ALFV include: improve workmanship, improve quality control (welding quality in particular), improve reliability, reduce time to replace Additional Replacement Components, reduce wet friction stopping distance, conform to all ADA requirements, reduce interior and exterior noise, and reduce particulate emissions.

The range of per passenger seat mile (ppsm) costs on a DGE basis was from $1.224 to $7.421. A compressed natural gas (CNG) vehicle was lowest, and a propane vehicle was highest. Eight vehicles achieved cost (DGE) per 100 passenger seat miles between $1.00 and $1.99. Vehicle 1301's cost per 100 passenger seat miles was $2.386 in DGE terms, which is 5.5 cents above the average of $2.331 for all 31 vehicles in the study. Eleven vehicles were between $2.00 and $2.99, with five vehicles between $3.00 and $3.99. One vehicle was in the $4.00 range, one in the $6.00 range, and one in the $7.00 range. The three at the highest cost levels appear to be a result of fewer passenger seats relative to the size of the bus. It should be noted that both propane vehicles were at the highest cost per passenger seat level. The lowest costs per 100 passenger seat miles, $1.224 to $1.842, were for six CNG vehicles, including a CNG hybrid, which had the lowest cost of all 31 vehicles, and for one gasoline and one diesel vehicle.

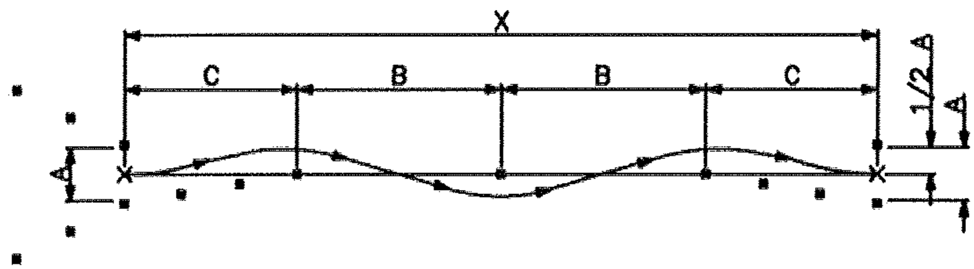
APPENDIX 1. BUS ROADEO COURSE DETAILS

International Bus Roadeo Handbook

APPENDIX 4: OPERATOR'S OBSTICAL DESCRIPTIONS

Serpentine

This obstacle tests a driver's ability to negotiate tight turns. The driver is required to enter a gate, steer in and out through three cones, and exit the obstacle through another gate. The bus is not permitted to touch any portion of any cone.



40' x 102" BUS:

A = 9'–6"
B = 36'–0"
C = 32'–0"
X = 136'–0"

35' x 96" BUS:

A = 9'–0"
B = 32'–0"
C = 25'–7"
X = 115'–0"

LEGEND

■ 28" CONE
—► PATH OF BUS
X—X SURVEY BASELINE

NOT TO SCALE

Figure 13. Diagram of the APTA Serpentine Course

International Bus Roadeo Handbook

Right Hand Turn

This obstacle tests a driver's ability to negotiate a right 90 degree turn. The corner is marked with cones and the rear tire of the bus is to pass within 6 inches of the corner pivot cone.

To measure this, a line should be marked out of 45 degrees from the corner and divided into six inch segments. The judge has only to see which segment the outside of the tire passes over in order to judge the driver.

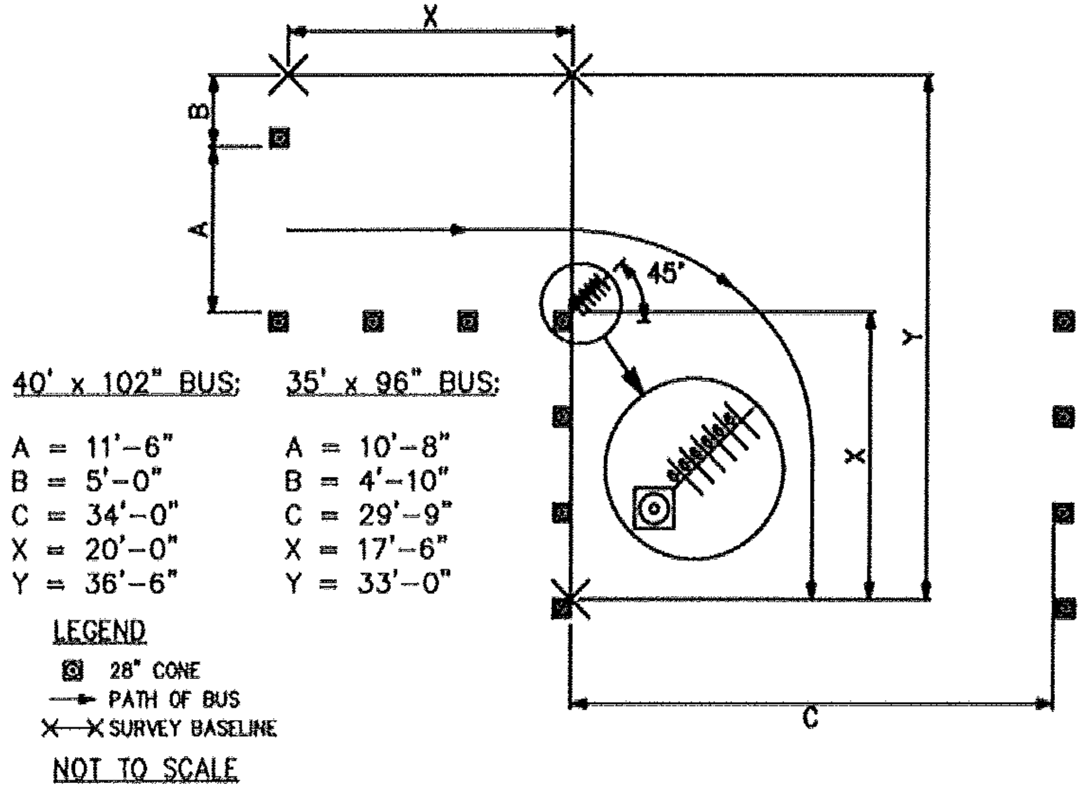


Figure 14. Diagram of the APTA Right-hand Turn

International Bus Roadeo Handbook

Left Hand Turn

This obstacle tests a driver's ability to make a tight left turn in a close situation. The driver is required to steer the bus into a 90 degree turn and not hit any of the cones outlining the obstacle.

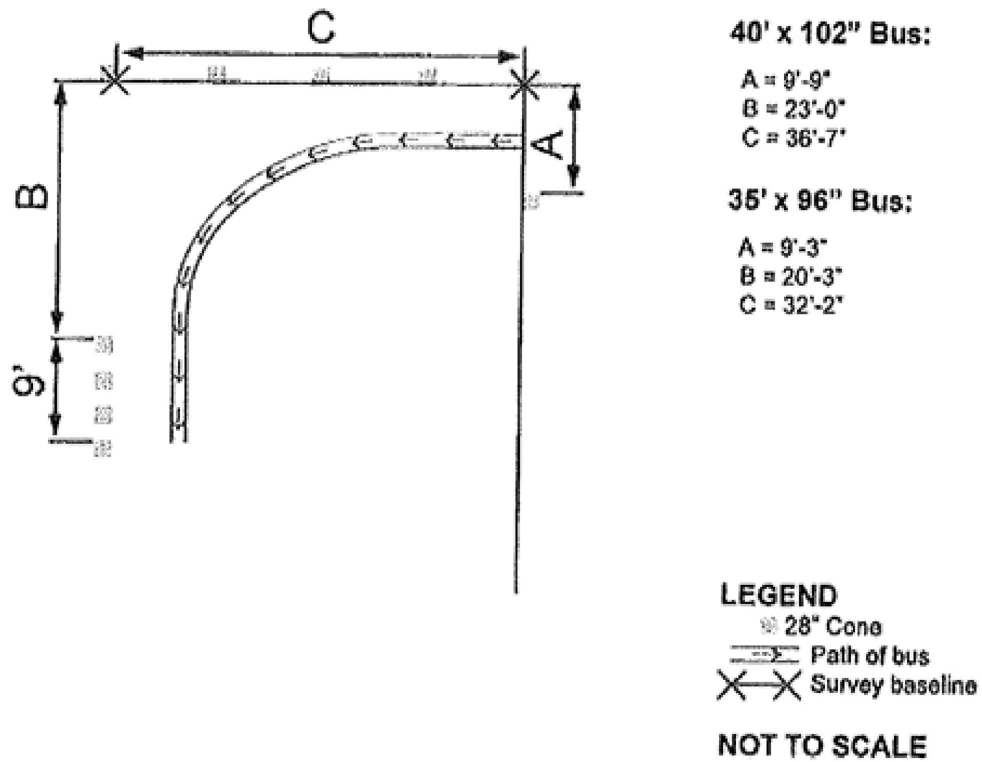
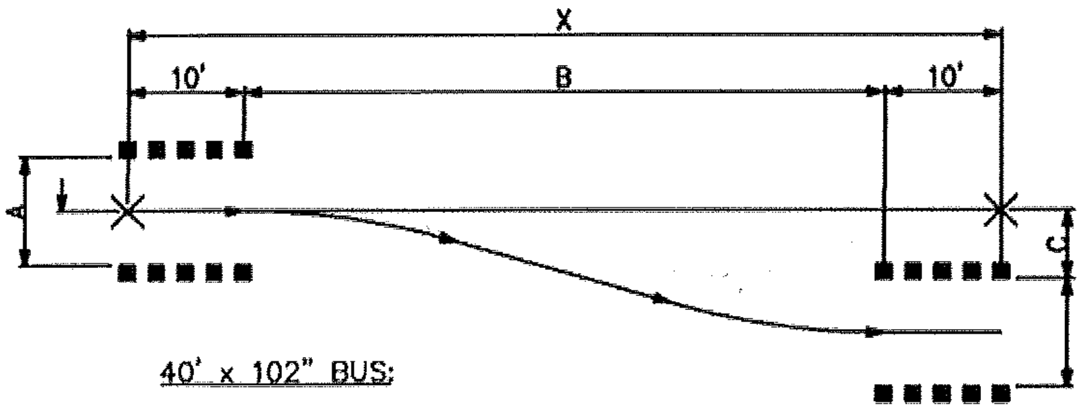


Figure 15. Diagram of the APTA Left-hand Turn

International Bus Roadeo Handbook

Offset Street

In this obstacle, the driver is required to drive through two separate narrow lanes that are offset one full lane's width from each other.



40' x 102" BUS:

A = 9'–6"
B = 55'–0"
C = 6'–0"
X = 75'–0"

35' x 96" BUS:

A = 9'–0"
B = 48'–0"
C = 4'–9"
X = 68'–0"

LEGEND
■ 28" CONE
→ PATH OF BUS
X—X SURVEY BASELINE
NOT TO SCALE

Figure 16. Diagram of the APTA Offset Street

International Bus Roadeo Handbook

First & Second Customer Stop

In this test the operator is required to stop the bus with the front wheels within 6 inches of the curb and the rear wheels within 15 inches of the curb.

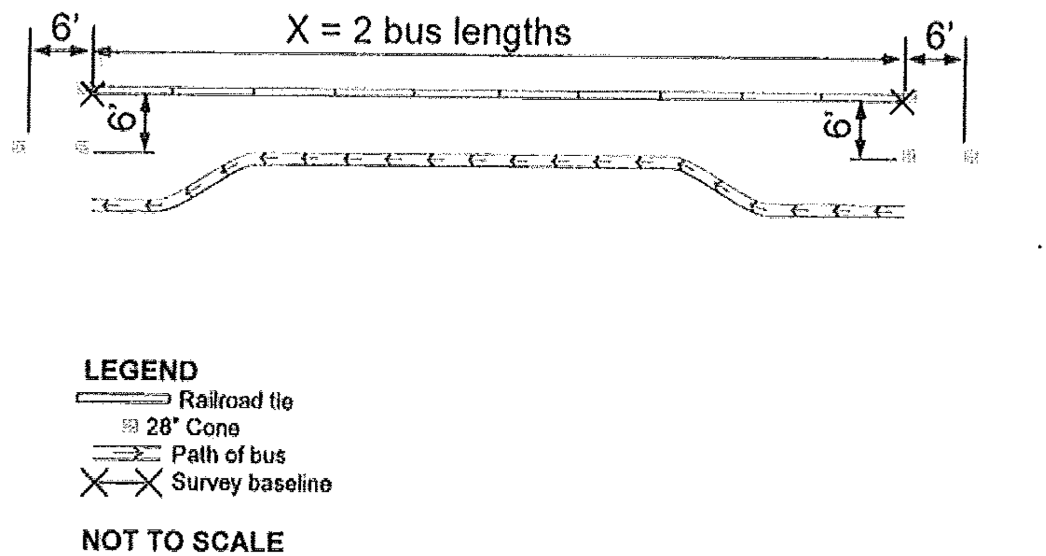
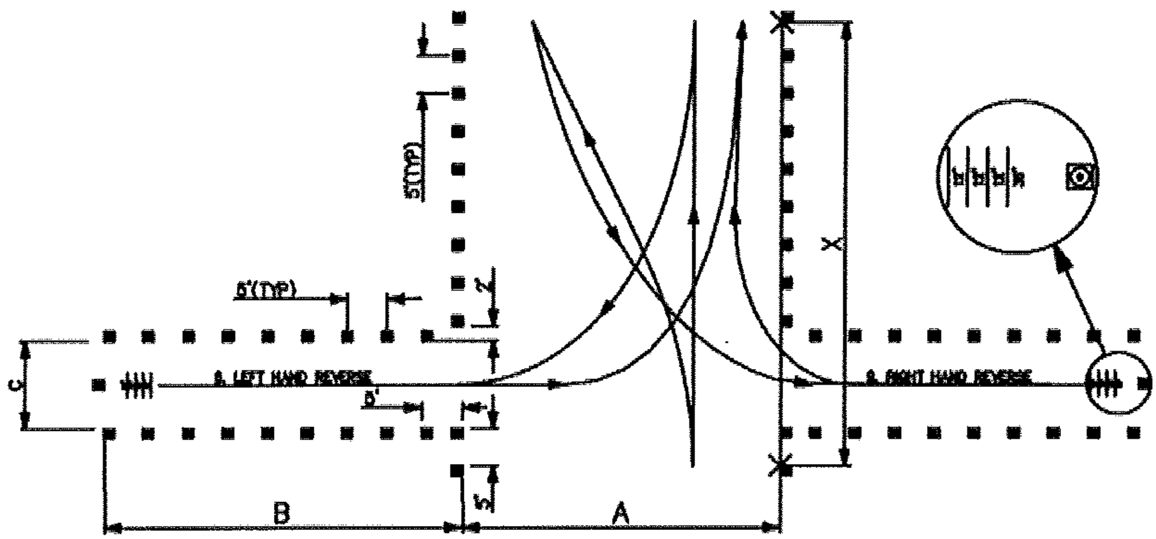


Figure 17. Diagram of the APTA First and Second Customer Stops

International Bus Roadeo Handbook

Left- and Right-Hand Reverse

This obstacle requires the operator to reverse the bus to the right or left between a set of cones stopping with the rear bumper within 36 inches of the cone in the rear without touching any of the cones.



40' x 102" BUS:	35' x 96" BUS:
A = 40'–0"	A = 35'–0"
B = 45'–0"	B = 40'–0"
C = 11'–5"	C = 10'–11"
X = 58'–5"	X = 57'–11"

LEGEND

- ■ 28" CONE
- ──► PATH OF BUS
- X──X SURVEY BASELINE

NOT TO SCALE

Figure 18. Diagram of the APTA Left- and Right-hand Reverse

APPENDIX 2. COMPARISON OF ALFV TO OTHER MID-SIZED BUSES

COMPARISON OF VEHICLE SPECIFICATIONS

This appendix contains tables and discussions that compare the specifications and results from Altoona tests of mid-size buses similar in length to the ALFV. It is noted that the sequence generally follows the order as found in Altoona bus test reports.

In each of the tables included herein, data from the bus test reports were summarized to provide:

- The number of vehicles having data reported for each item;
- The low number within the item;
- The high number within the item;
- Average of the reported data; and
- Data for the ALFV for easy comparison.

Vehicles having no data reported for a test (those under partial test) were indicated as not applicable (N/A) or by an X. Averages were calculated for the number of vehicles having data reported. The term “close to average” used in this study means that it is closer to the average figure than it is to either the high or low figure.

Table 11 shows the vehicle length, seated load weight, passenger seating capacities, and type and volume of fuel used for all 30 vehicles compared in this study. Twelve of the vehicles used diesel fuel, 10 vehicles used compressed natural gas (CNG), 7 vehicles used gasoline, and 2 vehicles used propane. The 6 gasoline-fueled vehicles were in the 7-year/200,000-mile category. Two of the 12 diesel-fueled vehicles were in the 10-year/350,000-mile category, with the remaining 10 in the 7-year category. All but one of the CNG-fueled vehicles were in the 7-year category. The one remaining CNG-fueled vehicle was in the 12-year/500,000-mile category. Both propane vehicles were in the 7-year category.

Table 11 also shows a comparison of some selected specifications and test data. It can be seen that Vehicle 1301 (the ALFV) is at the average length of all vehicles in the study. The seated load weight for the ALFV is above the average for the vehicles in the group. Although the ALFV has an above-average number of passenger seats and the highest number of wheelchair positions, it has no room for standing passengers. A review of the fuel data shows that the average miles-per-gallon rating for the 18 vehicles in the liquid fuel groups is higher than the miles-per-gallon of the ALFV.

Table 11. Comparison of Selected Specifications of the Vehicles

ATC Tested Mid-sized Vehicles: general data - FY 2014 market														
			Passenger Seating								Fuel Data		Frame	
Bus #	Years/ miles	Partial?	Seats	Stand	Pass. Capacy	W/Chair	Seat Loss	Length	SLW	Fuel	mpg	M/LB	Type	LF?
1301	10/350K		24	0	24	5	17	27	20,080	D	5.94		B	Y
1304	7/200K		9	0	9	2	2	26	12,380	P	5.94		C	N
1214	7/200K	P	16	0	18	2	0	25	12,500	G	10.81		C	N
1212	7/200K		12	8	23	2	0	24	12,360	G	10.18		C	N
1207	7/200K	P	14	7	21	0	X	25	13,260	P	4.47		C	Y
1204	7/200K		18	0	19	2	2	25	14,110	CNG		1.34	C	N
1203	7/200K		14	0	16	2	0	28	14,640	CNG		0.91	C	Y
1201	7/200K		8	2	10	4	4	27	13,980	CNG		1.06	C	N
1120	7/200K		10	0	10	0	X	28	12,720	CNG		2.4	C	Y
1116	7/200K	P	22	13	35	2	2	30	17,730	D			C	N
1114	7/200K		28	12	41	2	4	33	19,420	CNG		0.97	C	N
1113	7/200K		28	21	49	1	2	33	19,920	D	5.91		C	N
1112	7/200K		24	15	41	2	0	33	18,400	CNG		0.95	C	N
1111	7/200K		16	10	28	2	0	26	13,580	D	10.36		C	N
1109	12/500K		25	22	48	2	7	31	30,310	CNGH		1.17	B	Y
1106	7/200K	P	12	8	22	2	0	23	12,210	G	7.31		C	N
1012	7/200K	P	33	16	49	0	X	33	18,310	D	7.54		C	N
1009	7/200K	P	11	6	18	2	2	24	13,140	CNG		0.93	C	Y
1008	7/200K		16	9	27	2	0	26	13,670	CNG		1.08	C	N
1005	7/200K		14	6	20	2	2	23	12,530	G	7.86		C	N
1004	7/200K		18	18	38	2	0	34	17,360	D	6.43		C	N
1002	7/200K		19	14	34	3	9	27	14,350	D	7.19		C	Y
1001	7/200K		16	12	28	2	2	27	14,170	D	8.85		C	N
920	7/200K		8	7	16	1	0	24	10,730	D	11.34		C	N
916	7/200K	P	14	13	27	0	X	23	12,850	GH	7.87		C	Y
912	7/200K		21	0	22	1	0	29	14,180	G	7.19		C	N
910	7/200K	P	25	5	30	0	X	26	13,670	D			C	N
909	7/200K	P	20	7	27	2	4	26	13,960	CNG		1.23	C	N
908	7/200K	P	16	4	20	1	2	26	13,510	D	8.49		C	N
907	10/350K		26	18	46	2	0	34	23,250	D	5.9		B	N
903	7/200K	P	9	7	16	1	2	24	10,960	G			C	N

The range for seating capacity, excluding the driver, was from a low of 8 to a high of 33. The average number of passenger seats was 18. The 24 seats in the ALFV indicate an above-average seating capacity. The ALFV had the highest number of wheelchair positions (5) of any of the 31 vehicles compared. As can be expected, if all five wheelchair positions are occupied, the ALFV loses 17 passenger seats. Five vehicles had no wheelchair positions.

Due to the axle weight limits on some rural roads and bridges, one physical characteristic of importance for a flex-route vehicle is the axle weight. Three loading conditions—curb weight (CW), seated load weight (SLW), and gross vehicle weight (GVW)—are compared. The curb weight is the bus weight including the maximum fuel, oil, and coolant, without driver or passengers. The seated load weight is the curb weight plus 150 pounds (68 kilos) for each designated passenger seating position plus the driver. The gross vehicle weight is the seated load weight plus 150 pounds for each 1.5 square feet (0.14 square meters) of floor space available for standing passengers. It is noted that the FTA requires that the number of simulated passengers used for loading be based on the full complement of seats and free floor space available for standing passengers at 150 pounds per passenger, regardless of the vehicle's gross axle weight and gross vehicle weight ratings. As can be seen in Table 12, the axle weights of the ALFV were above the average weight, but within the minimum and maximum of all the buses compared.

Table 12. Axle Weights for Mid-Sized Vehicles Tested from 2009-2013

	Comparative Vehicles			Vehicle 1301
	Low/Min	**High/Max**	**Average**	
Vehicle Weight	pounds	pounds	pounds	pounds
Front Axle				
CW	3,140	7,860	4,242	4,990
SLW	3,080	8,900	4,634	6,940
GVW	3,610	10,220	4,905	6,940
GAWR (Gross Axle Weight Rating)	4,080	11,000	5,586	8,000
Rear Axle				
CW	4,740	18,450	7,473	10,960
SLW	7,130	21,410	10,664	13,140
GVW	7,180	23,220	11,600	13,140
GAWR (Gross Axle Weight Rating)	7,720	23,500	11,442	17,500
Total Weight Details				
CW	8,220	23,310	11,618	15,950
SLW	10,730	30,310	15,298	20,080
GVW	11,160	33,440	16,484	20,080
GVWR (Gross Vehicle Weight Rating)	11,030	34,500	16,645	25,500

The average curb weight of the vehicles compared was 11,618 pounds (5,270 kilos), the average seated load weight was 15,298 pounds (6,940 kilos), and the average gross vehicle weight was 16,484 pounds (7,477 kilos) (Table 12).

Table 13 shows that 22 of the 30 vehicles compared in this study had either one, or both axle weight and/or gross vehicle weight that that exceeded their ratings. Six of the vehicles were overloaded by more than 1,000 pounds (454 kilos).

Table 13. Axle and Vehicle Loads and Ratings

ID	Front Axle				Rear Axle				Total			
Test #	CW	SLW	GVW	GAWR	CW	SLW	GVW	GAWR	CW	SLW	GVW	GAWR
No.	31	31	31	31	31	31	31	31	31	31	31	31
Low	**3,140**	**3,080**	**3,610**	**4,080**	**4,740**	**7,130**	**7,180**	**7,720**	**8,220**	**10,730**	**11,160**	**11,030**
High	**7,860**	**8,900**	**10,220**	**11,000**	**18,450**	**21,410**	**23,220**	**23,500**	**23,310**	**30,310**	**33,440**	**34,500**
Avg.	**4,242**	**4,634**	**4,905**	**5,586**	**7,473**	**10,664**	**11,600**	**11,442**	**11,618**	**15,298**	**16,484**	**16,645**
1301	**4,990**	**6,940**	**6,940**	**8,000**	**10,960**	**13,140**	**13,140**	**17,500**	**15,950**	**20,080**	**20,080**	**25,000**
1304	3,490	3,850	3,850	4,600	6,530	8,530	8,530	9,600	10,020	12,380	12,380	14,200
1214	3,410	3,680	3,680	5,000	5,370	8,820	8,820	9,600	8,780	12,500	12,500	14,500
1212	3,140	3,080	3,370	5,000	6,110	9,280	10,170	9,600	9,250	12,360	13,540	14,500
1207	3,810	3,740	3,740	5,000	7,260	9,520	10,550	9,600	11,070	13,260	14,290	14,500
1204	3,720	4,040	4,040	5,000	6,690	10,070	10,070	9,600	10,410	14,110	14,110	14,500
1203	4,380	4,990	4,990	5,000	6,870	9,650	9,650	9,600	11,250	14,640	14,640	14,500
1201	3,530	4,060	4,200	5,000	7,350	9,920	10,080	9,600	10,880	13,980	14,280	14,500
1120	3,780	4,150	4,150	4,600	7,320	8,570	8,570	9,600	11,100	12,720	12,720	14,200
1116	4,570	4,610	4,840	7,000	8,780	13,120	14,830	14,706	13,350	17,730	19,670	19,500
1114	5,110	5,600	6,170	6,500	8,440	13,820	15,040	14,760	13,550	19,420	21,210	19,500
1113	5,970	6,750	7,220	7,000	9,090	13,170	14,580	13,500	15,060	19,920	21,800	19,500
1112	4,400	4,390	4,860	6,500	8,390	14,010	15,750	13,660	12,790	18,400	20,610	19,500
1111	4,100	4,380	4,820	4,600	5,940	9,200	10,180	9,600	10,040	13,580	15,000	14,200
1109	7,860	8,900	10,220	11,000	18,450	21,410	23,220	23,500	23,310	30,310	33,440	34,500
1106	3,140	3,240	3,610	5,000	6,040	8,970	9,810	9,500	9,180	12,210	13,420	14,050
1012	5,610	6,130	6,360	7,000	7,930	12,180	14,180	14,706	13,540	18,310	20,540	19,500
1009	3,490	3,810	3,960	4,600	7,050	9,330	10,070	9,600	10,540	13,140	14,030	14,200
1008	3,840	4,190	4,650	5,000	6,160	9,480	10,350	9,500	10,000	13,670	15,000	14,500
1005	3,250	3,470	3,760	5,000	6,190	9,060	9,650	9,500	9,440	12,530	13,410	14,500
1004	5,020	4,960	5,450	7,000	8,430	12,400	14,520	13,660	13,450	17,360	19,970	19,500
1002	4,120	4,720	4,970	5,000	6,450	9,630	11,480	9,500	10,570	14,350	16,450	14,500
1001	4,190	4,380	4,490	4,600	6,540	9,790	11,410	9,600	10,730	14,170	15,900	14,200
0920	3,480	3,600	3,980	4,080	4,740	7,130	7,180	7,720	8,220	10,730	11,160	11,030
0916	3,700	3,890	3,830	4,600	6,150	8,960	10,910	9,600	9,850	12,850	14,740	14,200
0912	3,860	4,470	4,470	5,000	6,410	9,710	9,710	9,500	10,270	14,180	14,180	14,500
0910	4,120	4,440	4,610	4,600	5,700	9,230	10,370	9,600	9,820	13,670	15,250	14,200
0909	3,730	4,100	4,770	5,000	6,560	9,860	10,840	9,500	10,290	13,960	14,670	14,500
0908	4,110	4,610	4,640	4,600	6,270	8,900	9,520	9,600	10,380	13,510	14,160	14,200
0907	6,370	7,020	7,730	8,000	11,810	16,230	18,170	21,000	18,180	23,250	25,900	29,000
0903	3,220	3,460	3,680	4,300	5,670	7,500	8,260	8,600	8,890	10,960	11,940	12,300

The dimensions of the ALFV indicate that it was very close to the average length of the 30 other vehicles compared for this specification (Table 14). The overall width of the ALFV was in the middle of all widths—6 inches less and 7.7 inches more than the extremes. It had the shortest rear overhang of any of the vehicles and one of the widest front wheel tracks. The 58-inch rear overhang of Vehicle 1301 was 19.75 inches less than the next shortest overhang. The longest rear overhang in this group of vehicles was 133.5 inches.

Table 14. Physical Measurements of the Mid-Sized Vehicles

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles Low/Min	High/Max	Average	Vehicle 1301
Dimensions		**31**				
Exterior Dimensions						
Length	**Feet**		23.17	34.29	27.45	**26.67**
Width	**Inches**		88.30	102.00	96.04	**96.00**
Height	**Inches**		106.50	133.50	117.24	**124.00**
Overhang						
Front	**Inches**		31.50	89.75	39.35	**56.00**
Rear	**Inches**		58.00	133.50	95.44	**58.00**
Wheelbase	**Inches**		158.50	262.50	194.79	**206.00**
Wheel Track						
Front	**Inches**		58.00	86.20	70.69	**84.00**
Rear	**Inches**		72.10	78.80	75.39	**72.10**
Clearances						
Lowest Point						
Outside - Front Axle	**Inches**	**31**	8.2	15.1	11.3	**9.8**
Outside - Rear Axle	**Inches**	**31**	8.0	20.2	12.2	**9.5**
Between Axles	**Inches**	31	6.4	13.9	9.0	**10.6**
Ground Clearance - Center	**Inches**	**31**	7.0	15.4	10.7	**10.6**
Approach Angle - Front	**Degrees**	**31**	8.7	22.2	18.2	**9.9**
Approach Angle - Rear	**Degrees**	**31**	4.1	13.4	9.5	**9.3**
Ramp Clearance Angle	**Degrees**	**31**	3.0	10.2	5.8	**5.8**
Inside Aisle						
W/C Aisle Width	**Inches**	**1**	6.5	6.5	6.5	**6.5**
Seat Aisle Width	**Inches**	**31**	9.8	26.1	17.4	**11.8**
Standing Height						
At Center Aisle	**Inches**	**31**	72.6	94.3	78.6	**84.2**
Rear - if different from Center	**Inches**	1	76.4	76.4	76.4	**X**

The ALFV was one of three vehicles in the study in the 80-inch (2.03-meter) range for front wheel track. The lowest point of clearance was very near the average for four of the seven locations measured and above the minimum for the other three locations. ALFV's combination of modest clearances and short rear overhang reduces chances of hang up, and it contributes to its off-road ability despite its low floor.

The seat aisle width in the ALFV bus was below average but was above the lowest value. Standing height room at the center aisle was above the average for all 31 mid-sized vehicles compared. These data can also be found in Table 14.

As seen in Table 15, free floor space was quite diverse among the 31 vehicles compared with the square footage ranging from 4.2 to 36.7 square feet (0.39 to 3.41 square meters). Twenty-four of the vehicles had accommodations for standing passengers, ranging from 2 to 22 standing positions. Due to the lack of any standing passengers, Vehicle 1301 was just below the average for maximum passengers aboard.

Table 15. Free Floor Space, Step Height, and Fuel Tank Capacities

			30 Comparative Vehicles			
Feature/Item	**Unit of Measure**	**No. Vehs**	**Low/Min**	**High/Max**	**Average**	**Vehicle 1301**
Height of Each Step at Normal Pos.	**Sq Ft/ Inch**					
Free Floor Space	**Sq Feet**	**31**	4.2	36.7	15.9	**4.8**
Front						
Step 1	**Inches**	**30**	9.1	16.1	12.2	**13.7**
Step 2	**Inches**	**23**	7.3	11.2	8.6	**X**
Step 3	**Inches**	**23**	7.3	12.0	8.7	**X**
Step 4	**Inches**	**11**	5.2	9.5	8.2	**X**
Middle		**0**	X	X	X	**X**
Rear						
Step 1	**Inches**	**1**	15.5	15.5	15.5	**X**
Step 2	**Inches**	**0**	X	X	X	**X**
Step 3	**Inches**	**0**	X	X	X	**X**
Step Elevation Change - Kneeling	**Inches**	**6**	1.6	4.7	3.8	**2.8**
Fuel Tank Capacity	**Gal/SCF**					
Gallons		**21**	25.0	68.0	49.4	**30.0**
SCF (Standard Cubic Feet)		**8**	3,452.0	21,636.0	8,128.0	**X**

Safety in stair design generally recognizes that all steps be the same height. This is especially important for elderly people and those with disabilities. A comparison is presented in Table 15 and Table 16. Of the 23 vehicles having two or more steps, none were found with all steps having the same height. When the first step is omitted from consideration, seven vehicles (two with three steps and five vehicles with two steps in addition to the first step) had all steps of an equal height. The height of the first step when the bus was in normal position for Vehicle 1301 was above average while its elevation change was below average when the bus was kneeling.

Table 16. Free Floor Space, Step and Kneeling Heights of Mid-Sized Vehicles

ID	Free Floor Space	Height of Each Step at Normal Position (in)								LF	Step Elevation Change - Kneeling (in)
		Front				Middle			Rear		
Test #	Sq Ft	1	2	3	4	1	2	3	1		
No.	31	30	23	23	11	X	X	X	1		6
Low	**4.2**	**9.1**	**7.3**	**7.3**	**5.1**	X	X	X	**15.5**		**1.3**
High	**36.7**	**16.1**	**11.2**	**12.0**	**9.5**	X	X	X	**15.5**		**4.7**
Avg.	**15.9**	**12.2**	**8.6**	**8.7**	**8.2**	X	X	X	**15.5**		**3.8**
1301	**4.8**	**13.7**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**Y**	**2.8**
1304	30.9	11.5	8.0	8.2	X	X	X	X	X	N	X
1214	17.1	12.7	8.1	8.1	X	X	X	X	X	N	X
1212	12.6	11.8	9.6	8.4	X	X	X	X	X	N	X
1207	11.2	12.5	8.1	8.5	5.1	X	X	X	X	Y	X
1204	11.8	12.4	8.2	8.5	X	X	X	X	X	N	X
1203	27.0	14.6	X	X	X	X	X	X	X	Y	3.8
1201	4.2	12.6	7.7	8.0	8.4	X	X	X	X	N	X
1120	14.3	X	X	X	X	X	X	X	X	Y	3.0
1116	20.0	10.9	8.2	8.4	8.0	X	X	X	X	N	X
1114	19.3	11.9	9.0	8.9	9.5	X	X	X	X	N	X
1113	32.3	9.5	8.2	8.2	8.2	X	X	X	X	N	X
1112	23.9	11.9	8.4	8.3	9.0	X	X	X	X	N	X
1111	16.3	10.6	9.1	9.1	X	X	X	X	X	N	X
1109	36.7	16.1	X	X	X	X	X	X	15.5	Y	F-3.9/R-1.3
1106	12.6	12.4	8.5	8.9	X	X	X	X	X	N	X
1012	24.9	10.6	9.4	9.3	9.5	X	X	X	X	N	X
1009	11.4	14.8	X	X	X	X	X	X	X	Y	3.5
1008	14.2	11.9	7.9	7.9	X	X	X	X	X	N	X
1005	10.4	12.3	7.3	7.3	6.8	X	X	X	X	N	X
1004	27.9	9.8	9.5	9.5	9.3	X	X	X	X	N	X
1002	22.6	15.4	X	X	X	X	X	X	X	Y	X
1001	20.0	9.1	7.5	7.4	7.5	X	X	X	X	N	X
0920	13.2	10.8	11.2	12.0	X	X	X	X	X	N	X
0916	20.5	16.0	X	X	X	X	X	X	X	Y	4.7
0912	20.5	11.6	9.0	9.7	X	X	X	X	X	N	X
0910	17.5	10.4	7.9	7.9	X	X	X	X	X	N	X
0909	16.2	12.5	X	X	X	X	X	X	X	N	X
0908	18.1	10.7	8.9	9.1	X	X	X	X	X	N	X
0907	27.1	12.7	9.1	9.1	9.1	X	X	X	X	N	X
0903	11.6	11.0	8.9	8.9	X	X	X	X	X	N	X

Table 16 shows the details of steps and step elevation change in kneeling buses. The average height of the first step for all buses was 9.1 inches (23.1 centimeters), while the ALFV's floor height (first step) was 13.5 inches (34.3 centimeters) before kneeling.

It is seen from Table 16 that only 8 of the 31 buses, including the ALFV, have low floors. They are highlighted in Table 16. It can also be seen that the other 23 step-up buses do not have kneeling capability, while all but one of low-floor buses have kneeling capability. The ALFV has a step elevation change after kneeling of 3.8 inches (9.65 centimeters), which is more than the average of the kneeling buses.

The fuel type of the vehicles compared included diesel (11 vehicles), CNG (10 vehicles), gasoline (8 vehicles), and propane (2 vehicles). The fuel tank capacity for those vehicles using liquid fuel ranged from 25 gallons to 68 gallons, with an average of 49 gallons. The CNG fuel tank capacities ranged from 3,452 to 21,636 scf at 3,600 psi. The average CNG tank size was 8,128 scf. The fuel tank capacity of the ALFV was below average and slightly above the low/min reported for the liquid fuel group (Table 15).

The HVAC capacity was reported for 24 of the 31 vehicles (Table 17). The lowest capacity was 13,000 btu/hr, the highest capacity was 94,000 btu/hr, and the average was 49,751 btu/hr (Table 17). Seven vehicles did not have a capacity rating reported. In some vehicles, two units were reported, one for the passenger cabin and one for the driver area. In these cases, the highest figure was used for this comparison. Air conditioning was installed in 30 vehicles. The ALFV's HVAC capacity for both heating and air conditioning is the lowest for all 24 vehicles in this group, as the ALFV was intended to be used in Florida.

Table 17. Suspension, HVAC, Emergency Exits

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Drive Axle Ratio		**29**	3.730	5.380	4.510	**4.560**
HVAC - Capacity	**Btu/hr**	**24**				
Heating System		**24**	13,000	94,000	49,751	**13,000**
Air Conditioning		**24**	13,000	105,000	62,008	13,000
Number of Compressors	**Count**	**4**	2	2	2	**2**
Other Items - Emergency Exits	**Count**	**30**				
Window - Exits			2	5	3	**2**
Door - Exits			1	6	2	**1**
Roof Hatch - Exits			0	2	1	**1**

Emergency exits listed bus 1301 as at the minimum for both window and door exits, but above average for roof hatch exits compared with the 30 vehicles. It was one of 16 vehicles that have all three types of exits. The comparison for these items is given in Table 17.

Emergency exits were reported on 30 vehicles (Table 17). There is one exit door on eleven vehicles, two exit doors on twelve vehicles, three exit doors on six vehicles, four exit doors on one vehicle, and six exit doors on one vehicle. Two exit windows were installed on nine vehicles, three exit windows were installed on six vehicles, four exit windows were installed on ten vehicles, and five exit windows on five vehicles. Roof hatch exits were installed on the vehicles as follows: two roof hatches on one vehicle, one roof hatch on 15 vehicles, and 14 vehicles with no roof hatch exit. Those with no roof hatch exit had both window and door emergency exits.

The 31 vehicles compared had doors located forward of the mid-section, in the mid-section, and/or to the rear of the mid-section, all on the curb-side of the vehicle. This study identified a front door as being forward of the midsection of the vehicle. Driver's doors (right or left side) were reported for 26 vehicles. The lowest number of front doors for the 31 vehicles was one, the highest number of front doors was three, with a group average of two doors per vehicle. Twenty-six vehicles had the average or above average number of front doors. The width of the driver's door ranged from 24.8 inches to 40.4 inches (0.63 to 1.03 meters). The average was not calculated because the majority of these doors come with the chassis on the cutaway vehicles.

For the passenger door size, only the width of the doors is considered in this comparison because this is the dimension that relates to accessibility. Passenger door size was reported for all 31 vehicles. A single manufacturer supplied front passenger doors for 22 of the 31 vehicles. Seven other firms supplied one door each. The smallest passenger door width was 26.1 inches (0.66 meters), the largest width was 45.3 inches (1.15 meters), and the group average passenger door width was 33.6 inches (0.85 meters). Eleven vehicles were above the average. Four vehicles had passenger doors with a width of 40.5 inches (1.03 meters) or wider. Rear passenger doors, other than wheelchair lift doors, had size measurements reported for 12 of the 31 vehicles in the study. The data for the 12 vehicles had a minimum width of 26.4 inches (0.67 meters), a maximum width of 45.1 inches (1.14 meters), and an average width of 33.9 inches (0.86 meters).

Wheelchair lift rear doors were identified on 21 vehicles. Nine different manufacturers were reported—one providing for four vehicles, one for two vehicles, and the rest had single vehicle customers. The lowest number of rear wheelchair lift doors on the group of 31 vehicles was zero, the highest number was three, and the group average was one door per vehicle.

Wheelchair lifts were on 22 of the 31 vehicles, 7 vehicles had wheelchair ramps, and 2 vehicles had neither ramp nor lift. Ramp types were either manual or electric fold-out. Twenty wheelchair lift locations were reported in the rear of the vehicle, while two were in the middle.

The width of the door for wheelchair lifts was compared by this study because it is an important factor for wheelchair access to the vehicle. The smallest width was 31.8 inches (0.81 meters), the largest width was 46.7 inches (1.19 meters), and the average width was 43.3 inches (1.1 meters). All but two vehicles had wheelchair lift doors in the 40-inch range. The two vehicles in the 30-inch range were 31.8 and 34.6 inches wide (0.81 to 0.88 meters). ADA specifies the wheel chair platform width: "...minimum clear width of 28 ½ inches at the platform, a minimum clear width of 30 inches measured from 2 inches above the platform surface to 30 inches above the platform," apparently presuming that the door will be wider than the lift. All 31 vehicles comply with that requirement.

Twenty-two vehicles had independent front suspension (Table 18). The remaining nine vehicles had front beam suspension. The front suspension was spring for 23 vehicles and air for the remaining 8 vehicles. The rear axle had beam suspension for all 31 vehicles. Twenty-four vehicles had spring suspension, and seven vehicles had air suspension on the rear axle.

Three of the 31 vehicles compared had bus body types that were semi-monocoque (i.e., partly single-shell) construction. The remaining 28 vehicles reported "integral" or a truck-type chassis with steel as the material because these vehicles were cutaways. The ALFV has a semi-monocoque stainless steel frame with aluminum skin. Both of these materials are expected to improve the service life of the bus, as they are more corrosion resistant compared to mild steel frames and skins.

Table 18. Suspension Data

	Front		Rear		
ID #	**Axle**	**Suspension**	**Axle**	**Suspension**	**Ratio**
1301	**Beam**	**Air**	**Beam**	**Air**	**4.560**
1304	Independent	Spring	Beam	Spring	4.100
1214	Independent	Spring	Beam	Spring	4.560
1212	Independent	Spring	Beam	Spring	4.560
1207	Independent	Spring	Beam	Spring	4.560
1204	Independent	Spring	Beam	Spring	4.560
1203	Independent	Air	Beam	Air	X
1201	Independent	Spring	Beam	Spring	4.560
1120	Independent	Air	Beam	Air	4.100
1116	Beam	Spring	Beam	Spring	4.880
1114	Beam	Spring	Beam	Spring	3.730
1113	Beam	Spring	Beam	Spring	4.880
1112	Beam	Spring	Beam	Spring	4.880
1111	Independent	Spring	Beam	Spring	4.100
1109	Beam	Air	Beam	Air	5.380
1106	Independent	Spring	Beam	Spring	4.560
1012	Beam	Spring	Beam	Spring	4.880
1009	Independent	Air	Beam	Air	4.100
1008	Independent	Spring	Beam	Spring	4.560
1005	Independent	Spring	Beam	Spring	4.560
1004	Beam	Spring	Beam	Spring	X
1002	Independent	Air	Beam	Air	4.560
1001	Independent	Spring	Beam	Spring	3.730
0920	Independent	Spring	Beam	Spring	3.923
0916	Independent	Air	Beam	Air	4.100
0912	Independent	Spring	Beam	Spring	4.560
0910	Independent	Spring	Beam	Spring	4.100
0909	Independent	Spring	Beam	Spring	4.560
0908	Independent	Spring	Beam	Spring	4.100
0907	Beam	Air	Beam	Spring	5.290
0903	Independent	Spring	Beam	Spring	4.100

COMPARISON OF SCHEDULED/UNSCHEDULED MAINTENANCE AND FAILURES ENCOUNTERED

Scheduled maintenance includes the manufacturer's specified periodic maintenance program. Their work hours are compared in Table 19. Scheduled maintenance inspections were at the average for the ALFV, and well below the high, both for the number of inspections and for work hours.

Replacement times for "Additional Replacement Components" (ARC), shown in Table 19, for 22 vehicles reported the ALFV as having the highest number of work hours for three of the five items and below average for the other two items. Other components, those that were replaced or repaired during the testing program, were reported as high for Vehicle 1301 among the 20 vehicles in this test program for both number of incidents and work hours required. The total additional replacement components include both the five selected subsystems as well as any other components requiring repair or replacement while the vehicle is undergoing testing. The lowest total work hours required for this work was 8.5, the highest required was 69.75 work hours, and the average required was 21.17 work hours. Fifteen vehicles of the 22 in this group required less than the average number of work hours for repair.

Table 19. Scheduled Maintenance

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles Low/Min	Comparative Vehicles High/Max	Comparative Vehicles Average	Vehicle 1301
Scheduled Maintenance and ARC						
Scheduled Maintenance-Inspections	**Count**	**26**	7.00	14.00	8.92	**10.00**
Scheduled Maintenance-Work Hrs required	**Man Hrs**	**25**	28.00	60.00	40.00	**40.00**
Additional Replacement Components						
Transmission	**Man Hrs**	**22**	4.00	11.00	7.15	**11.00**
Alternator	**Man Hrs**	**22**	0.50	5.00	1.86	**2.25**
Starter	**Man Hrs**	**22**	0.25	2.00	0.72	**2.00**
Batteries	**Man Hrs**	**22**	0.50	1.00	0.57	**0.50**
Windshield Wipers	**Man Hrs**	**22**	0.25	1.00	0.53	**0.50**
Other Components - Number of Items	**Count**	**20**	1.00	18.00	4.00	**18.00**
Other Components - Work Hours required	**Man Hrs**	**20**	0.50	53.50	12.85	**53.50**
Total ARC Work Hours (all above items)	**Man Hrs**	**22**	8.50	69.75	21.17	**69.75**

Figure 19 shows a comparison of unscheduled maintenance occurring on the vehicles. Unscheduled maintenance includes components that were unexpectedly replaced or repaired during the testing program, typically due to failure or premature wear. These data provide a closer connection to the cost of maintenance and repairs on the vehicle, as these are generally calculated by the cost of parts and labor. The total of these items often dictates the amount of the transit operator's budget for inventory (parts) and labor (mechanics' salaries). The lowest total number of unscheduled vehicle repairs of all vehicles was one repair. The highest number of unscheduled vehicle repairs was 43, and the average for the group was 9 repairs. Fifteen vehicles had less than the average number of repairs. The total unscheduled maintenance work hours required by all 25 vehicles tested for unscheduled maintenance averaged 35.24 hours. The lowest number of work hours was 2 and the highest required (by the ALFV) was 113 work hours. The ALFV had more than five times the work hours of unscheduled repairs than the vehicle with the least number of work hours.

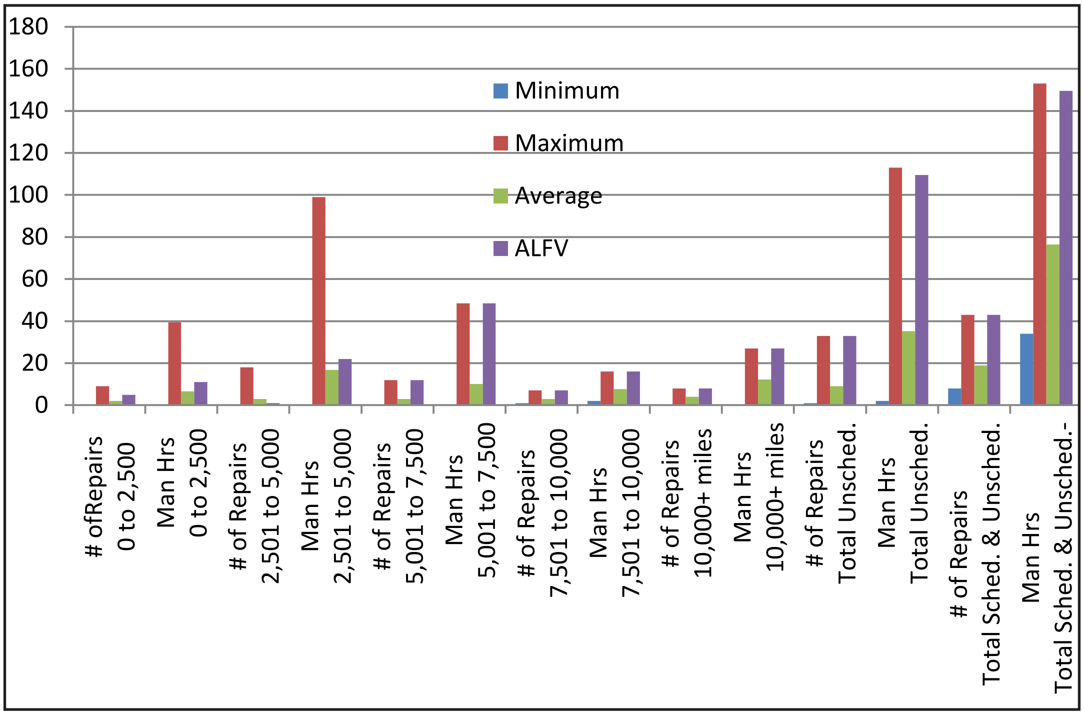


Figure 19. Comparison of Unscheduled Maintenance Minimum, Maximum, Average Repair Time and Hours

A review of these items by Ride Solution led to the conclusion that most of these items were attributable to workmanship, as this was a research vehicle built by local mechanics in a rural bus repair shop without adequate production training, supervision, or quality control that would be present in a commercial manufacturing facility. As an example, it was difficult to remove the alternator because one of the brackets was welded at the wrong location, which caused an obstruction to removing the alternator. Other components had to be removed before the alternator could be taken out, and that increased the time for removal and replacement. This will not happen in a production vehicle.

The high incidence of unscheduled maintenance for the ALFV is also attributed to the fact that the prototype ALFV bus was not built in a production shop. Ride Solution is confident that once the design is manufactured in a production facility, the number of failures and the time to repair will be close to the average. As an example, a cold weld failure is shown in Figure 20.

Figure 20. Cold Weld Failure on ALFV

COMPARISON OF RELIABILITY

There were 12 different subsystems identified in the reliability section for the 24 vehicles compared (Table 20). These subsystems included the suspension system, engine/drive system, door/window/wheelchair lift, body/frame system, brake system, steering/axles, exhaust, fuel, air system, electrical/accessory system, tires/wheels, and air conditioning system.

The subsystems with the lowest number of total failures were the steering/axles subsystem and the air subsystem, with 21 vehicles having no failures during the tests. The brake subsystem followed closely with 20 of 24 vehicles having no failures.

Table 20. Number of Failures Reported by Subsystem

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Suspension-Failures	**Count**	**24**	0.0	15.0	2.0	**15.0**
Suspension-Work Hours Required	**Man Hrs**	**24**	0.0	51.5	7.7	**49.5**
Engine/Drive System-Failures	**Count**	**24**	0.0	7.0	1.0	**7.0**
Engine/Drive System-Work Hrs Required	**Man Hrs**	**24**	0.0	21.0	3.2	**21.0**
Door/Window/W/C Lift-Failures	**Count**	**24**	0.0	5.0	1.0	**5.0**
Door/Window/W/C Lift-Work Hrs Required	**Man Hrs**	**24**	0.0	12.0	1.8	**12.0**
Body/Frame-Failures	**Count**	**24**	0.0	7.0	2.0	**3.0**
Body/Frame-Work Hours Required	**Man Hrs**	**24**	0.0	56.0	9.2	**33.5**
Brakes-Failures	**Count**	**24**	0.0	3.0	0.0	**2.0**

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Brakes-Work Hours Required	**Man Hrs**	**24**	0.0	14.5	1.0	**4.0**
Steering/Axles-Failures	**Count**	**24**	0.0	1.0	0.0	**1.0**
Steering/Axles-Work Hours Required	**Man Hrs**	**24**	0.0	6.0	0.5	**6.0**
Exhaust System-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Exhaust System-Work Hours Required	**Man Hrs**	**24**	0.0	2.0	0.4	**0.0**
Fuel System-Failures	**Count**	**24**	0.0	4.0	0.0	**0.0**
Fuel System-Work Hours Required	**Man Hrs**	**24**	0.0	37.0	3.1	**0.0**
Air System-Failures	**Count**	**24**	0.0	4.0	0.0	**0.0**
Air System-Work Hours Required	**Man Hrs**	**24**	0.0	11.0	1.1	**0.0**
Electric Sys. & Accessories-Failures	**Count**	**24**	0.0	8.0	1.0	**0.0**
Electric Sys & Accessories-Work Hrs Required	**Man Hrs**	**24**	0.0	63.0	5.2	**0.0**
Wheel/Tire-Failures	**Count**	**24**	0.0	4.0	1.0	**0.0**
Wheel/Tire-Work Hours Required	**Man Hrs**	**24**	0.0	13.0	1.7	**0.0**
A/C System-Failures	**Count**	**24**	0.0	2.0	0.0	**0.0**
A/C System-Work Hours Required	**Man Hrs**	**24**	0.0	14.0	1.4	**0.0**
Total-Failures	**Count**	**24**	1.0	33.0	9.0	**33.0**
Total-Work Hours Required	**Man Hrs**	**24**	2.0	126.0	35.4	**126.0**

The lowest number of work hours required to perform repairs on a single vehicle was two, which was for the vehicle with only one failure (Table 20). The highest number of work hours spent repairing a single vehicle (the ALFV) was 126. The average number of work hours for repairs was 35.4. Seventeen vehicles were below the average work hours of repair time. Seven vehicles had higher than average repair hours. The subsystems requiring the lowest number of work hours for repairs were the steering/axles subsystem, requiring 12 total work hours of repairs, and the exhaust subsystem, with a total of 13 work hours of repair time.

The ALFV had zero failures in 6 of the 12 categories tracked, resulting in zero work hours of repair time for those categories (Table 20). For both the brakes and body/frame categories, the ALFV had an above-average number of failures. The ALFV had the highest number of failures in the suspension, engine/drive system, door/window/-wheelchair lift, and steering/axles categories. In terms of work hours required for the failures, the ALFV was above average for three categories (suspension, body/frame, and brake). In total, the ALFV had 33 failures and required 126.0 work hours of repair work, which was the highest value recorded among the surveyed buses. Comparisons of the number and types of failures encountered are also summarized in Table 20.

Referring to Table 20, “body/frame work hours required” totaled 33.5, or 27% of the total repair work hours. Weld failures and lack of adherence to the weld schedule caused the failure of the rear bulkhead/suspension structure, as well as a steering failure (Table 20), both occurring after the midpoint in testing. Table 20 also indicates 33.5 “Body/Frame Work Hours Required” in repairing Class 3 failures, or 51% of the Class 3 failure work hours.

Failure of the rear bulkhead may have resulted in misalignments or excessive stresses that affected the suspension and drive train. Though the transmission was replaced under warranty and accounted for 21 work hours, or 16% of the ALFV work hours in Table 20, possible damage to the transmission due to rear bulkhead failure cannot be ruled out.

Suspension failures accounted for 39% of the ALFV work hours in Table 20 and were largely confined to premature bushing wear. Replacement of suspension components also accounted for 64% of the “Other Components--Work Hours” reported as scheduled maintenance in Table A9. Redesign of the suspension components is being undertaken, as a result.

The ALFV body/frame, suspension, and engine/drive (transmission) failures in Table 20 total 83%, or 104 of the 126 work hours required to repair failures. Better workmanship and further development of the suspension will address the shortfalls in reliability of the ALFV prototype experienced at Altoona.

There are four classes of failures reported in the bus test reports from which the data were obtained to perform these analyses. The hierarchy of the failure classification is:

- Class 1 is most serious and relates to personal, physical safety;
- Class 2 requires a road call;
- Class 3 calls for a bus change; and
- Class 4 is minor and relates to a bad order.

A Class 1 failure is one that could lead directly to passenger or driver injury and represents a potential for a severe accident. There was only one Class 1 failure in the test group of 24 vehicles (Table 21). The failure was in the steering/axle subsystem of the ALFV that involved a steering problem due to an improper weld of the mounting bracket for the steering miter box. This occurred at the 10,821st mile of the 11,250-mile durability test and required 6 work hours to repair. Table 21 shows a summary of the Class 1 and Class 2 failures that occurred on the 31 vehicles in the study.

Table 21. Class 1 and Class 2 Failures Reported by Subsystem

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Class 1 Failures by Subsystem	**No./M Hrs**	**24**				
Steering/Axles-Failures	**Count**	**24**	0.0	1.0	0.0	**1.0**
Steering/Axles-Work Hours Required	**Man Hrs**	**24**	0.0	6.0	0.5	**6.0**
Class 2 Failures by Subsystem	**No./M Hrs**	**24**				
Engine/Drive System-Failures	**Count**	**24**	0.0	1.0	-	**0.0**
Engine/Drive System-Work Hours Required	**Man Hrs**	**24**	0.0	16.0	-	**0.0**
Door/Window/W/C Lift-Failures	**Count**	**24**	0.0	1.0	-	**0.0**
Door/Window/W/C Lift-Work Hrs Required	**Man Hrs**	**24**	0.0	2.0	-	**0.0**

A Class 2 failure is one resulting in an en-route interruption of revenue service that would be discontinued until the bus is replaced or repaired at the point of failure. There were two Class 2 failures in the test group. One was in the engine/drive subsystem, which required 16 work hours of repairs. The second was in the door/window and wheelchair lift subsystem, taking two work hours to repair. There were no Class 2 failures for the ALFV.

A Class 3 failure requires removal of the vehicle from its normal services; however, it is operable to a rendezvous point with a replacement bus. All categories of subsystems experienced Class 3 failures, as can be found in Table 22. The lowest number of Class 3 failures in all subsystems was zero, as was the low number of work hours for repairs. The average total number of failures for the group of vehicles was six. The highest total number of repair work hours for all subsystems for a single vehicle was 101.5. The highest number of failures and the highest number of work hours were not for the same vehicle. There were two vehicles out of 24 with no failures in the Class 3 rating.

Table 22. Class 3 Failures Reported by Subsystem

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Suspension-Failures	**Count**	**24**	0.0	8.0	2.0	**8.0**
Suspension-Work Hours Required	**Man Hrs**	**24**	0.0	47.5	5.3	**12.5**
Engine/Drive System-Failures	**Count**	**24**	0.0	4.0	1.0	**4.0**
Engine/Drive System-Work Hrs Required	**Man Hrs**	**24**	0.0	20.0	2.1	**12.0**
Door/Window/W/C Lift-Failures	**Count**	**24**	0.0	3.0	1.0	**3.0**
Door/Window/W/C Lift-Work Hrs Required	**Man Hrs**	**24**	0.0	4.0	1.0	**4.0**
Body/Frame-Failures	**Count**	**24**	0.0	3.0	1.0	**3.0**
Body/Frame-Work Hours Required	**Man Hrs**	**24**	0.0	52.0	7.7	**33.5**
Brakes-Failures	**Count**	**24**	0.0	3.0	0.0	**2.0**
Brakes-Work Hours Required	**Man Hrs**	**24**	0.0	14.5	1.0	**4.0**
Steering/Axles-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Steering/Axles-Work Hours Required	**Man Hrs**	**24**	0.0	4.0	0.2	**0.0**
Exhaust System-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Exhaust System-Work Hours Required	**Man Hrs**	**24**	0.0	2.0	0.3	**0.0**
Fuel System-Failures	**Count**	**24**	0.0	3.0	0.0	**0.0**
Fuel System-Work Hours Required	**Man Hrs**	**24**	0.0	35.0	2.9	**0.0**
Air System-Failures	**Count**	**24**	0.0	4.0	0.0	**0.0**
Air System-Work Hours Required	**Man Hrs**	**24**	0.0	11.0	0.9	**0.0**
Electric Sys. & Accessories-Failures	**Count**	**24**	0.0	8.0	1.0	**0.0**
Electric Sys & Accessories-Work Hrs Required	**Man Hrs**	**24**	0.0	63.0	4.9	**0.0**
Wheel/Tire-Failures	**Count**	**24**	0.0	4.0	0.0	**0.0**
Wheel/Tire-Work Hours Required	**Man Hrs**	**24**	0.0	13.0	0.9	**0.0**
A/C System-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
A/C System-Work Hours Required	**Man Hrs**	**24**	0.0	14.0	1.3	**0.0**
Total-Failures	**Count**	**24**	0.0	18.0	6.0	**18.0**
Total-Work Hours Required	**Man Hrs**	**24**	0.0	101.5	28.2	**66.0**

A total of 677.5 work hours for repairs were performed on 139 Class 3-rated failures during the test program for the 24 vehicles being compared. This is an average of 4.8 hours per failure.

The ALFV encountered 18 Class 3 failures (Table 22) that required 66 work hours to repair. This is the equivalent of 3 hours and 40 minutes per incident. Vehicle 1301 had zero Class 3 failures on seven of the 12 categories tracked—also having no associated work hours of repair. Vehicle 1301 experienced two failures in the brake category, which was above the average. The ALFV had the highest number of failures for the suspension, engine/drive system, door/window/wheelchair lift, and body/frame categories. The work hours required to repair the Class 3 failures was above average for four categories (suspension, engine/drive train, body/frame, and brakes).

The ALFV had the highest number of work hours to repair failures in the door/window/wheelchair lift category (Table 23). Analysis of these 18 failures indicated that 14 might be attributed to workmanship, one is covered by the transmission warranty, two appear to be due to normal wear, and the cause of one failure is uncertain.

Table 23. Class 4 Failures Reported by Subsystem

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Suspension-Failures	**Count**	**24**	0.0	7.0	1.0	**7.0**
Suspension-Work Hours Required	**Man Hrs**	**24**	0.0	37.0	2.5	**37.0**
Engine/Drive System-Failures	**Count**	**24**	0.0	3.0	0.0	**3.0**
Engine/Drive System-Work Hrs Required	**Man Hrs**	**24**	0.0	9.0	0.5	**9.0**
Door/Window/W/C Lift-Failures	**Count**	**24**	0.0	4.0	0.0	**4.0**
Door/Window/W/C Lift-Work Hrs Required	**Man Hrs**	**24**	0.0	8.0	0.8	**8.0**
Body/Frame-Failures	**Count**	**24**	0.0	4.0	1.0	**0.0**
Body/Frame-Work Hours Required	**Man Hrs**	**24**	0.0	4.0	1.1	**0.0**
Brakes-Failures	**Count**	**24**	0.0	0.0	0.0	**0.0**
Brakes-Work Hours Required	**Man Hrs**	**24**	0.0	0.0	0.0	**0.0**
Steering/Axles-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Steering/Axles-Work Hours Required	**Man Hrs**	**24**	0.0	2.0	0.1	**0.0**
Exhaust System-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Exhaust System-Work Hours Required	**Man Hrs**	**24**	0.0	1.0	0.1	**0.0**
Fuel System-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Fuel System-Work Hours Required	**Man Hrs**	**24**	0.0	2.0	0.2	**0.0**
Air System-Failures	**Count**	**24**	0.0	0.0	0.0	**0.0**
Air System-Work Hours Required	**Man Hrs**	**24**	0.0	0.0	0.0	**0.0**
Electric Sys. & Accessories-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
Electric Sys & Accessories-Work Hrs Required	**Man Hrs**	**24**	0.0	4.0	0.3	**0.0**
Wheel/Tire-Failures	**Count**	**24**	0.0	3.0	0.0	**0.0**
Wheel/Tire-Work Hours Required	**Man Hrs**	**24**	0.0	6.0	0.8	**0.0**
A/C System-Failures	**Count**	**24**	0.0	1.0	0.0	**0.0**
A/C System-Work Hours Required	**Man Hrs**	**24**	0.0	4.0	0.3	**0.0**
Total-Failures	**Count**	**24**	0.0	14.0	3.0	**14.0**

Total-Work Hours Required	**Man Hrs**	**24**	0.0	54.0	6.1	**54.0**

A Class 4 failure does not require the removal of the vehicle from service immediately, but it does degrade its operation and would require repairs when it returns to the garage. With the exception of the brakes and the air subsystems, all other categories had Class 4 failures, which are listed in Table 23. The lowest number of Class 4 failures for all subsystems in a single vehicle was zero, as was the lowest number of work hours for repairs for five of the vehicles. The highest number of Class 4 failures in all subsystems for a single vehicle was 14. The highest repair time for all subsystems for a single vehicle was 54 work hours. The highest number of Class 4 failures and the highest number of repair hours occurred on the ALFV. The average number of total repairs was three, and the average total repair work required 6.1 work hours. There were 19 vehicles with failures in the Class 4 rating.

The ALFV had Class 4 failures (Table 23) in only three of the 12 categories tracked. It had the highest number of incidents in each of the three failure groups (suspension, engine/drive shaft, and door/window/wheelchair lift), as well as the highest work hours required in each of these groups for repairs. Total number of failures was 14 and required 54 work hours for repairs. This was an average of 3.9 work hours for each incident. Analysis of the 14 failures indicates that six failures might have been due to workmanship, five were due to normal wear, one occurred on a part of the chassis, and two were of undetermined origin.

SAFETY COMPARISON

The data for the vehicles that completed a double-lane change or obstacle avoidance test were used for this comparison. Handling and stability of the bus were determined by measuring speed through a double lane change maneuver performed in both right and left directions up to a maximum speed of 45 mph. Twenty-two vehicles were compared for the safety tests, and all 22, including the ALFV, achieved the maximum speed of 45 mph through the double lane change for both right and left directions. The position of the vehicle remained within the lane of operation, and tire-to-ground contact was maintained throughout the test for all vehicles.

PERFORMANCE COMPARISON

The objective of this test is to provide, for comparison purposes, (1) the acceleration, grade ability (a measure of the vehicle's ability to maintain speed on a steep grade, calculated from acceleration data), and top speed capabilities of the bus; and (2) braking performance data of different transit buses. The top-speed dynamometer test was recently added to the test program, and limited data on two buses were available from 2013. Data on braking were available for 19 buses, and acceleration data were available for 27 buses. The data for the performance tests on the vehicles being compared are provided in Table 24.

Table 24. Performance Test Results

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles Low/Min	Comparative Vehicles High/Max	Comparative Vehicles Average	Vehicle 1301
Performance Tests						
Acceleration, Gradeability, Top Speed						
Max Speed	**mph**	27	50	50	50	**50**
Time to Obtain Max Speed	**seconds**	27	29.47	13.60	18.17	**27.55**
Top Speed on Dynamometer	**mph**	2	63.0	82.1	72.6	**63.0**
Braking Tests						
High Friction Test						
20 mph	**Feet**	19	21.91	36.56	27.07	**25.90**
30 mph	**Feet**	19	44.32	82.39	55.29	**52.36**
40 mph	**Feet**	19	76.93	151.79	94.90	**90.04**
45 mph	**Feet**	19	93.83	188.94	118.97	**110.99**
Low Friction Test	**Feet**	19	21.68	41.58	27.62	**41.58**
Stability-Deviation from 12' Test Lane	**Feet**	19	0	0	0	**0**
Parking Brake Test						
Uphill Parking						
Slip	**Inches**	19	0	0	0	**0**
Roll	**Inches**	19	0	0	0	**0**
Hold	**minutes**	19	0	0	0	**0**
Downhill Parking						
Slip	**Inches**	19	0	0	0	**0**
Roll	**Inches**	19	0	0	0	**0**
Hold	**minutes**	19	5	5	5	**5**

All 27 vehicles compared were able to accelerate to a maximum speed of 50 mph. The ALFV had the second slowest time to obtain 50 mph. The slowest vehicle took 29.47 seconds, and the fastest vehicle took 13.60 seconds to obtain 50 mph. The average time to accelerate to 50 mph was 18.17 seconds. There were 18 vehicles with a time faster than the average. Only two vehicles were tested on the dynamometer for top speed. The lower speed was 63.0 mph, and the higher speed was 82.1 mph. Vehicle 1301 had the lower speed. It should be noted that the top speed limits on interstate highways in most states range from 65 to 75 mph, and many primarily urban transit operations do not routinely exceed 50 mph. However, primarily rural transit might operate at highway speeds some of the time, and the top speed of 63 mph is adequate.

The stopping distance test is composed of two parts: a high friction (dry) surface and a low friction (wet) surface. The high friction braking tests were conducted at four speeds—20 mph, 30 mph, 40 mph, and 45 mph. At 20 mph, the shortest distance to a full stop was 21.91 feet, the longest distance was 36.56 feet, and the average stopping distance was 27.07 feet (6.68, 11.14, and 8.25 meters). At 20 mph, 11 vehicles of the 19 tested were able to come to a complete stop in less than the average stopping distance, or 10 meters). At 45 mph, the shortest stopping distance was 93.83 feet, the longest stopping distance was 188.94 feet, and the average stopping distance was 118.97 feet (28.6, 57.6, and 36.26 meters). Eleven of the 19 vehicles being compared were able to stop in less than the average stopping distance. Of the vehicles that exceeded the average stopping distance, two vehicles required more than 10% (130.77 feet, or 40 meters) additional stopping distance. On the high-friction brake test, the stopping distance for Vehicle 1301 was better than the average for all four speeds of the test.

The shortest stopping distance for the low-friction braking test was 21.68 feet, the longest stopping distance was 41.58 feet, and the average stopping distance was 27.62 feet (6.6, 12.7, and 8.4 meters). Thirteen vehicles were able to stop in less than the average stopping distance on the low-friction test. Four of the vehicles exceeded the average stopping distance by more than 10% (30.38 feet, or 9.3 meters). The ALFV had the longest stopping distance of the vehicles compared on the low-friction braking test.

The stability and parking brake tests were completed by all 19 vehicles, with 100% success. No vehicles deviated from the 12-foot (3.7-meter) lane during the four straight-line brake applications at maximum deceleration with the wheels on a wet surface on one side and a dry surface on the other side. There was no slippage or roll for the 19 vehicles on the 20% grade during 5 minutes' stand time at GVW with the parking brake on, after the release of the service brake.

STRUCTURAL INTEGRITY COMPARISON

The structural integrity tests consist of seven parts: a static loading test, a longitudinal twist simulation, static towing, dynamic towing, jacking, hoisting, and structural durability. The comparison of the vehicles for each of these tests is described in more detail in the paragraphs below.

Static Loading

The objective of the static load test (Table 25) is to determine bus floor deflection and permanent structural deformation under a static, distributed load of 2.5 times gross load. This is the equivalent of 375 pounds (170 kilos) on each passenger seat, the driver's seat, and each 1.5 square feet (0.14 square meters) of free floor space. The loading sequence is performed three times. After each loading, the deflection is measured and reported for each of 12 reference points. After the third loading, the maximum permanent deflection from the original position is measured and reported. Deflection can be either positive or negative; the optimum is zero deflection.

Table 25. Static Loading Permanent Deformation

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles Low/Min	Comparative Vehicles High/Max	Comparative Vehicles Average	Vehicle 1301
Static Loading Test-Perm Deflection	**Inches**	**21**				
Loading Reference Point (LRP)						
Clockwise (Left to Right)						
LRP-01	**Inches**	**21**	0.000	0.006	0.003	**0.001**
LRP-02	**Inches**	**21**	0.000	0.035	0.003	**0.002**
LRP-03	**Inches**	**21**	0.000	0.052	0.004	**0.004**
LRP-04	**Inches**	**21**	0.000	0.069	0.006	**0.004**
LRP-05	**Inches**	**21**	0.000	0.082	0.006	**0.003**
LRP-06	**Inches**	**21**	0.000	0.020	0.003	**0.004**
LRP-07	**Inches**	**21**	0.000	0.028	0.004	**0.004**
LRP-08	**Inches**	**21**	0.000	0.083	0.006	**0.002**
LRP-09	**Inches**	**21**	0.000	0.069	0.006	**0.004**
LRP-10	**Inches**	**21**	0.000	0.035	0.004	**0.003**
LRP-11	**Inches**	**21**	0.000	0.029	0.003	**0.003**
LRP-12	**Inches**	**21**	0.000	0.010	0.003	**0.002**
Range per Bus	**Inches**	**21**				
Total Deflection	**Inches**	**21**	0.002	0.080	0.011	**0.003**
Test Load - for reference only	**lbs**	**21**	4,125	19,350	11,428	**9,375**

Data in Table 25 show the permanent deflection after the third and final test loading sequence. The actual range of deflection is the difference between the lowest and the highest of all deflections from all reference points on a single vehicle. The lowest range of deflection of the 21 vehicles compared was 0.002 inches. The highest range of deflection was 0.080 inches, with the average being 0.011 inches. There were 18 vehicles at or below the average difference and three vehicles above the average difference between deviations.

It should be noted that a single vehicle had deflections at all reference points, except Loading Reference Point (LRP) 1, that were substantially larger than the other 20 vehicles. This would cause the average to be much higher than might be expected. Therefore, the average was calculated by excluding the outlier. There were 18 vehicles at or below the 21-vehicle based average deflection, and when compared with the 20-vehicle based average, were found to be the same.

The comparison of the static loading test data showed that the ALFV had permanent deflection in 8 of the 12 measured points that was below average. Three of the measurement points returned average deflection, while one was slightly above average. The total deflection calculated by this analysis was 0.001 of an inch above the lowest reported for all 21 vehicles tested.

Jacking

The objective of the jacking test is to inspect for damage due to a deflated tire and to determine the feasibility of jacking the bus with a portable hydraulic jack to a height sufficient to replace the deflated tire. No difficulty was noted with any of the tested buses, including the ALFV. There was no deformation reported for any of the 19 vehicles compared (Table 26).

Table 26. Comparison of Vehicles for the Jacking Test Results

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Jacking Test	**Inches**	**19**				
Frame Point Clearance						
Front Axle-1 Flat Tire	**Inches**	**19**	7.8	18.6	13.2	**12.5**
Rear Axle-1 Flat Tire	**Inches**	**19**	7.1	20.0	14.4	**9.9**
Rear Axle-2 Flat Tires	**Inches**	**19**	4.6	17.2	12.5	**7.8**
Deformation or Difficulty Noted		**19**	None	None	None	**None**

Longitudinal Twist Simulation

The objective of the longitudinal twist simulation test is to observe the operation of the bus subsystems when the bus is loaded at GVWR and placed in a longitudinal twist simulating operation over a curb or through a pothole. There were no deficiencies reported with body, steering, undercarriage, handicapped devices/special seating, or engine subsystem for any of the 22 vehicles compared. Only one vehicle of the 22 compared had a problem with water leakage at the front doors. This same vehicle had a problem with water leakage at the rear door. Another vehicle had two window leaks on each of the repeated tests. A third vehicle had one problem with the service door. Twenty-one of the 22 vehicles compared had no deficiencies noted with air conditioning leaks. No problems were reported for the ALFV.

Static and Dynamic Towing

The objective of the static towing test is to determine the characteristics of the bus tow mechanisms under static loading conditions. Five vehicles completed the static towing test, and none showed any damage or permanent deformation due to the test.

The objective of the dynamic towing test is to verify the integrity of the towing fixtures and determine the feasibility of towing the bus under manufacturer-specified procedures. Due to manufacturers' recommendations, only the front lift tow position was tested on 19 vehicles. All were reported as having "No Damage Noted" either to the bus interface or to the wrecker after the tow.

Hoisting

No instability or damage was noted during the hoisting test for the front wheels, the rear wheels, or both front and rear wheels simultaneously for any of the 19 vehicles. The objective of this test is to determine possible damage or deformation caused by the jack/stands.

Durability

The objective of the structural durability test is to perform an accelerated wear test that approximates up to 25% of the service life of the vehicle. Out of the 24 vehicles that underwent the structural durability test, 21 were tested under the seven-year, 7,500-mile test; two were tested under the 10-year, 11,250-mile test; and one was tested under the 12-year, 15,000-mile test (Table 11).

The vehicles that were compared for this study completed testing between January 2009 and December 2013. The time required for testing the 7-year category vehicle ranged from 1 month to 10 months, and the average was 3.4 months. The two 10-year category vehicles required 3 and 5 months to complete testing, while the single 12-year category vehicle spent 7 months in testing. For the purposes of this study, the months required for testing were counted as whole months if any part of the month was included in the schedule. It should be noted that some vehicles in all groups had only partial tests during this time period (Table 27).

Eleven of the 7-year category vehicles had partial tests. Of these, five completed the structural durability test requiring one month (one vehicle), two months (three vehicles), and four months (one vehicle). Of the 7-year vehicles having the full test program, one remained for ten months, one remained for seven months, two took five months, two finished in four months, seven were done in three months, and four were tested in two months. The average time to complete the 7-year full test program was 3.8 months.

Table 27. Test Durations

				Segment 1		Segment 2		Segment 3	
ID	Test Type	Start	End	Miles	GVL Weight	Miles	SLW Weight	Miles	CW Weight
No.		24	24	24	24	24	24	24	24
Low	**7**	**01.29.09**	**02.23.09**	**3,000**	**11,160**	**1,500**	**10,730**	**3,000**	**8,780**
High	**12**	**01.11.13**	**06.18.13**	**4,625**	**33,440**	**2,500**	**30,310**	**4,625**	**26,310**
Avg.					**16,726**		**15,631**		**12,071**
1301	**10**	**01.11.13**	**06.18.13**	**4,625**	**20,080**	**2,000**	**20,080**	**4,625**	**15,950**
1304	7P	X	X	X	X	X	X	X	X
1214	7	08.22.12	12.10.12	3,000	12,500	1,500	12,500	3,000	8,780
1212	7	X	X	X	X	X	X	X	X
1207	7P	X	X	X	X	X	X	X	X
1204	7	04.09.12	06.13.12	3,000	14,110	1,500	14,110	3,000	10,410
1203	7	04.12.12	06.22.12	3,000	14,640	1,500	14,640	3,000	11,250

				Segment 1		Segment 2		Segment 3	
ID	Test Type	Start	End	Miles	GVL Weight	Miles	SLW Weight	Miles	CW Weight
1201	7	02.13.12	04.25.12	3,000	14,280	1,500	13,980	3,000	10,880
1120	7	01.18.12	06.06.12	3,000	12,720	1,500	12,720	3,000	11,100
1116	7P	X	X	X	X	X	X	X	X
1114	7	09.14.11	02.20.12	3,000	21,210	1,500	19,420	3,000	13,550
1113	7	08.17.11	06.25.12	3,000	21,800	1,500	19,920	3,000	15,060
1112	7	08.31.11	03.13.12	3,000	20,610	1,500	18,400	3,000	12,790
1111	7	07.26.11	10.24.11	3,000	15,000	1,500	13,580	3,000	10,040
1109	12	06.15.11	12.09.11	6,250	33,440	2,500	30,310	6,250	26,310
1106	7P	X	X	X	X	X	X	X	X
1012	7P	X	X	X	X	X	X	X	X
1009	7P	07.12.10	11.24.10	3,000	14,030	1,500	13,140	3,000	10,540
1008	7	06.28.10	10.18.10	3,000	15,000	1,500	13,670	3,000	10,000
1005	7	04.19.10	06.30.10	3,000	13,410	1,500	12,530	3,000	9,440
1004	7	05.28.10	08.05.10	3,000	19,970	1,500	17,360	3,000	13,450
1002	7	02.16.10	05.06.10	3,000	16,450	1,500	14,350	3,000	10,570
1001	7	02.15.10	05.11.10	3,000	15,900	1,500	14,170	3,000	10,730
0920	7	11.06.09	02.23.10	3,000	11,160	1,500	10,730	3,000	11,030
0916	7P	X	X	X	X	X	X	X	X
0912	7	07.22.09	10.22.09	3,000	14,180	1,500	14,180	3,000	10,270
0910	7P	06.17.09	08.28.09	3,000	14,260	1,500	13,671	3,000	9,820
0909	7P	06.15.09	08.28.09	3,000	14,670	1,500	13,960	3,000	10,290
0908	7P	06.06.09	08.21.09	3,000	14,160	1,500	13,510	3,000	10,380
0907	10	06.10.09	09.24.09	4,625	25,900	2,000	23,250	4,625	18,180
0903	7P	01.29.09	02.23.09	3,000	11,940	1,500	10,960	3,000	8,890

An overload condition was found on a number of vehicles being compared (Table 28). This occurred when the vehicle was loaded for the indicated number of seated and/or standing passengers, and the weight of the vehicle resulted in a load heavier than the axle manufacturer's specified GAWR. In some cases the load was reduced for purposes of this test to meet the axle specification of the manufacturer, thereby reducing the number of passengers theoretically on the test vehicle. The majority of overloads were on the rear axle in the GVW condition. Twelve of the 21 vehicles, ranging from the low of 50 pounds (22.7 kilos) to the high of 2,090 pounds (948 kilos), with an average of 895 pounds (406 kilos), were overloaded on the rear axle. Two vehicles were noted as overloaded by 220 pounds (99.8 kilos) on the front axle at GVW. There were eight vehicles with a gross vehicle weight rating (GVWR) overload. A low overload weight of 140 pounds (63.5 kilos) and a high overload weight of 2,300 pounds (1.043 kilos) resulted in an average overload of 1,091 pounds (494.9 kilos). Only three buses were found to be overloaded in the SLW condition. The lowest overload amount was 130 pounds, the highest overload was 320 pounds, and the average overload was 213 pounds (60, 145, and 96.6 kilos). The ALFV was within its axle weight ratings in all test conditions. Details of individual vehicles were provided earlier in this appendix (Table 13) and the discussion therein.

Table 28. Structural Durability Over Loading Conditions

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Overload	**Lbs**	**12/2**				
Front GVL over GAWR (by)	**Lbs**	**2**	220	220	220	**0**
Rear GVL over GAWR (by)	**Lbs**	**12**	50	2,090	895	**0**
SLW over GAWR (by)	**Lbs**	**3**	130	320	213	**0**
GVL over GVWR (by)	**Lbs**	**8**	140	2,300	1,091	**0**

FUEL ECONOMY COMPARISON

The objective of the fuel economy test is to provide comparable fuel consumption data on transit buses tested. (This test bears no relation to the Environmental Protection Agency's Corporate Average Fuel Economy Program.) Four different operating phases are used in the test: central business district (CBD) phase, arterial phase, commuter phase, and idle phase. For the purpose of this study, the four phases of the test were reported separately for each type of fuel to make the fuel consumption data easier to compare.

Fuel economy data from 28 vehicles in mpg, dge, cost per 100 miles, and cost per 100 passenger seat miles are compared. Of these, 16 used a liquid fuel (gasoline or diesel), measured in gallons, two used propane, also measured in gallons, and ten used CNG, measured in pounds. Fuel consumption for the propane and CNG vehicles for the test was measured in pounds per hour stated as “lb/hr” for the idle test and in miles per pound stated as “m/lb” for the moving tests.

As shown in Table 29, the consumption rate for the liquid fuel group of 16 vehicles in the idle phase had a low measured use of 0.23 gallons per hour, a high of 0.67 gph, and an average of 0.43 gph. Twenty-five percent of the liquid-fueled vehicles were below the average gph in the idle phase. The same group of vehicles had a low fuel economy of 3.26 mpg, a high fuel economy of 9.90 mpg, and an average of 6.89 mpg in the Central Business District CBD phase. Nine vehicles had better fuel economy than average in the CBD phase. During the arterial phase, the low mpg measured was 5.22, the high was 10.40, and the average mpg measured was 7.26. Six vehicles obtained mpg above the average mpg in the arterial phase. The commuter phase had a low of 8.69 mpg, a high of 16.47 mpg, and an average mpg of 12.14. Six vehicles reported mpg data higher than average for the commuter phase. Fuel consumption for the entire test for the liquid-fueled group of vehicles had a low measured mpg of 5.91, a high measured mpg of 11.34, and an average measured mpg of 8.09. Ten vehicles were above the average mpg.

Table 29. Fuel Economy Results for the Vehicles Compared

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles Low/Min	High/Max	Average	Vehicle 1301
Idle Phase						
Liquid fuel	**Gal/Hr**	**16**	0.23	0.67	0.43	**0.55**
Propane	**Gal/Hr**	**2**	1.02	1.85	1.44	**X**
CNG	**Lbs/Hr**	**10**	3.84	18.58	7.59	**X**
CBD Phase						
Liquid fuel	**MPG**	**16**	3.26	9.90	6.89	**5.04**
Propane	**MPG**	**2**	4.45	5.33	4.89	**X**
CNG	**M/Lbs**	**10**	0.67	1.86	1.00	**X**
Arterial Phase						
Liquidfuel	**MPG**	**16**	5.22	10.40	7.26	**5.37**
Propane	**MPG**	**2**	3.79	5.23	4.51	**X**
CNG	**M/Lbs**	**10**	0.73	2.48	1.12	**X**
Commuter Phase						
Liquid fuel	**MPG**	**16**	8.69	16.47	12.14	**9.52**
Propane	**MPG**	**2**	5.93	8.79	7.33	**X**
CNG	**M/Lbs**	**10**	1.49	4.01	1.92	**X**
Average for All Phases						
Liquid fuel	**MPG**	**16**	5.91	11.34	8.09	**5.94**
Propane	**MPG**	**2**	4.47	5.94	5.21	**X**
CNG	**M/Lbs**	**10**	0.91	2.40	1.20	**X**

The ALFV recorded lower fuel economy than average in the idle phase and for the three driving phases. It was also below the average mpg in the combined average for all test phases. The fuel data for the ALFV indicated the next-to-lowest miles per gallon rating when compared with the 16 liquid-fueled vehicles tested. When compared only with the ten diesel vehicles having completed the fuel economy measurement, the fuel consumption of the ALFV was next to the highest in miles per gallon.

Only two vehicles were in the propane group. In the idle phase of the fuel economy test, one vehicle consumed 1.02 gph, and the second consumed 1.85 gph, resulting in an average of 1.44 gph. The consumption during the CBD phase was 4.45 mpg and 5.33 mpg, with an average of 4.89 mpg. During the arterial phase, 3.79 mpg and 5.23 mpg were consumed. The vehicles consumed 5.93 mpg and 8.79 mpg in the commuter phase. Total fuel consumption in all phases of the test for the propane group resulted in an average of 5.21 mpg.

A group of 10 CNG-fueled vehicles comprised the gaseous group. The idle fuel consumption of CNG vehicles varied widely from 3.84 pounds per hour to 10.35 pounds per hour, presumably due to the difference in engine size and the inclusion of two hybrid vehicles. One vehicle at 18.58 pounds per hour is an outlier and not included in the calculations. This results in an average of 6.36 pounds per hour in the idle phase of the test. The CBD phase of the test showed the lowest to be 0.67 miles per pound (m/lb), the highest to be 1.86 m/lb, and an average of 1.00 m/lb for the CNG vehicles. Seven vehicles had better fuel economy than the average m/lb for the CBD phase. During the arterial phase, the lowest recorded was 0.73 m/lb, the highest recorded was 2.48 m/lb, and the average was 1.12 m/lb. Eight vehicles had better fuel economy than the average in the arterial phase. The commuter phase had a fuel economy low of 1.49 m/lb, a high of 4.01 m/lb, and an average 1.92 m/lb, with nine vehicles performing better than average. The lowest total fuel consumption in all phases of the test for the CNG vehicles was 0.91 m/lb, the highest was 2.40 m/lb, and the average was 1.20 m/lb. Seventy percent of the vehicles were better than average for all of the phases combined.

Operational management requires that fuel economy data of all fuel types be compared and applied to the local transit situation. In Table 30 and Table 31, the fuel volume has been converted to the diesel gallon equivalent (DGE) cost in order to better equate all vehicles' fuel economy data. Table 31 has converted CNG to gallons using 5.66 pounds of CNG to equal 1 gallon of diesel.[9] The fuel prices used in the tables represent the nationwide average price at the time of writing this report. Calculations have been performed to provide a cost per mile ($\frac{DGE\$}{mpg}$), cost per 100 miles (cost per mile × 100), and cost per 100 passenger seat miles ($\frac{cost\ per\ 100\ mile}{number\ of\ seats}$).

Table 30. Comparison of Fuel Costs per 100 Miles to Operate Diesel and Gasoline Vehicles

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles Low/Min	High/Max	Average	Vehicle 1301
Gasoline Vehicles (DGE)						
SLW / Ft - SLW per Foot of Length	**Lbs**	**6**	489	559	523	**744**
MPG per Report	**Miles/Gal**	**6**	7.19	10.81	8.54	**5.94**
Fuel Costs at SLW for DGE's						
Cost per DGE	**$**	**6**	$3.341	$3.341	$3.341	**$3.402**
Cost per Mile (in DGE's)	**$**	**6**	$0.3091	$0.4647	$0.4014	**$0.5727**
Cost per 100 Vehicle Miles (in DGE's)	**$**	**6**	$30.907	$46.467	$40.143	**$57.273**
Cost per 100 Passenger Seat Miles (in DGE's)	**$**	**6**	$1.717	$3.265	$2.558	**$2.386**
Diesel Vehicles (DGE)						
SLW / Ft - SLW per Foot of Length	**Lbs**	**10**	447	744	564	**744**
MPG per Report	**Miles/Gal**	**10**	5.90	11.34	7.80	**5.94**
Fuel Costs at SLW for DGE's						
Cost per DGE	**$**	**10**	$3.402	$3.402	$3.402	**$3.402**
Cost per Mile (in DGE's)	**$**	**10**	$0.3000	$0.5766	$0.4592	**$0.5727**
Cost per 100 Vehicle Miles (in DGE's)	**$**	**10**	$30.000	$57.661	$45.919	**$57.273**
Cost per 100 Passenger Seat Miles (in DGE's)	**$**	**10**	$1.367	$3.750	$2.417	**$2.386**

Table 31. Comparison of Fuel Costs per 100 Miles to Operate Propane and CNG Vehicles

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Propane Vehicles (DGE)						
SLW / Ft - SLW per Foot of Length	**Lbs**	**2**	495	510	503	**744**
MPG per Report	**Miles/Gal**	**2**	4.47	5.94	5.21	**5.94**
Fuel Costs at SLW for DGE's						
Cost per DGE	**$**	**2**	$3.967	$3.967	$3.967	**$3.402**
Cost per Mile (in DGE's)	**$**	**2**	$0.6678	$0.8875	$0.7777	**$0.5727**
Cost per 100 Vehicle Miles (in DGE's)	**$**	**2**	$66.785	$88.747	$77.766	**$57.273**
Cost per 100 Passenger Seat Miles (in DGE's)	**$**	**2**	$6.339	$7.421	$6.880	**$2.386**
CNG Vehicles (DGE)						
SLW / Ft - SLW per Foot of Length	**Lbs**	**10**	454	978	579	**744**
M/lb - Miles per Lb (as reported)	**Miles/lb**	**10**	0.91	2.40	1.20	**X**
MPG (M/lb x 5.66) - as computed	**Miles/Gal**	**10**	5.15	13.58	6.81	**5.94**
Fuel Costs at SLW for DGE's						
Cost per DGE	**$**	**10**	$2.027	$2.027	$2.027	**$3.402**
Cost per Mile (in DGE's)	**$**	**10**	$0.1492	$0.3935	$0.3208	**$0.5727**
Cost per 100 Vehicle Miles (in DGE's)	**$**	**10**	$14.922	$39.355	$32.080	**$57.273**
Cost per 100 Passenger Seat Miles (in DGE's)	**$**	**10**	$1.224	$4.223	$2.045	**$2.386**

Two of the gasoline vehicles were below the average cost per 100 vehicle miles for that category, while three were below the average cost per 100 passenger seat miles. Comparing the ALFV to the six gasoline vehicles in Table 30, the fuel costs are slightly higher on the comparable DGE basis than the gasoline vehicles. The ALFV also has a higher cost per 100 vehicle miles. However, the ALFV does have a lower cost per 100 passenger seat miles than the average of the six gasoline vehicles.

Ten of the diesel vehicles had a below-average cost per 100 vehicle miles, but only seven of them had a below-average cost per 100 passenger seat miles. The ALFV has the next-to-the-lowest mpg for any of the 10 diesel vehicles. Calculated fuel costs in DGE placed the ALFV above the group average for cost per mile and cost per 100 vehicle miles (more expensive to operate the bus itself), but below the group average for cost per 100 passenger seat miles (less expensive to transport 25 passengers).

Data comparing the ALFV to the two propane vehicles in the study found it to be comparable to the propane vehicle with the maximum fuel economy on an mpg basis (Table 31). However, the higher price of propane and the lower price of CNG in comparison with diesel and gasoline are reflected in the cost per 100 miles and the cost per 100 passenger miles in Table 31.

NOISE COMPARISON

The objective of the noise tests is to measure and record interior noise levels and check for audible vibrations under various operating conditions, and also to record exterior noise levels when a bus is operated under various conditions. The source of noise is noted from three areas: engine and accessories, windows and doors, and seats and wheelchair lifts. A summary of the interior noise comparison is found in Table 32. The first interior noise test measures the decibels recorded at each of six locations inside the bus with 80 dB(A) white noise generated on the exterior left side of the bus. The lowest measured noise, the highest measured noise, the average noise of the six locations measured, and the ambient noise level of the interior measured for each vehicle were used for purposes of this study. Interior noise was also measured during full throttle acceleration from zero to 30 mph for 28 vehicles. The results of these measurements are provided in Table 32.

The average interior noise level of the ALFV during the full-throttle acceleration was higher than the group average (78.9 decibels versus 72.5). As found in Table 32, none of the 28 vehicles being compared were found to have significant interior vibrations, rattles, or other noises noted at the time of testing.

Table 32. Interior Noise Levels

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Internal Noise Tests	**Decibels**					
80 Db(A) Exterior of Bus on Left Side						
Average	**Decibels**	**26**	43.6	53.4	47.1	**46.7**
Low	**Decibels**	**26**	43.3	52.1	47.6	**45.4**
High	**Decibels**	**26**	44.0	55.9	50.4	**48.0**
Ambient	**Decibels**	**26**	27.1	31.4	32.6	**30.0**
Acceleration 0 to 30 mph						
Average	**Decibels**	**28**	69.1	78.9	72.5	**78.9**
Low	**Decibels**	**28**	66.0	76.0	70.5	75.2
High	**Decibels**	**28**	70.3	82.1	75.1	**82.1**
Ambient	**Decibels**	**28**	24.9	38.8	32.2	**30.0**
Vibrations, Rattles and Other Noises		**28**	None	None	None	**None**

Multiple conditions are tested during the exterior noise tests and are found in Table 33. The noise levels for the ALFV (Vehicle 1301) were above the group average on the right side and were the highest measured on the left side during acceleration from a constant speed. One-half of the 28 vehicles had noise levels below the group average. Of the 28 vehicles, 19 had lower noise levels than the group average. Fifty percent of the 28 vehicles performed below the average ambient noise level. The right and left side noise levels of vehicle 1301 were the highest exterior noise measurements obtained during the acceleration from a standstill.

Five of the buses had an individual average that was below the group average for low idle with all accessories turned on. Seven of the vehicles had individual averages that were below the group average for the high idle condition with all accessories turned on. Twenty-eight vehicles were compared in the wide-open throttle condition. Sixteen vehicles had individual average interior noise levels that were below the group average for wide-open throttle with all accessories turned on.

The final exterior noise data reported are for low idle, high idle, and wide-open throttle with all of the vehicle's accessories and air conditioning powered off. The data for this test are reported in the number of decibel difference, plus or minus, when compared with the readings in the test where the vehicle's accessories and air conditioning are powered on.

Table 33. Exterior Noise Levels

Feature/Item	Unit of Measure	No. Vehs	30 Comparative Vehicles Low/Min	High/Max	Average	Vehicle 1301
External Noise Tests	**Decibels**	**28/13**				
Vehicle Moving						
Accelerating from Constant Speed						
Right Side	**Decibels**	**28**	64.7	78.6	72.6	**76.1**
Left Side	**Decibels**	**28**	66.2	83.3	73.5	**83.3**
Ambient	**Decibels**	**28**	33.8	51.6	40.9	**42.0**
Accelerating from Standstill						
Right Side	**Decibels**	**28**	66.8	80.8	71.6	**80.8**
Left Side	**Decibels**	**28**	67.3	91.5	72.6	**91.5**
Ambient	**Decibels**	**28**	35.3	51.8	41.3	**42.3**
Vehicle Stationary						
Accessories and A/C On						
Low Idle	**Decibels**	**27**	42.8	59.3	47.0	**59.1**
High Idle	**Decibels**	**13**	52.5	64.7	58.4	**62.9**
Wide Open	**Decibels**	**28**	51.1	85.1	69.1	**85.1**
Accessories and A/C Off (diff. from On)						
Low Idle (+ or -)	**Decibels**	**27**	-10.4	+5.9	-2.1	**-0.2**
High Idle (+ or -)	**Decibels**	**14**	-5.8	+0.1	-1.1	**-0.1**
Wide Open (+ or -)	**Decibels**	**28**	-2.8	+0.5	-0.1	**+0.5**
Ambient for Vehicle Stationary		**28**	33.8	49.8	41	42

For purposes of this study, the data were averaged together to show the difference, either louder or quieter than when the vehicle was operating with all accessories and air conditioning powered on. The negative numbers indicate a reduction in noise level, while positive numbers indicate an increase in noise level. Nineteen vehicles had a larger reduction in interior noise than the group average. Fourteen vehicles were compared for the high idle condition with the accessories and air conditioning off. Eight of the 14 vehicles compared experienced greater reductions in noise levels than the group average reduction of -1.1 dB(A) for high idle with the accessories off. The wide-open throttle test included 28 buses. Eighteen of the 28 vehicles compared experienced greater reduction in noise levels than the group average reduction of -0.1 dB(A) for wide-open throttle with the accessories turned off.

The exterior ambient noise level for both “on” and “off” conditions was the same. Fifty percent of the vehicles were tested when ambient noise level was below the average ambient noise level.

During the stationary vehicle exterior noise measurements, the ALFV demonstrated a higher than average noise level for both the low and high idle conditions and the highest noise level on the wide-open throttle condition, all with the accessories and air conditioning on. The ALFV had less than the average noise reduction between operating the vehicle with the accessories turned on compared with accessories turned off at low and high idle. Vehicle 1301 measured the highest increase in noise at wide-open throttle with the accessories turned off.

EMISSIONS COMPARISON

This chassis dynamometer-based emissions comparison is based on the measurement of the gaseous engine emissions CO (carbon monoxide), CO_2 (carbon dioxide), NO_x (oxides of nitrogen), THC (total hydrocarbons), NMHC (non-methane hydrocarbons), and particulates (diesel vehicles only). Emissions tests were not conducted on nine of the vehicles in this comparison because this test was not required prior to 2010. One vehicle had a partial test in which the FTA did not require an emissions test. The remaining 21 vehicles included in this study were used in the emissions comparison. Of the 21 vehicles in the emissions comparison, nine were defined as CNG vehicles, two were propane vehicles, and ten vehicles were liquid-fueled (five gasoline and five diesel) vehicles. There was one CNG hybrid vehicle that was included in the CNG fuel group for the purpose of this study’s analysis.

The analysis of the five gaseous emissions for each of the fuel groups and the particulate results for the diesel category are provided for each of the three test cycles in Table 34. Vehicle lows, vehicle highs, and group averages are presented for the entire test group (21 vehicles). It is important to note that the average (or group average) is calculated for the above combination of the number of diesel, gasoline, propane, and CNG vehicles included in this study, and it is not representative of any fuel type. It represents the average of the mid-size buses in this study only.

Carbon Dioxide (CO_2)

For all fuel types, the lowest level of carbon dioxide (CO_2) emitted by a vehicle during the Manhattan cycle was 1,327 g/mile, and the highest was 2,409 g/mile. The average for all vehicle fuel types was 1,690 g/mile. Eleven vehicles were below the group average. The vehicle with the lowest carbon dioxide level was fueled by diesel. No single fuel type had all vehicles below the group average. Analysis by fuel type confirms that two-thirds of the CNG vehicles were below the group average. In the liquid-fueled group, two gasoline and two diesel vehicles were below the group average for CO_2 emissions. Three gasoline and three diesel vehicles were above the group average. A CNG-fueled vehicle had the highest emission level of CO_2 at 2,409 g/mile.

During the Orange County Bus (OCB) cycle, the lowest emission of CO_2 was obtained by a diesel vehicle and measured at 935 g/mile. The highest level of CO_2 emitted was by a CNG vehicle at 1,641 g/mile. Twelve of the vehicles compared were below the group average of 1,211 g/mile. Analysis by fuel type confirms that seven of the nine CNG vehicles, both of the propane vehicles, and three of the liquid-fueled vehicles (two gasoline and one diesel) were below the group average g/mile.

Table 34. Emissions Comparison

Feature/Item	Unit of Measure	No. Vehs	Comparative Vehicles			Vehicle 1301
			Low/Min	High/Max	Average	
Emissions Tests (after Jan.1, 2010)						
CO2						
Manhattan Cycle	**g/mile**	**21**	1,327	2,409	1,690	**2,269**
Orange County Bus	**g/mile**	**21**	935	1,641	1,211	**1,511**
UDDS	**g/mile**	**21**	757	1,312	1,016	**1,181**
CO						
Manhattan Cycle	**g/mile**	**21**	0.000	11.900	1.402	**0.040**
Orange County Bus	**g/mile**	**21**	0.000	12.800	1.589	**0.040**
UDDS	**g/mile**	**21**	0.070	15.500	2.182	**0.070**
THC						
Manhattan Cycle	**g/mile**	**21**	0.016	14.600	1.247	**0.040**
Orange County Bus	**g/mile**	**21**	0.009	3.300	0.557	**0.080**
UDDS	**g/mile**	**21**	0.009	2.200	0.412	**0.030**
NMHC						
Manhattan Cycle	**g/mile**	**14**	0.006	1.500	0.207	**0.030**
Orange County Bus	**g/mile**	**14**	0.010	0.280	0.089	**0.080**
UDDS	**g/mile**	**14**	0.010	0.200	0.074	**0.020**
NOx						
Manhattan Cycle	**g/mile**	**21**	0.000	11.750	1.848	**2.990**
Orange County Bus	**g/mile**	**21**	0.000	9.790	1.376	**0.900**
UDDS	**g/mile**	**21**	0.000	7.590	0.993	**0.380**
Particulates						
Manhattan Cycle	**g/mile**	**5**	0.001	0.030	0.007	**0.030**
Orange County Bus	**g/mile**	**5**	0.001	0.010	0.004	**0.010**
UDDS	**g/mile**	**5**	0.000	0.020	0.005	**0.020**

A CNG vehicle produced the lowest carbon dioxide emissions (757 g/mile) during the UDDS cycle. Eleven vehicles had emission levels below the group average of 1,016 g/mile. Analysis by fuel type for the carbon dioxide emissions during the UDDS cycle shows that seven CNG vehicles, one propane vehicle, and three liquid-fueled vehicles (two gasoline and one diesel) were below the group average. Vehicle 1301 was above average on all three driving cycles for the CO_2 emissions.

Carbon Monoxide (CO)

For the Manhattan cycle, 17 vehicles were below the group average of 1.402 g/mile. Seven CNG vehicles, one propane vehicle, and nine liquid-fueled vehicles (all but one diesel) were below the group average emissions for carbon monoxide on the Manhattan cycle.

Seventeen vehicles (seven CNG, one propane, and nine liquid-fueled) were below the group average emission for the Orange County Bus cycle, which was 1.589 g/mile. The one liquid-fueled vehicle that was above the group average was a diesel. The ALFV was below average for both the Manhattan and the Orange County Bus cycles.

The lowest CO emissions measured during the Urban Dynamometer Driving cycle was 0.070 g/mile and was measured on a diesel vehicle. The highest carbon monoxide emissions measured were 15.500 g/mile on a CNG vehicle. Fifteen vehicles were below the group average of 2.182 g/mile. Thirty-three percent of the CNG vehicles, 50% of the propane, and 20% of the liquid-fueled vehicles (both gasoline) were above the group average emissions. The ALFV had the lowest recorded CO emissions for the Urban Dynamometer Driving cycle.

Total Hydrocarbons (THC)

The total hydrocarbons emissions measured under the Manhattan cycle had a low value of 0.016 g/mile on a diesel vehicle and a high value of 14.600 g/mile on a CNG vehicle. Four of the CNG-fueled vehicles, both of the propane-fueled vehicles, and all ten of the liquid-fueled vehicles were below the group average of 1.247 g/mile. Five CNG vehicles were the only vehicles above the average in this cycle.

The lowest level of total hydrocarbons emissions measured during the Orange County Bus cycle was 0.009 g/mile on a propane-fueled vehicle. The highest level of total hydrocarbons emissions measured was 3.300 g/mile on a CNG-fueled vehicle. Three of the CNG vehicles, both of the propane vehicles, and all ten of the liquid-fueled vehicles were below the group average of 0.557 g/mile.

For the Urban Dynamometer Driving cycle, the lowest value for total hydrocarbons measured was 0.009 g/mile on a propane vehicle. The highest value for total hydrocarbons measured was 2.200 g/mile on a CNG vehicle. With a group average of 0.412 g/mile, 15 vehicles were below this value: three CNG, both propane, and all ten liquid-fueled vehicles. The ALFV had below average total hydrocarbons emissions for all three of the test cycles.

Non-Methane Hydrocarbons

The non-methane hydrocarbons (NMHC) produced under the Manhattan cycle had a low of 0.006 g/mile measured on a propane vehicle, a high of 1.500 g/mile measured on a CNG vehicle, and a group average of 0.207 g/mile. Of the 14 vehicles (eight CNG, two propane, and four liquid fuel) compared for NMHC emissions, 12 were below the group average and consisted of six CNG, both propane, and three liquid-fueled vehicles.

During the Orange County Bus cycle, the lowest measurement of non-methane hydrocarbons was 0.010 g/mile, and the highest measurement was 0.280 g/mile, both on CNG-fueled vehicles. The group average was 0.089 g/mile. Ten vehicles were below the group average. Of these ten vehicles, five were CNG, two were propane, two were gasoline, and one was diesel.

The lowest non-methane hydrocarbons measured during the Urban Dynamometer Driving cycle was 0.10 g/mile, and the highest was 0.200 g/mile, both on CNG-fueled vehicles. Nine vehicles (six CNG, two propane, and one diesel) were below the group average of 0.074 g/mile. Vehicle 1301 demonstrated below average NMHC emissions during all three driving cycles.

Oxides of Nitrogen (NO_x)

The comparison of the vehicles for oxides of nitrogen (NO_x) during the Manhattan cycle shows that a CNG vehicle delivered the lowest emissions level (zero), while the highest was reported for a diesel vehicle (11.750 g/mile). Of the 21 vehicles compared, 15 of the vehicles were below the group average of 1.848 g/mile. Of the 15 vehicles, seven were CNG, two were propane, and six were liquid-fueled (five gasoline and one diesel). Vehicle 1301 was above average in NOx emissions for the Manhattan cycle.

A gasoline vehicle had the lowest emissions of NO_x during the Orange County Bus cycle, measuring zero oxides of nitrogen. One of the diesel vehicles had the highest NOx value of 9.790 g/mile, while the group average was 1.376 g/mile. Two vehicles (one CNG and one diesel) from the comparison group had high NO_x emissions and are believed to have skewed the group average. Eighty-one percent of the vehicles compared were below the group average. The vehicles below the group average included eight CNG vehicles, two propane vehicles, five gasoline vehicles, and two diesel vehicles. Vehicle 1301 had lower than average NO_x emissions for the OCB cycle.

Oxides of nitrogen were measured during the Urban Dynamometer Driving cycle, providing an individual vehicle low of zero and a high of 7.590 g/mile, both for CNG vehicles. Ten of the 14 vehicles had emissions less than the group average of 0.993 g/mile. Again, two vehicles with high NO_x emissions appeared to skew the group average. Of the vehicles that were below the group average, eight were CNG, two were propane, and seven were liquid-fueled (five gasoline and two diesel). The ALFV had lower than average NO_x emissions for the UDDS cycle.

Diesel Exhaust Particulate Matter (DPM)

Diesel exhaust particulate matter—also referred to as DPM—leaving the tail pipes of buses with modern diesel engines is very low because of their use of particulate traps (diesel particulate filters or DPF). As these particulates are produced only from diesel fuel, the five diesel buses in this study were the only ones compared.

The individual vehicle low particulate measurement in the Manhattan cycle was 0.001 g/mile, the individual vehicle high measurement was 0.030 g/mile, and the group average was 0.007 g/mile. For the Orange County Bus cycle, the individual vehicle low particulate measurement was 0.001 g/mile, the individual vehicle high measurement was 0.010 g/mile, and the group average was 0.004 g/mile. A low individual vehicle particulate measurement of zero, a high measurement of 0.020 g/mile, and a group average of 0.005 g/mile were obtained during the Urban Dynamometer Driving cycle. Vehicle 1301 is a diesel-fueled vehicle and had the highest particulates emissions for all three driving cycles, which could result from failing or defective particulates reduction equipment in the bus.

APPENDIX 3. SURVEY DOCUMENT

AMPV

[next]

11/13113 Advanced Multi-Purpose Vehicle Survey

AMPV OVERVIEW

Advanced Low-Floor Vehicle Project, An FTA Research Project

Ride Solution, Inc of Palatka, Florida has developed the Advanced Multi-Purpose Vehicle (AMPV). This is a purpose built vehicle for use in rural and urban flex routes. As part of the development project, we are surveying other transportation agencies to determine interest in such a vehicle and rating the importance of the design features. Please take the time to look over the information included in this brief survey and let us know how these features would impact your current transportation model.

This vehicle was built at the Ride Solution shop in Palatka, Florida and has just completed tests at the Altoona Bus Testing Center, operated by Pennsylvania State University, under the direction of Mr. David Klinkowski. While the bus was at Altoona we became aware of the development of a new hydraulic hybrid drive that will reduce fuel consumption up to 50%.

Investigation indicated that this hybrid drive would work with the same Cummins engine we are using. This hybrid vehicle will be the one that will be produced, rather than the current “Brevi” shown in the video.

Thank you, Ride Solution

*1. What is the name of your Agency?

*2. What is the name of the person completing this survey?

[next]

AMPV

Please view this short informational video regarding the AMPV project in Putnam County, Florida.

You can click arrow in middle of the screen, then on lower right corner click “full screen” to view video in full screen mode.

[next]

AMPV - Advanced Multi-Purpose Vehicle

The AMPV chassis is a purpose built monocoque structure designed for the rigors of the rural bus market with bus quality suspension, axles, and cooling system.

Engine:
Cummins ISB07 200
Horsepower: 200 @ 2,300 rpm
Torque: 520 ft.lbs @ 1,600 rpm
Optional: Integral engine exhaust brake

Drivetrain:
Transmission: Allison 2100 PTS 5 speed automatic with electronic push button shifter
Transfer Case: Helical (3) gear set, 1:1 ratio with oil cooler
Mounting: Cooling system, engine, and gear train assembled in rubber-mounted 41003 stainless steel pallet.

Cooling System:
950 in^2, 11 fins per inch radiator
625 in^2, 11 fins per inch charge air cooler
Composite headers and tanks
2-speed electro/mechanical engine driven fan clutch
27” dynamically balanced composite fan

Vehicle Weight Ratings: GVW: 25,000 lbs

Wheelbase:
206” for 26’ bus
Optional; 176 for 22’ bus

Body Structure:
100% 41003 utility stainless steel construction
Tubular space frame construction
FEA tested for 1.5G roof loading, 3G vertical loading, and 4,000# vehicle side impact

Fuel Tank: 30-gallon aluminum tank

Front Axle/Suspension:
Meritor I-beam with 15” x 5” Q+ brakes, 8,000 lbs.
Ridewell 2 Air spring 5-Link torque beam suspension
Optional: Park interlocked kneeling

Drive Axle:
Meritor RS 17-144, 17,500 lbs
Coach Quiet gearing, 4.56:1 ratio
Ridewell 2 Air spring 5-Link torque beam suspension
Park interlocked kneeling

Tires/Wheels:
Goodyear G647 245/70R 19.5 14-ply tire (6)
Alcoa 19.5 *x* 7.5” aluminum wheels, all outer position
Optional: Accuride 19.5 x 7.5 Steel wheels w/10 bolt hub pilot

Braking System:
Wabco 4S/4M ABS and air valve system
Meets FMVSS 121 requirements

Steering:
Tilt/Telescoping steering column
TRW series power steering gear

Electrical:
J 1939 Multiplex System
Leece-Neville 12V, 270 Amp alternator

AC System:
ThermoKing Roof Mounted Low Profile and Low Weight AC System
Dual serpentine belt driven, engine mounted twin TM21 R 134a AC compressors
Radiator mounted dash-air condenser
Complete dash assembly with AC controls

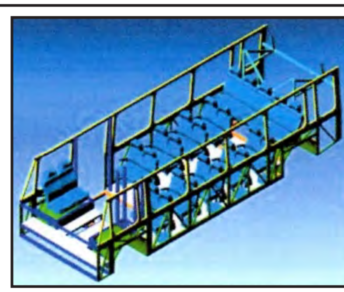
Instrumentation:
Multiplex black face gauges: 3” Speedometer w/integral message center. 3” Tachometer, Fuel gauge, Volt meter, Engine oil press, Coolant temp, Transmission Temp, Sys #1 air pressure, Sys #2 air pressure, light bar.

Note: Specifications subject to change without notice.

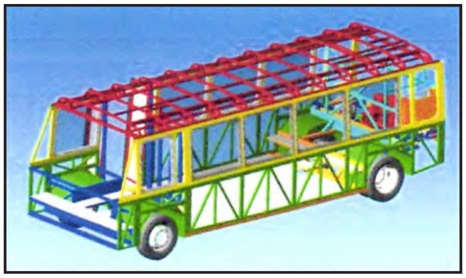
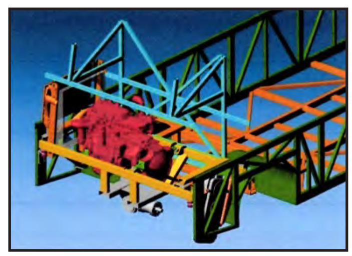
[next]

AMPV – Advanced Multi-Purpose Vehicle

AMPV



Isometric seating layout view

 LH side view	 RH side view shown with ramp, door and side glass
 Engine Access	 Protected Hose Channel
Ride Solution 220 N 11"' Street Palatka, Fl 32177 Phone: 388-325-9999 Boyd Thompson , Director of Operations www.theridesolutlon.com	 Removable Engine Carriage
 AC/Heater	 AMPV Interior

[Next]

AMPV

*3. Based upon the video and specifications you just viewed, how interested would your agency be in acquiring an advanced low-floor vehicle such as the AMPV?

Not Interested	Slightly Interested	Interested	Very Interested

[Next]

AMPV

*4. The AMPV was built for urban and rural flex-routes. Its low-floor design holds 25 ambulatory or 5 wheelchair passengers in 26 foot of vehicle length. The AMPV also has the capacity and agility to allow walk-on passengers at published stops while still fitting into residential drives for door-to-door service.

Unimportant	Slightly Important	Important	Very Important

How important are these vehicle attributes to your agency?

*5. The AMPV was also built for rural to urban commuter services. Reclining foldaway seats with headrests and 12V laptop power ports provide comfort on the rural to urban commute. With seats folded, the five wheelchair, capacity allows the vehicle to then address the urban paratransit market during the day. This results in a vehicle minimum work day of over 10 hours.

Unimportant	Slightly Important	Important	Very Important

How important are these vehicle attributes to your agency?

*6. The AMPV was built for rugged rural service. Ruggedized space frame construction, short wheelbase, and short overhangs allow the vehicle to surmount and endure rural dirt roads. Engine weight over the rear axle maintains maximum traction in all conditions. By being built to the rural worst-case scenario, the vehicle anchors rural transit, which, in turn anchors regional transit.

Unimportant	Slightly Important	Important	Very Important

How important are these vehicle attributes to your agency?

[Next]

AMPV

*7. The AMPV was built for disaster relief. Reconfiguration of the seats, as shown in the video, can allow for the carriage of 6 canvas stretchers or 2.5 tons of supplies. By building disaster relief into our rural and urban transit systems, we have emergency infrastructure that is maintained on a daily basis.

Unimportant	Slightly Important	Important	Very Important

How important are these vehicle attributes to your agency?

*8. The AMPV was built by mechanics for mechanics everywhere. The entire power module, which is self-contained and can be run outside the vehicle, can be removed and replaced in two hours, allowing a minimum of down time on major repairs by retaining a reserve power package. The engine bay is fully accessible from the front and the rear. All hoses and wiring are run in tunnels that are accessible the full length of the vehicle.

Unimportant	Slightly Important	Important	Very Important

How important are these vehicle attributes to your agency?

*9. The AMPV was built for extended vehicle life. With stainless steel frames and aluminum skin, the chassis is built as a long-life vehicle. At 20 years of service, the life cycle costs are significantly less than those of typical 7 and 10 year buses. As technology creates more fuel efficient engines and transmissions, the modular engine bay is easily upgraded, as we are doing with the hydraulic hybrid drive.

Unimportant	Slightly Important	Important	Very Important

How important are these vehicle attributes to your agency?

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AMPV

AMPV vs Mid-sized bus: 10 year/28 seat vehicle $159,000

AMPV vs Mid-sized ‘31 cut-a-way: 7 year/18 seat vehicle $352,500

Prices for 10 and 7 year buses were taken from the Florida DOT Vehicle Procurement Website http ://www. tripsflorida.org/md7.html, as of August 2013, with price calculated at median cost for 10 and 7 year buses.

By Dr. Carl E. Thomblad

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AMPV

AVERAGE ANNUAL VEHICLE PURCHASE PRICE AND SEAT COST ANALYSIS

August 27, 2013

AMPV 20 Year Purchase Price Savings:

The vehicle purchase price is a major component inthe life cycle cost analysis of a vehicle when added to maintenance, repair, fuel and driver costs. Annual vehicle purchase price for AMPV and comparable mid-sized buses are as follows:

Bus...Purchase Price............Annual Purchase Price

AMPV: 20 year vehicle ....$350,000 ....$17,500

Mid-sized bus: 10 year vehicle ....$285,050 ....$28,505

Mid-sized ‘31 cut-a-way: 7 year vehicle.....$177,000 ....$25,282

Vehicle Purchase Price Comparison......................AMPV **Purchase Price Savings**

AMPV vs Mid-Sized 10 year vehicle $220,100

AMPV vs Mid-Sized 7 year vehicle...............................$155,640

AMPV 20 Year Seat Cost Savings:

Seat cost is the true measure of costing for buses. When purchasing a bus, you are really purchasing “seating capacity.” At peak utilization, the more seats, the more cost effective the bus.

Bus...Annual Purchase Price...........Annual Cost per Seat

AMPV: 20 year/25 seat vehicle............................$17,500 ....$700

Mid-sized bus: 10 year/28 seat vehicle ....$28,505 .... $1,018

Mid-sized ‘31 cut-a-way: 7 year/18 seat vehicle..$25,282 ....$1,405

Vehicle Seat Cost Comparison.....AMPV **Seat Cost Savings @ 25 Seats** (Annual Seat Cost x 20 Years x 25 Seats)

[Next]

Who can we contact from your agency to discuss your answers in more detail?

What is their title?

What is a good contact number to reach this person?

These are the additional areas of interest we would like to discuss when we call:

- A brief summary of your transit operations.
- Your opinion of the AMPV Vehicle from your review of the data provided.
- The advantages of using the AMPV in your operation.
- The features of a mid-sized vehicle that you would like to see incorporated in future

AMPV development for use by your transit agency.

[Next]

AMPV

*13. Would your agency be willing to submit a legally non-binding “letter of interest,” on your letterhead, by e-mail or regular mail, stating the possible number of vehicles you would be willing to purchase if funding were available? A sample letter is attached.

Yes No

[Next]

AMPV

14. How many AMPV vehicles would you be interested in potentially purchasing for use in your transit agency?

[Next]

AMPV

Please copy and paste the following text on your letterhead to mail or email to Ride Solution at drct30@gmail.com.

Ride Solution, Inc.

AMPV Marketing Study Project 220 N. 11th Street

Palatka, FL 32177 ATIN: Boyd Thompson

Thank you for contacting us regarding the Advanced Multi-Purpose Vehicle (AMPV) Project.

The AMPV may offer our department the opportunity to better serve our riders, by virtue of being specifically designed with our ridership in mind, as well as designed to operate in the specific areas of our community that are less accessible to our current fleet.

We would be interested in a possible purchase of up to 12 AMPV vehicles.

Although we cannot commit to any purchases at this time, funding to replace a portion of our current fleet will be available in the next several fiscal years. The AMPV is certainly an option for us due to its unique design and ride.

Please keep us informed as to production plans. We look forward to hearing from you in the near future.

Sincerely,

BT

Director of Operations RS

[Next]

AMPV

We thank you for taking the time to complete our survey and for your interest in the Advanced Multi-Purpose Vehicle Project. We will be getting in touch with you soon to discuss the project and how your answers may assist us in our endeavors.

You can reach us for questions at boyd@theridesolution.org.

[Next]

ENDNOTES

1. Puro, Sarah. “Statement for the Record, Status of the Highway Trust Fund, Analyst for Surface Transportation Programs.” For the Committee on the Budget, US House of Representatives, April 24, 2013.

2. Wise, Dave. “Transportation-Disadvantaged Populations.” US Government Accountability Office (U.S. GAO). United States Government Accountability Office Statement for the Record, 6 November 2013.

3. APTA National Bus Roadeo 2013 Standardized Course (http://www.apta.com/mc/busroadeo/Pages/default.aspx).

4. SAE J1050 (2009), “Describing and Measuring the Driver’s Field of View.”

5. SAE J941 (2010), “Motor Vehicle Drivers’ Eye Locations.”

6. National Highway Traffic Safety Administration. Mazzae & Barickman, 2009. “Direct Rear Visibility of Passenger Cars: Laser-Based Measurement Development and Findings for Late Model Vehicles.”

7. CFR 2005, Title 49, Vol 1, Part 38 (2005), “Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles.”

8. NCTR. “Flexible Public Transportation Services in Florida.” 2013. http://www.nctr.usf.edu/wp-content/uploads/2013/09/77942-Flexible-Public-Transportation-in-Florida.pdf.

9. The National Conference of Weights & Measurements (NCWM) standard unit of measurement for compressed natural gas, as defined in the NIST Handbook 44 (2013) *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*, Appendix D, which states: “Gasoline [US] gallon equivalent (GGE) means 5.660 lb of natural gas.”

BIBLIOGRAPHY

APTA National Bus Roadeo 2013 Standardized Course (http://www.apta.com/mc/busroadeo/Pages/default.aspx).

CFR 2005, Title 49, Vol 1, Part 38 (2005), "Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles."

National Highway Traffic Safety Administration. Mazzae & Barickman, 2009. "Direct Rear Visibility of Passenger Cars: Laser-Based Measurement Development and Findings for Late Model Vehicles."

NCTR. "Flexible Public Transportation Services in Florida," 2013. http://www.nctr.usf.edu/wp-content/uploads/2013/09/77942-Flexible-Public-Transportation-in-Florida.pdf.

Puro, Sarah, "Statement for the Record, Status of the Highway Trust Fund, Analyst for Surface Transportation Programs," For the Committee on the Budget, US House of Representatives, April 24, 2013.

SAE J941 (2010), "Motor Vehicle Drivers' Eye Locations."

SAE J1050 (2009), "Describing and Measuring the Driver's Field of View."

Wise, Dave, "Transportation-Disadvantaged Populations," US Government Accountability Office (U.S. GAO). United States Government Accountability Office Statement for the Record, 6 November 2013.

ABOUT THE AUTHORS

SURESH IYER, PHD

Dr. Iyer is a research associate at the Larson Institute of The Pennsylvania State University and served as the lead investigator for this project at Penn State. Dr. Iyer contributes more than thirty years' experience in design, manufacture, and testing of automobiles and components. He currently directs emissions research and testing at the Bus Research and Testing Center of the Larson Institute. He teaches courses on internal combustion engines and mentors graduate students in combustion science and emissions research. He has published his work in several refereed journals and presented at technical meetings and conferences. He received the co-performer award for Project of the Year for work related to Combustion Science for Military Platforms from the Strategic Environmental Research Development Program.

PARTHA MISHRA

Mr. Mishra is a graduate student in mechanical engineering at Penn State. His research experience includes design and fabrication of an all-terrain vehicle for a nationwide competition in India, and a comparative study of biomass gasification systems to establish the merits of a cyclone-type gasifier for low-density biomass feedstock. Mr. Mishra received an Institute Merit Scholarship, gold medal for first place in the senior state-level Mathematics Olympiad, and senior state-level Chemistry Olympiad. He also received a scholarship from India's Central Board of Secondary Education for academic excellence.

DAVID KLINIKOWSKI

Mr. Klinikowski is director of the Bus Research and Testing Program operated by the Larson Institute at Penn State. He has served as program manager, mechanical/vehicle test engineer, project supervisor, and engineering research technician. He has experience in the development and implementation of testing procedures and programs, the design of fabrication automotive electronic and mechanical systems, and data analysis. The testing program is involved in active research and testing new transit technologies, vehicle emissions test methods, advanced materials and propulsion systems, and transit vehicle durability, safety, and performance. Mr. Klinikowski's responsibilities also include managing the test track operations at the Penn State Bus Research Testing Facility. He is author of many publications and has received several awards for his contributions to research, including Penn State's Research and Graduate School's Outstanding Staff Award.

BOYD THOMPSON

Mr. Thompson is the director of operations for Ride Solution, Inc., Florida. His interest in human service and public transportation derives from having been a school bus driver in high school, a California Class A Mechanic and dynamometer technician in late 1960s, a UCLA graduate with a BA in psychology in 1972, and a social worker from that point on. The coordination of human service transportation in Florida, under Chapter 427, F.S., offered him the opportunity in 1986 to merge his technical interests with human service. Along with

Dr. Carl Thornblad and Ms. Myra Strange, he is responsible for Ride Solution's in-house development of software that enabled Florida's first flex-route system. Ride Solution's strategies for flex-route development were published in 1996 under the US Department of Transportation Technology Sharing program as DOT-T-97-01, "Operational Strategies for Rural Transportation." Mr. Thompson's current efforts include development of a hydraulic hybrid version of the ALFV bus, as well as software development to merge flex route and ride share management into regional transit.

MYRA STRANGE

Ms. Strange is operations manager for Ride Solution Inc., Florida. She started with Ride Solution as a transportation coordinator in 1996 and worked with Mr. Boyd Thompson and Dr. Carl Thornblad in developing a structured flex-route system for Putnam County, as well as supporting software. She has observed firsthand the benefits of the flex route system in improving access to rural public transportation and was instrumental in educating Ride Solution employees, as well as agencies and riders throughout the county, about the benefits of a coordinated, routed system over the traditional demand-response format. Ms. Strange has been a key resource to the North East Florida Mobility Coalition's "One Call-One Click" regional scheduling software project, which, under the leadership of the Jacksonville Transit Authority, is linking nine counties in northeast Florida into a single trip management database. Public service remains the central motivation for her work in community transportation and the ongoing development projects of Ride Solution.

WANDA BOGGS

Ms. Boggs is Ride Solution's Office Manager. She also started as a transportation coordinator in 2000 and worked on flex routing with Mr. Boyd Thomson and Ms. Myra Strange. Ms. Boggs' compassionate approach is felt throughout the Ride Solution system. She was named Dispatcher of the Year in 2005 by the Florida State Commission for the Transportation Disadvantaged. She is integral to all Ride Solution development projects. Ms. Boggs is also a key resource in the regional "One Call-One Click" project.

CARL THORNBLAD, PHD

Dr. Thornblad is a consultant to Ride Solution, Inc. and prepared a market study for this project. He has considerable experience, and he designed and programmed an advanced computerized transportation management system that was awarded a State of Florida citation by the Governor's Office and an award for outstanding national rural transportation use of computers by the Administrator of the Federal Transit Administration. Dr. Thornblad has also served as a transportation consultant to the Iowa Department of Transportation, the Jacksonville (Florida) Transit Authority, Volusia County, Florida Council of Governments, Bluebird Bus Company, and Carpenter Bus Company. In addition, he served as a financial and computer consultant to McAuto, the computer division of McDonald Douglas Aircraft of St. Louis, and as a management consultant to the speaker of the Illinois House of Representatives. His government experience includes service as associate secretary for Finance, Legislation and Research of the Illinois Junior College Board, project leader of the Higher Education Budget for the Governor's Office, Bureau of the Budget, State of Illinois, and a member of the Planning Department of the Illinois Secretary of State's Office. He has had a number of years' experience at the federal level working on transportation and education issues, including a special study in education finance for the US Congress.

PEER REVIEW

San José State University, of the California State University system, and the MTI Board of Trustees have agreed upon a peer review process required for all research published by MNTRC. The purpose of the review process is to ensure that the results presented are based upon a professionally acceptable research protocol.

Research projects begin with the approval of a scope of work by the sponsoring entities, with in-process reviews by the MTI Research Director and the Research Associated Policy Oversight Committee (RAPOC). Review of the draft research product is conducted by the Research Committee of the Board of Trustees and may include invited critiques from other professionals in the subject field. The review is based on the professional propriety of the research methodology.

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