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M-PRT System Energy Assessment and Advanced Small Transit Vehicle Study, Final Report

PREPARED BY

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West Virginia University

U.S. Department of Transportation
Federal Transit Administration

APRIL
2022

COVER PHOTO

Courtesy of Scott Wayne, Morgantown WV, September 2021

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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14. ABSTRACT
This project conducted an energy assessment of the Morgantown (West Virginia) Rapid Transit System, performed upgrades to improve the system's energy efficiency, assessed the current state of the small transit vehicle industry, and provided recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities. The Brevi Bus prototype developed at Ride Solution in Palatka, Florida, was specifically designed to address these unique vehicle requirements of rural transit providers. Further vehicle development based on the Brevi Bus design could dramatically improve upon the features of current vehicle offerings.

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Rural transit, small transit vehicles, transit vehicle procurement, transit vehicle specifications

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

This report documents work performed by West Virginia University to improve the energy efficiency of the Morgantown (West Virginia) Rapid Transit System, to assess the current state of the small transit vehicle industry, and to provided recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities. The Brevi Bus prototype developed at Ride Solution in Palatka, Florida, was specifically designed to address these unique vehicle requirements of rural transit providers. Further vehicle development based on the Brevi Bus design could dramatically improve upon the features of current vehicle offerings.

Executive Summary

This project had two distinct objectives: (1) conducting and energy assessment of the Morgantown Rapid Transit System and performing upgrades to improve the system's energy efficiency and (2) assessing the current state of the small transit vehicle industry and providing recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities.

The West Virginia University (WVU) Personal Rapid Transit (PRT) System is an automated people mover system in Morgantown that connects the WVU Downtown, Evansdale, and Health Sciences campuses and the Morgantown Central Business District (CBD) and serves as the primary mass transit system for the movement of students, employees, and visitors; its operation is vital to the success of WVU. The PRT relies on a hydronic guideway heating system that uses natural-gas-fired boilers to heat a solution of water and propylene glycol circulated through a network of pipes embedded in the guideway running surface. Based on an energy assessment, $414,700 of FTA funding from this grant and $251,000 of local cost-share funding were allocated to replace the boilers in two of the boiler plants used to melt snow and ice from the guideway during the winter months.

The second objective of this project was to assess the current state of the small transit vehicle industry and provide recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities. Rural transit applications have unique vehicle requirements that are not fully addressed by the vehicles currently available on the market. These features include:

- Accessibility for mobility-impaired and handicapped passengers; vehicles with a low, flat floor and a convenient loading ramp are preferred to high floor buses with a wheelchair lift.
- Flexible seating arrangements able to accommodate multiple wheelchair position and rider parcels and packages.
- Maneuverability to navigate narrow roads and varying climate conditions to provide service near the front door of passenger residences.
- High ground clearance to maneuver on rough poorly maintained roads with steep approach and departure angles.
- Low original cost of $250,000–$300,000.

The Brevi Bus prototype developed at Ride Solution in Palatka, Florida, was specifically designed to address these unique vehicle requirements of rural transit providers. Further vehicle development based on the Brevi Bus design could dramatically improve upon the features of current vehicle offerings.

Ease of maintenance, durability, and a long service life are paramount for rural transit vehicles. One of the most common complaints about small transit vehicles is durability. The most common maintenance issues include:

- Galvanic corrosion between aluminum bus bodies and steel chassis components.
- Water infiltration in hidden areas that go unnoticed until significant damage occurs; plywood floors in the buses can rot due to water infiltration.
- Electrical systems that sometimes suffer damage due to chaffing where wiring passes through bulkheads and body panels.
- Bus bodies not adequately designed to endure twisting imposed by terrain in rural areas.
- Strength of tie-downs for wheelchairs in cabins not adequate given increasing size and weight of powered wheelchairs and passengers.
- HVAC system reliability issues.

Many rural transit providers rely on local Original Equipment Manufacturer (OEM) dealerships for powertrain and chassis maintenance. However, most reliability issues are associated with bus bodies and HVAC systems for which there are often no local service facilities. Body and HVAC system repairs must be performed by transit agency personnel, although parts and labor costs are reimbursed under the vehicle warranty coverage. There is a need to improve the reliability and durability of the bodies and HVAC systems of currently available vehicles on the market and to improve training and support to assist rural transit maintenance personnel related to body and HVAC repairs.

Frequently, there is a desire on the part of local governments and transit boards to integrate advanced propulsion technologies into transit fleets to reduce their carbon footprint and environmental impacts and to improve energy efficiency. Available propulsion technologies include alternative fuels such as compressed natural gas (CNG), propane, biodiesel, ethanol, and hydrogen (for combustion as an internal combustion engine fuel) and hybrid-electric and battery-electric buses and fuel cell-electric vehicles. Integration of a new fuel or propulsion technology into an existing transit vehicle fleet presents several challenges, including:

- *Availability or installation of charging and fueling infrastructure* – Installation of a refueling station for alternative-fueled vehicles and charging facilities for battery-electric vehicles represents a significant financial investment.
- *Construction or modification of maintenance facilities* – Introduction of gaseous fuels typically requires that maintenance facilities be upgraded due to the flammability of the gaseous fuel. Modification can include replacing light fixtures, modifying ceiling designs to prevent accumulation

of gaseous fuel, or constructing separate maintenance facilities for the gaseous-fueled buses.

- *Unique vehicle maintenance requirements* – Small transit providers often rely on local OEM dealerships for powertrain maintenance. Alternative fuel and advanced propulsion vehicles have unique maintenance requirements that local OEM dealership maintenance departments may not be able to support. Onsite mechanics will require specialized training and specialized diagnostic equipment and tools to maintain alternative-fueled, hybrid-electric, and battery-electric vehicles. Adequate manufacture support in the form of technical support and timely delivery of parts are also important considerations.
- *Vehicle range* – The distance that an alternative-fueled or battery-electric vehicle can travel must be considered. Fueling and charging facilities for advanced technology vehicles will often be available only at the maintenance depot. Transit vehicle providing paratransit service often travel long distances though rural areas, and vehicle range must have adequate range to meet the service demands.

When considering integration of advanced propulsion technologies, rural transit agencies should favor technologies that have reached technology readiness levels 7–9. Hybrid-electric propulsion is a well-established technology in heavy duty transit and light duty personal transportation. Hybrid-electric vehicles are relatively easy to integrate into an existing transit fleet, can use existing gasoline or diesel fueling infrastructure, and generally do not require battery charging infrastructure. OEM dealerships that sell hybrid-electric vehicles should be equipped to provide powertrain maintenance. Hybrid-electric vehicles can provide improved fuel efficiency compared to conventional internal combustion engine vehicles. CNG- and propane-fueled internal combustion engine vehicle also are mature technologies. Although propane and CNG buses may require some specialized fuel system maintenance, maintenance of an internal combustion engine is similar to maintenance of conventional gasoline or diesel engines and typically requires only a modest investment in specialized diagnostic tools. Battery-electric buses have also reached a stable level of maturity in the heavy-duty bus market. Hydrogen fuel cell buses and hydrogen internal combustion engine buses represent a more challenging technology to implement in small rural transit operations.

The purchase of transit vehicles for rural transit are eligible for funding through Federal Transit Administration (FTA) Section 5311 Formula Grants for Rural Areas program. Under this program, FTA funds 80% of capital projects including vehicle purchases. Vehicle procurements under this program often are executed by state departments of transportation, which develop and distribute vehicle technical specifications and requests for quotes and execute procurement contracts on the behalf of small and rural transit providers in the state. Rural

transit providers contacted by WVU reported that they typically have limited input into the development of vehicle specifications, requests for proposals, and vehicle procurement schedules. Transit managers observed that state procurement departments should communicate with transit providers about the strengths and shortcomings of existing vehicles prior to making new vehicle purchases.

Unlike purchases of large buses, for which detailed guidance on the purchase process and on bus technical specifications are available through the APTA Standard Bus Procurement Guidelines, fewer resources are available to small transit providers to guide the development of technical specifications for small- and medium-size cutaway and body-on-chassis buses. As a result, small- to medium-size cutaway bus specifications vary markedly from state to state. To encourage the development of standardized vehicle technical specifications and procurement guidance, a set of vehicle technical specifications was developed for cutaway buses, provided as an addendum to this report, that include several alternative descriptions for vehicle systems, components, and features and can serve as a starting point for future development of a procurement guidance document for small transit vehicles such as the APTA Standard Procurement Guidelines.

Section 1

Introduction

This project had two distinct objectives: (1) conducting an energy assessment of the Morgantown Rapid Transit System and performing upgrades to improve the system's energy efficiency and (2) assessing the current state of the small transit vehicle industry and providing recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities.

Morgantown Personal Rapid Transit (PRT) System Upgrades

The West Virginia University (WVU) PRT System is an automated people mover system in Morgantown that connects the WVU Downtown, Evansdale, and Health Sciences campuses and the Morgantown Central Business District (CBD) and serves as the primary mass transit system for the movement of students, employees, and visitors; its operation is vital to the success of the University. The PRT was designed for full winter weather operation using an independent guideway heating system that uses gas-fired boilers to keep the running surface of the guideway free of snow and ice. Based on an energy assessment, $414,700 of FTA funding from this grant and $251,000 of local cost share funding were allocated to replace the boilers in two of the boiler plants used to melt snow and ice from the guideway during the winter months.

Advanced Small Transit Vehicle Study

The rapid growth of the small transit vehicle market is driven by three main factors—1) the initiation and expansion of rural transit systems, 2) the growth of transit agency-supported services for persons with disabilities as a result of Americans with Disabilities Act (ADA) paratransit requirements, and 3) downsizing of vehicles in urban and smaller urban areas to reduce operational costs and respond to demand pattern fluctuations [1]. For many years, federal funding primarily supported the purchase of large buses. "In a 30-year period from 1965 to 1995, nearly 85% of all federally funded buses were 35-40 feet in length or longer articulated buses" [1]. However, in recent years only about a third of all federally-assisted purchases were for large vehicles [2].

Peterson [1] identified common issues that inhibit the small transit vehicle industry from reaching peak efficiency—1) quality and reliability concerns with the available small transit vehicles, 2) high maintenance costs, 3) widely varying procurement policies, procedures, and guidelines at state and local levels, and 4) production fluctuations stemming from demand uncertainties, the relatively small size of individual orders, and the large number of competitors in the market. The American Public Transportation Association (APTA) publishes Standard Bus Procurement Guidelines for heavy-duty transit buses

[3] that outline a standardized request for proposal (RFP) for a negotiated bus procurement contracts including vehicle technical specifications. The APTA guidelines do not address small light- and medium-duty minivans, vans, cutaway buses, and body-on-chassis buses commonly used by small transit agencies that provide public transit in rural areas.

The second objective of this project was to assess the current state of the small transit vehicle industry and provide recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities. Although it was not within the scope of this project to develop formal procurement guidelines for small transit vehicles, a template with sample vehicle specifications drawn from multiple publicly available state requests for quotes was developed to serve as a starting point for a broader initiative by transit industry organizations such as APTA or the Community Transportation Association of America (CTAA) to develop procurement guidelines for small transit vehicle similar to the APTA Guidelines [3].

Section 2

PRT Energy Assessment and Guideway Heating Upgrades

Background

WVU originally established this research program to perform upgrades of the Morgantown PRT System (M-PRT) to improve energy efficiency. WVU's PRT System, shown in Figure 2-1, is an automated people mover system in Morgantown that connects the WVU Downtown, Evansdale, and Health Sciences campuses and the Morgantown CBD and serves as the primary mass transit system for the movement of students, employees, and visitors; its operation is vital to the success of the University. Originally designed and developed in the early 1970s by Boeing as a demonstration project, the PRT is a public transportation service that receives capital funding assistance from FTA and consists of a fleet of 71 electronically-powered, rubber-tired vehicles operating on 8.7 miles of dedicated guideway. Each car can accommodate 8 seated passengers and 12 standing passengers, and cars can reach a maximum speed of 30 mph; a ride from the Walnut Street station to the Health Sciences station takes 11.5 minutes. The M-PRT system began passenger service in 1975 and has transported over 83 million people traveling over 22 million miles along its guideway. Approximately 15,000 people per day ride the M-PRT during the WVU academic school year. The system was designed for full winter weather operation using an independent guideway heating system that uses gas-fired boilers to keep the running surface of the guideway free of snow and ice; it also employs an electric power rail heating system to prevent ice deposits on the power feed system in adverse weather conditions. System operation during winter months requires triple the utility costs of equivalent operation during warm weather months.

Planning for long-term, cost-effective operation of the M-PRT dictated that a detailed energy management program be initiated. Beginning in 2001, WVU began contemplating a major modernization effort; an energy assessment analysis was completed, and the results and findings were summarized in an FTA report, FTA-WV-26-7006. Recommendations were assembled into a comprehensive energy management program to reduce operating costs and help ensure high system reliability in the future. Based on this energy assessment, $414,700 of FTA funding from this grant and $251,000 of local cost-share funding were allocated to replace the boilers in two of the boiler plants used to melt snow and ice from the guideway during the winter months.

Energy Assessment Study

In the first phase of this project, a complete energy assessment audit of the PRT system was conducted. The audit identified all energy loads in the

system including vehicle usage, fixed facility usage, mission critical control system usage, and winter operational loads. Complete usage patterns were developed and summarized based on existing utility data and collection of load analysis data. The analysis of utility costs focused on each of the major energy-consuming systems. The energy assessment identified four major areas for significant upgrades—guideway heating system, power rail heating system, HVAC systems in the electronics rooms at each of the five passenger stations, and vehicle propulsion and control systems. Upgrades to the vehicles and Automatic Train Control (ATC) system were not within the scope of this project and were addressed in separate modernization campaign. The energy assessment results indicated that utility costs could be reduced by 26% by completing a series of upgrades at a cost of $849,000. The savings represented a reduction of approximately 3.5% in the system operating budget. Upgrades to the guideway heating system were undertaken with funding from this project.

Figure 2-1 *Morgantown PRT System Beechurst passenger station*

PRT Guideway Heating System

To enable operation in winter weather, the PRT guideway running surfaces must remain clear of snow and ice for safe operation. The guideway heating system is a hydronic system that uses natural-gas-fired boilers to heat a solution of water and propylene glycol circulated through a network of pipes embedded in the guideway running surface. The 8.7-mile guideway is divided into seven heating zones serviced by four boiler plants. Each boiler plant services only its own zones; the service is not manifolded to adjacent zones. The water and glycol solution is pumped through the guideway at approximately 140 °F and 100 psi, and the boilers are controlled manually from the central control facility.

The control system allows the system operator to control the number of boilers in operation at each plant and whether the boilers are in low or high fire mode. The response time for the system to reach operating temperature ranges from 60–90 minutes. The system can be cycled on and off to maintain sufficient deicing of the guideway surface.

Temperature sensors embedded in the guideway display the running temperature to a monitoring computer system. During snow and ice conditions, the temperature in the coldest zones of the guideway is maintained between 40 °F and 43 °F. All boilers perform the same function of discharging the propylene glycol-water mixture at 140 °F. Pump discharge temperatures are maintained by a lead-lag sequence control system. Operational boilers are added or subtracted as necessary, and firing rates are modulated as appropriate to maintain guideway temperature. Each boiler plant was originally equipped with Cleaver-Brooks Mark 4 boilers. Supplemental equipment includes expansion tanks pressurized with nitrogen that maintains constant pressure in the boilers and an automatic boiler feed system that maintains an acceptable fluid level in the expansion tanks.

Although the guideway heating system was effective and reliable, the 34-year-old boilers were not as efficient, as newer technology boilers and degradation over time had significantly reduced their efficiency. At boiler plant number 1, one boiler was warped; at plants 2 and 4, deposits in the boiler tubes were reducing coolant flow. Tubes had been drilled out and manually cleaned in the past, but the numerous repairs had resulted in tubes walls being too thin to repair. Consequently, boiler plant number 3 was upgraded to more modern Flextube-type boilers in 2009. Newer Cleaver-Brooks Flextube boilers are designed with larger, serpentine-tangent tubing to minimize potential thermal shock damage due to water temperature fluctuation. Other features, such as modular casing design, assist in installation and maintenance.

PRT Boiler Replacement

The boilers in boiler plants number 1 and 2 were replaced under this grant. Replacement of the boilers at each plant involved removal of the existing boilers, installation of a new roof to accommodate the taller height of the replacement boilers, interior preparations, fabrication of the new boilers, and installation. Building modification and boiler installation were performed by Pine Hollow Construction. FTA funds in the amount of $414,700 were expended to purchase the new boilers, and WVU expended $253,000 of local cost share to pay for the removal of the existing boilers, building modifications, and installation of the new boilers.

Ongoing and Future PRT System Upgrades

In 2009, WVU engaged Gannett Fleming, an internationally-recognized transit consultant, to develop a PRT Master Plan as a roadmap for system modernization. The plan concluded that the PRT was unsustainable using its current operation technologies and vehicles and identified major needs essential to continued operation of the system. A detailed assessment of the PRT infrastructure and operation, public input, and a life cycle cost analysis led to a recommendation to purchase and install a new ATC system, upgrade the guideway, and replace the existing vehicles.

WVU embarked on a three-phase modernization program. Phase 1 targeted replacement of the on-board vehicle computer systems. Although located on each vehicle, the vehicle control and communication system (VCCS) is part of the ATC system. Replacement of the on-board computer and propulsion control system in each vehicle is intended to extend the life of the existing vehicle fleet pending replacement in a later phase of the modernization plan. Phase 1 was authorized by the WVU board of Governors in 2012 and was completed in 2016 at a cost of approximately $15 million.

Phase 2 targeted redesign and replacement of the ATC system, replacement of substation and electrical gear, and repair of a roadway underpass. WVU contracted with Thales Corporation to develop an ATC system based on its proven fixed-block technology with added features that mimic the original PRT system's functionality. The installation of the new ATC included new vehicle controllers, wayside and station computer control equipment, central control equipment, and fare gates. The new ATC replaced the deteriorated in-track communication loops with radio frequency communications, thereby reducing maintenance needs and reliability problems. The ATC upgrade was completed in the summer of 2018 at an approximate cost of $52.6 million.

The final phase, Phase 3, will target replacement of the entire PRT vehicle fleet and address needed repairs to the PRT guideway. The estimated cost of Phase 3 is $34.3 million, and the time frame for completion has not yet been determined.

Section 3

Advanced Small Transit Vehicle Technology Study

Background

Due to changing national energy and public transportation priorities, WVU was asked by FTA to modify the project scope to better align the research program to FTA's strategic research goals and to increase the national relevance of the effort. WVU was tasked to study ways to improve the features, utility, reliability, and procurement processes of small transit vehicle used to provide transit service in small rural communities.

For many years, federal funding primarily supported the purchase of large buses. "In a 30-year period from 1965 to 1995, nearly 85% of all federally funded buses were 35-40 feet in length or longer articulated buses" [1]. However, in recent years only about a third of all federally-assisted purchases were for large vehicles [2]. The rapid growth of the small transit vehicle market is driven by three main factors—1) the initiation and expansion of rural transit systems, 2) the growth of transit agency-supported services for persons with disabilities as a result of ADA paratransit requirements, and 3) downsizing of vehicles in urban and smaller urban areas to reduce operational costs and respond to demand pattern fluctuations [1]. The supply chain for small transit vehicles has not received the same attention as heavy-duty transit buses. Numerous resources such as the APTA Standard Bus Procurement Guidelines [3] exist to assist with the development of vehicle procurement RFPs for 30-ft or larger transit buses. Similar resources to assist with the procurement of small transit vehicles are not as readily available.

Peterson [1] identified common issues that inhibit the small transit vehicle industry from reaching peak efficiency—quality and reliability concerns with the available small transit vehicles; high maintenance costs; widely varying procurement policies, procedures, and guidelines at state and local levels; and production fluctuations stemming from demand uncertainties, the relatively small size of individual orders, and the large number of competitors in the market. Many of these same issues persist today. The second objective of this project was to assess the current state of the small transit vehicle industry and provide recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities. Although it is not within the scope of this project to develop formal procurement guidelines for small transit vehicles, a major goal of this demonstration program was to provide specific relevant data and analysis to inform the future development of procurement guidelines and improve vehicle procurement practices for small rural transit providers.

Advanced Small Transit Vehicle Technology Demonstrations

At the outset of the advanced small transit vehicle study, FTA identified three small rural transit fleets participating in FTA-funded projects to implement advanced small transit vehicles into their fleet. The intent was to collect operational data and document start-up experiences to evaluate the advantages and disadvantages of the advanced technology vehicles with respect to similar baseline vehicles, assess technology suitability and readiness for integration into small rural transit applications, and develop best practices for implementing new technologies at small and rural transit agencies. The original data collection plan was modeled after the National Renewable Energy Laboratory's (NREL) Transit Bus Evaluations of heavy-duty full-size (30-ft or longer) transit buses. The objectives of data collection portion of the study were to:

- Provide credible data analysis results to small transit to demonstrate the feasibility of implementing the target technology into small rural transit fleets.
- Provide results on vehicle performance, availability, reliability, capital costs of vehicles facilities and infrastructure, maintenance requirements, and operating costs including fuel costs, maintenance costs, and infrastructure operating and maintenance costs.
- Document start-up experiences and best practices for integrating new vehicle, fuel, and powertrain technologies into an existing small transit fleet.

Data Collection Protocol

The data collection protocol was based on the NREL protocol [4] designed to collect several levels of data, as follows:

1. Description of the transit agency profile, types of transit service provided, service area, population, and ridership.
2. Detailed descriptions of the evaluation vehicles and baseline comparison vehicles including system and component level information.
3. Description of baseline operation including route information, vehicle assignments, and duty-cycle characteristics.
4. Descriptions of facilities and infrastructure built specifically to support the advanced technology vehicles including fueling station, maintenance facilities, modifications to existing structures to accommodate the new technology vehicles.
5. Capital costs for vehicles, facilities, supporting equipment, and training.
6. Vehicle availability for passenger service, reliability, and road calls.

7. Scheduled and unscheduled maintenance requirements, maintenance costs, and warranty repairs.
8. Fuel/energy use and cost.
9. Implementation experience, lessons learned, and best practices.

Ride Solution, Inc.

Transit Agency Profile

Headquartered in Palatka, Florida, Ride Solution provides transportation services in Putnam County. The company was established to provide a routed, scheduled, flex-route service to transport riders to and from public services such as Medicare offices, doctor's offices, shopping centers etc. At the time data were collected, Ride Solution operated 38 routes and paratransit services, as shown in Table 3-1. A significant number of Ride Solution passengers were older adults, persons with disabilities or with mobility challenges, and non-ambulatory and ambulatory passengers. The agency's operation strategy resulted in a need for the transit vehicles to pick many passengers up at or near the door of their residence. The vehicles needed to accommodate wheelchair and stretcher-bound passengers as well as ambulatory riders.

Table 3-1 *Ride Solution Routes and Vehicle Assignments (September 2, 2011)*

Route	Route Name	Time	Vehicle
10-1 / 10-2	ARC Ambulatory	6:45-8:45AM / 1:45-3:45PM	1
12-1 / 12-2	ARC Ambulatory	6:30-8:15AM / 1:45-3:00PM	2
B-AM	City Bus	7:15AM-2:15PM	40
B-PM	City Bus	2:15PM-5:15PM	40
C-AM	Crescent City Feeder	5:00AM-12:00PM	20
C-PM	Crescent City Feeder	1:00PM-3:00PM	20
D-1	City Wheelchair	5:15AM-1:00PM	12
D-2	City Wheelchair	9:00AM-12:PM	4
D-3	City Wheelchair	9:00AM-4:30PM	27
E1-AM	Interlachen Express	5:40AM-3:00PM	16
E2-AM	Satsuma Express	6:15AM-5:00PM	34
Feeder	Interlachen Feeder	6:00AM-4:00PM	3
G-AM	Gainesville Bus	5:40 AM-6:30PM	12, 30
H	East Palatka		
I	Interlachen Dialysis	8:30-AM-4:00PM	2
K	Bardin	8:15AM / 2:30 PM	2
M-1 / M-2	JTA		
14-1	Silver Lake	8:30 AM	23
14-2	Silver Lake (Returns)	3:00 PM	23

Route	Route Name	Time	Vehicle
16-1	ARC – San Mateo	6:30AM-8:00 AM	23
16-2	ARC San Mateo	2:00PM-3:30PM	23
18-1 / 18-2	ARC Non-Ambulatory East	6:30-8:00AM	14
20-1 / 20-2	ARC Non-Ambulatory West	6:15-8:30AM /1:15-3:30PM	26
On Call	Jacksonville		
S			
T	Stretcher Van		25
UO	Crescent City Wheelchair		
U-AM	Crescent City Wheelchair	9:30AM-11:15AM	1
U-PM	Crescent City Wheelchair	4:00PM-7:00PM	23, 22
G-Late	Gainesville Bus – PM Returns	4:45PM-6:00PM	26
22-1	South Putnam ARC	6:30AM-8:00AM	22
22-2	South Putnam ARC	1:30PM-3:30PM	22
W-1	ARC Interlachen	8:30AM-9:45AM	54
W-2	ARC Interlachen	2:30PM-3:30PM	12
On Call	After Hours Stretcher	On-Call	25
JTA-AM	Choice Ride	5:15AM-8:15AM	29
JTA-AM	Choice Ride	4:15PM-6:30PM	29
Greyhound	Palatka-Gainesville-St Augustine	6:15AM-6:00PM	30
Greyhound	Palatka-Orange Park-Jacksonville	6:30AM-6:00PM	32

The Ride Solution rural service area comprised primarily or unpaved roads. The terrain and roadways required transit vehicles with a relatively short wheelbase for maneuverability on narrow roadways with tight turns and access roads within mobile home communities. Transit vehicles with a tight turning radius, short overhangs, and large approach and departure angles were desirable. Given that Ride Solution provided service to a significant number of mobility-challenged riders, vehicles with low, flat floors were preferred; however, small low-floor buses were not available in the marketplace. The industry standard transit vehicle for small rural transit applications was the 23-ft van cutaway typically with 12 ambulatory and 2 wheelchair positions. Ride Solution experimented with several production and modified transit bus models including cutaway and body-on-chassis models, a Bluebird Citybird, a General Motors RTS bus that was shortened from 35 to 30 ft by removing a section between the front and rear axles, and an RTS bus that was shortened from 35 to 25 ft. Finding deficiencies in these models, Ride Solution received FTA funding to develop a prototype low-floor, rear-engine, short-overhang bus specifically designed for rural transit service. Two prototypes of the Brevi Bus were designed, built, and operated within the Ride Solution transit service.

Vehicle Technology Descriptions

Ride Solution developed two prototypes of the Brevi Bus. It was designed as a low-floor flexible seating bus; a 22-ft version was designed to accommodate 21 passengers and a 25-ft version would accommodate 25 seated passengers. The first Brevi Bus prototype, shown in Figure 3-1, was built on a modified medium-duty International truck chassis. The donor chassis provided the frame rails, engine, aftertreatment system, steering, and drive axles. The engine and transmission were relocated from the front of the chassis to the rear and connected to the rear drive axle by a proprietary 90-degree drive system. The dashboard and driver controls were also modified. The bus body consisted of a stainless-steel unibody frame and fiberglass panels. The second Brevi Bus prototype incorporated some design modifications based on lessons learned from fabrication of the first prototype. The second prototype was withheld from revenue service for testing at the Altoona Bus Research and Testing Center. The initial intent was to build 5 prototype buses followed by 20 prototype buses; however, only two prototypes were completed.

Figure 3-1 *Ride Solution Brevi Bus prototype low-floor transit bus*

Ride Solution operated 34 vehicles including 14 vans, 9 buses capable of transporting 30+ passengers, 1 trolley, 8 cutaway buses, and the 2 Brevi Bus prototypes. The buses identified as baseline buses were:

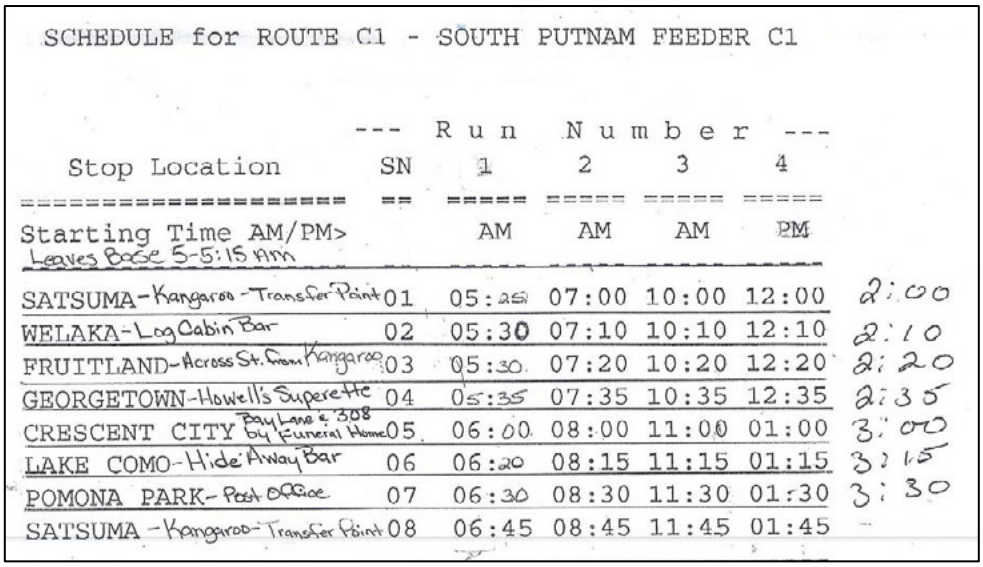
- Bus No. 20 – International MFV cutaway bus, 24 passengers with 2 wheelchair positions
- Bus No. 31 – International MFV cutaway bus, 24 passengers with 3 wheelchair positions
- Bus No. 21 – Modified GMC RTS bus, 27 passengers with 2 wheelchair positions
- Bus No. 30 – Eldorado Bus, 29 passengers with wheelchair positions

Refueling and Maintenance Facilities

The Brevi Bus prototype buses used the same diesel fueling and maintenance facilities as the existing buses; no special modifications to existing facilities were required. The Brevi Bus prototypes were also fabricated in the existing bus maintenance facility.

Route Assignments

Ride Solution identified Route C1, the South Putnam Feeder route, and Route E1, the Cross County Interlachen Express route, as the best routes for which to collect data on the operation of the Brevi Bus prototype. Routh C1 was a circular route driven 4–5 times per day and serviced Satsuma, Georgetown, and Crescent City and returned to Satsuma. Driving time was typically 1 hour and 45 minutes, and route distance was approximately 50–60 miles. The route often included deviation onto small side roads to pick up and drop off passengers. Address deviations were recorded on the operator manifest. Figure 3-2 shows a sample of the route schedule for the C1 Route. Route E1 was also a circular typically driven four times per day servicing Satsuma, Palatka, and Interlachen and returning to Satsuma. Driving time was typically 2 hours and 45 minutes, and the route covered 50–60 miles. On most days, there were extra stops and deviations. Most roadways on Route E1 were paved.



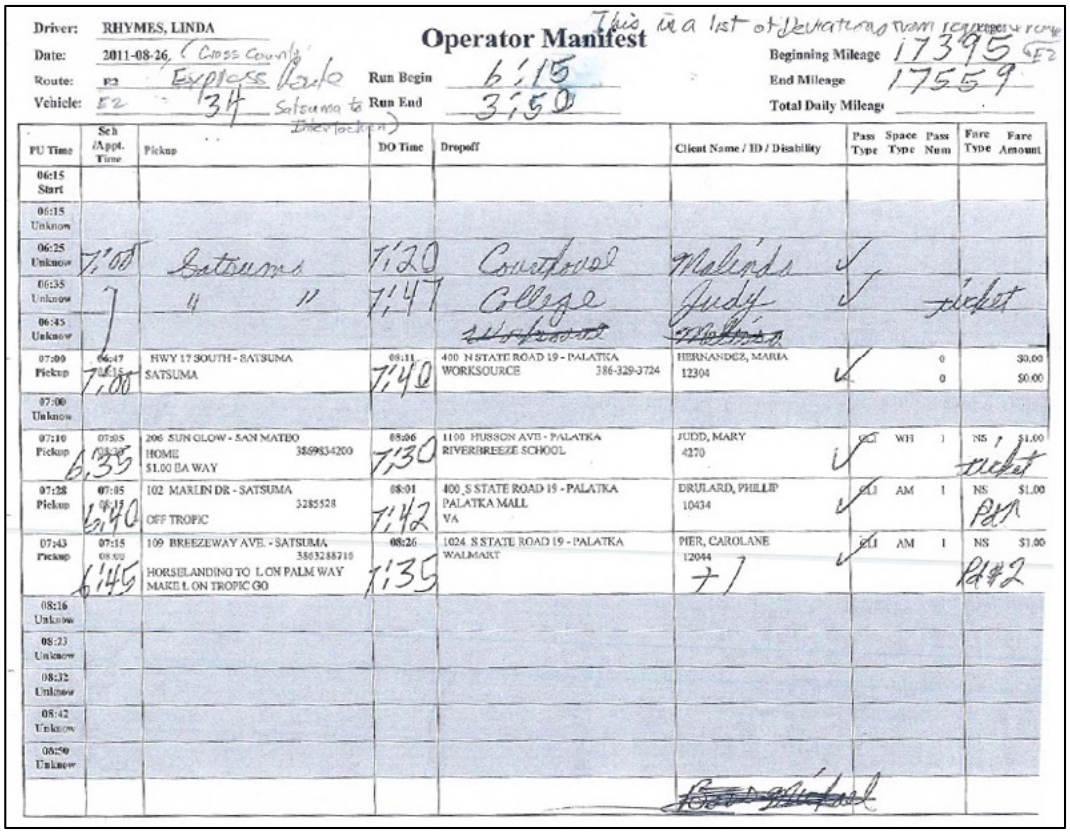
SCHEDULE for ROUTE C1 - SOUTH PUTNAM FEEDER C1

Stop Location	SN	Run Number 1	2	3	4	
Starting Time AM/PM> Leaves Base 5-5:15 AM		AM	AM	AM	PM	
SATSUMA-Kangaroo-Transfer Point	01	05:25	07:00	10:00	12:00	2:00
WELAKA-Log Cabin Bar	02	05:30	07:10	10:10	12:10	2:10
FRUITLAND-Across St. from Kangaroo	03	05:30	07:20	10:20	12:20	2:20
GEORGETOWN-Howell's Superette	04	05:35	07:35	10:35	12:35	2:35
CRESCENT CITY Bay Lane & 308 by Funeral Home	05	06:00	08:00	11:00	01:00	3:00
LAKE COMO-Hide Away Bar	06	06:20	08:15	11:15	01:15	3:15
POMONA PARK-Post Office	07	06:30	08:30	11:30	01:30	3:30
SATSUMA-Kangaroo-Transfer Point	08	06:45	08:45	11:45	01:45	

Figure 3-2 *Sample of C1 Route schedule with dispatcher annotations*

It is notable that dispatchers often used handwritten annotations on printed schedules to document daily alterations of the route schedules. Daily deviations along the route were documented on the driver's manifest; Figure 3-3 shows a sample of a driver manifest for Route E1. The manifest also documented starting and ending odometer readings. The handwritten hardcopy driver manifests

were filed daily in the folder for each route and maintained in a filing cabinet. If the vehicle was assigned to a different route from day-to-day, then the driver manifest for that day was filed with records from that route. Therefore, to document vehicle miles traveled (VMT), the paper records from each route had to be searched to compile VMT data for a specific vehicle. The lack of electronic records presented significant challenges to the data collection effort.



Driver: RHYMES, LINDA
Date: 2011-08-26
Route: E2
Vehicle: E2

Operator Manifest

Run Begin 6:15
Run End 3:50
Beginning Mileage 17395
End Mileage 17559
Total Daily Mileage

PU Time	Sch Appt. Time	Pickup	DO Time	Dropoff	Client Name / ID / Disability	Pass Type	Space Type	Pass Num	Fare Type	Fare Amount
06:15 Start										
06:15 Unknow										
06:25 Unknow	7:05	Satsuma	7:20	Courthouse	Malinda					
06:35 Unknow		4 "	7:47	College	Judy				ticket	
06:45 Unknow										
07:00 Pickup	06:47 7:00	HWY 17 SOUTH - SATSUMA SATSUMA	08:11 7:40	400 N STATE ROAD 19 - PALATKA WORKSOURCE 386-329-3724	HERNANDEZ, MARIA 12304			0 0		$0.00 $0.00
07:00 Unknow										
07:10 Pickup	07:05 6:35	206 SUN GLOW - SAN MATEO HOME $1.00 EA WAY 3869834200	08:06 7:30	1100 HUSSON AVE - PALATKA RIVERBREEZE SCHOOL	JUDD, MARY 4270		WH	1	NS ticket	$1.00
07:28 Pickup	07:05 6:40	102 MARLIN DR - SATSUMA OFF TROPIC 3285528	08:01 7:42	400 S STATE ROAD 19 - PALATKA PALATKA MALL VA	DRULARD, PHILIP 10434		AM	1	NS PAR	$1.00
07:43 Pickup	07:15 6:45	109 BREEZEWAY AVE. - SATSUMA HORSELANDING TO L ON PALM WAY MAKE L ON TROPIC GO 3863288710	08:26 7:35	1024 S STATE ROAD 19 - PALATKA WALMART	PIER, CAROLANE 12044 +1		AM	1	NS PAR#2	$1.00
08:16 Unknow										
08:23 Unknow										
08:32 Unknow										
08:42 Unknow										
08:50 Unknow										

Figure 3-3 *Sample driver manifest for Route E1 showing deviations*

Bus Use and Fuel Efficiency

Mileage accumulation and vehicle availability for service are indications of vehicle reliability. Buses undergoing maintenance or repairs are deemed unavailable for service at morning pull-out. Fuel efficiency is generally evaluated based on daily vehicle miles traveled (VMT) and fuel dispensing records. Fuel efficiency directly relates to operating cost.

WVU attempted to document monthly VMT for the Brevi Bus and baseline buses by making several visits to Ride Solution to collect records, but the lack of detailed recordkeeping by the transit agency made it impossible to reliably document VMT and fuel efficiency. WVU ultimately abandoned the effort.

Maintenance Analysis

Ride Solution tracked scheduled and unscheduled maintenance through work orders. All vehicles underwent preventive maintenance and inspection every 30 days. Work orders contained a description of the work performed along with parts, and labor costs were filed in paper form according to vehicle. Figures 3-4, 3-5, and 3-6 show samples of a maintenance work order, a service worksheet, and a30-day vehicle inspection worksheet.

RIDE SOLUTION

Number: 5,869

WORK ORDER

Customer:	RIDE SOLUTION						
Equipment:	016	Mileage:	207327	Service Type:	A	Date:	01/20/2011
Clerk/Name:	MIKE MCLAUGHLIN						

Work Requested:

PERFORM A 30 DAY INSPECTION

Comments and Work Performed:

CHANGED ENGINE OIL AND FILTER. REPLACED FUEL FILTERS. REPAIRED FAN CLUTCH. REPAIRED SEVERAL AIR LEAKS. REPAIRED COOLANT LEAK. REPLACED COOLANT FILTER. REPLACED AIR FILTER. ADJUSTED BRAKES. INSPECTED AND LUBED FRONT END AND DRIVE LINE. ADDED BUG WASH TO W/S WASHER TANK. 30 DAY INSPECTION COMPLETE.

Material, Labor & Other Costs:

Part Number/Employee	Description	Quantity	Price/Rate	Total	
MIKE MCLAUGHLIN	01/20/2011	8.50	20.00	170.00	L
01/20/2011	1649 OIL FILTER	1.00	22.48	22.48	O
01/20/2011	SAE 40 OIL	24.00	2.24	53.76	O
01/20/2011	3358 FUEL FILTER	1.00	8.43	8.43	O
01/20/2011	4071 COOLANT FILTER	1.00	12.37	12.37	O
01/20/2011	6737 AIR FILTER	1.00	35.50	35.50	O
01/20/2011	3370 FUEL FILTER	1.00	11.78	11.78	O
01/20/2011	BUG WASH	1.00	2.74	2.74	O

Work Order Totals:

Total Parts:	0.00
Total Labor:	170.00
Total Other:	147.06
0.000% Total Tax:	0.00
Total W/O Cost:	317.06

Figure 3-4 *Sample Ride Solution vehicle maintenance work order*

RIDE SOLUTION

SERVICE WORKSHEET

Customer:	RIDE SOLUTION	Date:	01/20/2011	Work Order #:	5869
Equipment:	016	Mileage:	207327	Service Type:	A

Work Requested:

PERFORM A 30 DAY INSPECTION

HUB- 217340

Problems Found	Work Performed and Comments
	CHANGED ENGINE OIL + FILTER-
	REPLACED FUEL FILTERS-
	REPAIRED FAN CLUTCH
	REPAIRED SEVERAL AIR LEAKS-
	REPAIRED COOLANT LEAK - REPLACED
	COOLANT FILTER-
	REPLACED AIR FILTER
	ADJUSTED BRAKES-
	INSPECTED AND LUBED FRONT END
	AND DRIVE LINE-
	ADDED BUG WASH TO W/S WASHER
	TANK-
	30 DAY INSPECTION - COMPLETE-

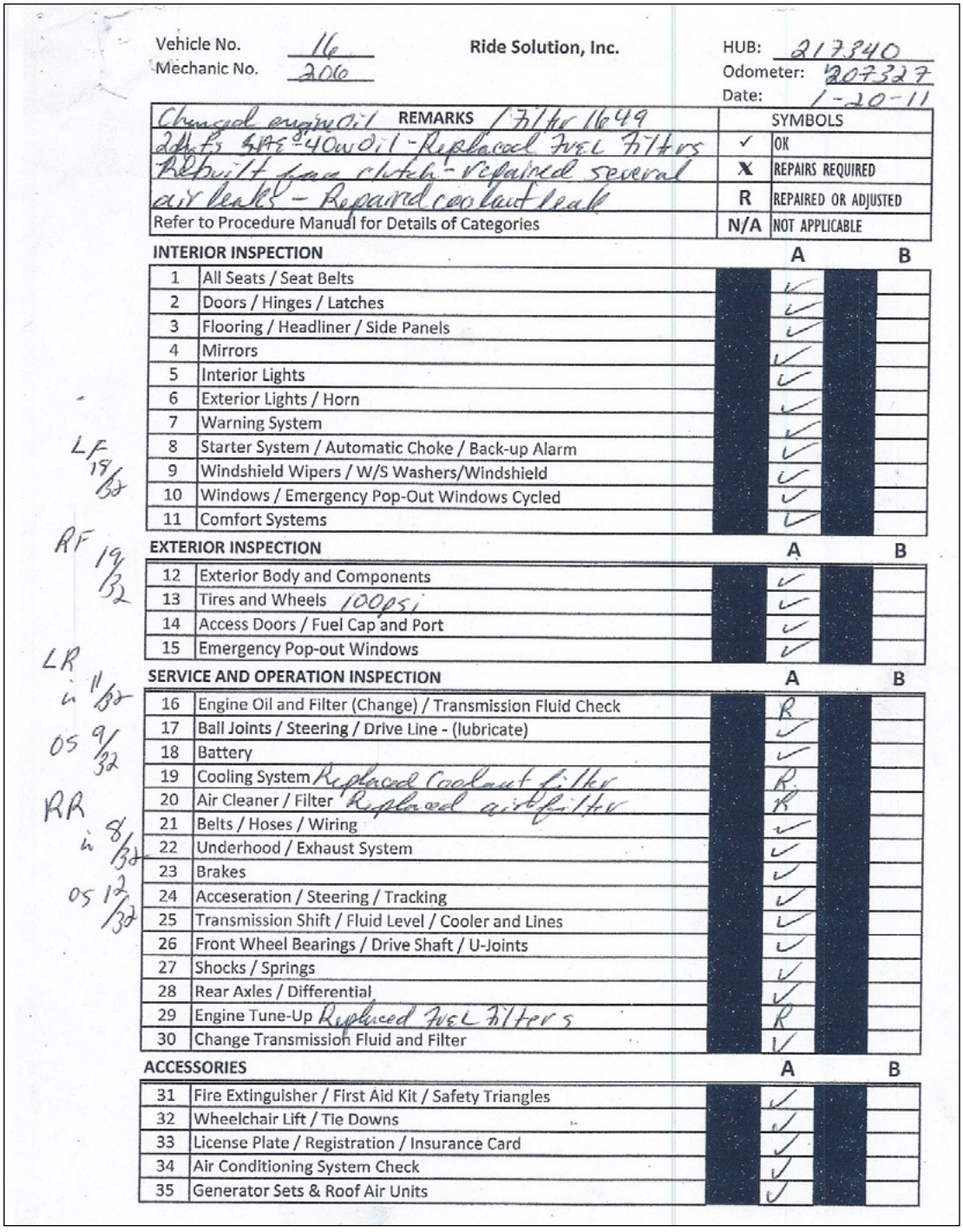
Parts Used

Qty	Part #	Cost Each
1	1649 OIL FILTER	22.48
24	SAE 40 OIL	2.24 QT
1	3358 Fuel FILTER	8.43
1	4071 coolant FILTER	12.37
1	6737 AIR FILTER	35.50
1	3370 Fuel FILTER	16.28
1	BUG WASH	2.74

Mechanic	206	Hours	8.5
Mechanic		Hours	
Mechanic		Hours	
Mechanic		Hours	

Signature X Mike MC 1-20-11

Figure 3-5 *Sample Ride Solution vehicle service worksheet*



Vehicle No. 16 Ride Solution, Inc. HUB: 217340
Mechanic No. 206 Odometer: 207327
Date: 1-20-11

REMARKS
Changed engine oil / filter 1649
20 lbs SAE-40w Oil - Replaced fuel filters
Rebuilt fan clutch - repaired several air leaks - Repaired coolant leak
Refer to Procedure Manual for Details of Categories

SYMBOLS
✓ OK
X REPAIRS REQUIRED
R REPAIRED OR ADJUSTED
N/A NOT APPLICABLE

	INTERIOR INSPECTION	A	B
1	All Seats / Seat Belts	✓	
2	Doors / Hinges / Latches	✓	
3	Flooring / Headliner / Side Panels	✓	
4	Mirrors	✓	
5	Interior Lights	✓	
6	Exterior Lights / Horn	✓	
7	Warning System	✓	
8	Starter System / Automatic Choke / Back-up Alarm	✓	
9	Windshield Wipers / W/S Washers/Windshield	✓	
10	Windows / Emergency Pop-Out Windows Cycled	✓	
11	Comfort Systems	✓	

LF 19/32

	EXTERIOR INSPECTION	A	B
12	Exterior Body and Components	✓	
13	Tires and Wheels 100psi	✓	
14	Access Doors / Fuel Cap and Port	✓	
15	Emergency Pop-out Windows	✓	

RF 19/32

LR in 11/32
OS 9/32

	SERVICE AND OPERATION INSPECTION	A	B
16	Engine Oil and Filter (Change) / Transmission Fluid Check	R	
17	Ball Joints / Steering / Drive Line - (lubricate)	✓	
18	Battery	✓	
19	Cooling System Replaced Coolant filter	R	
20	Air Cleaner / Filter Replaced air filter	R	
21	Belts / Hoses / Wiring	✓	
22	Underhood / Exhaust System	✓	
23	Brakes	✓	
24	Acceseration / Steering / Tracking	✓	
25	Transmission Shift / Fluid Level / Cooler and Lines	✓	
26	Front Wheel Bearings / Drive Shaft / U-Joints	✓	
27	Shocks / Springs	✓	
28	Rear Axles / Differential	✓	
29	Engine Tune-Up Replaced fuel filters	R	
30	Change Transmission Fluid and Filter	✓	

RR in 8/32
OS 12/32

	ACCESSORIES	A	B
31	Fire Extinguisher / First Aid Kit / Safety Triangles	✓	
32	Wheelchair Lift / Tie Downs	✓	
33	License Plate / Registration / Insurance Card	✓	
34	Air Conditioning System Check	✓	
35	Generator Sets & Roof Air Units	✓	

Figure 3-6 *Preventive maintenance inspection record*

Ride Solution was able to provide some summary statistics regarding frequency and miles between maintenance for the Brevi Bus and several baseline buses. Table 3-2 shows total accumulated mileage, number of work orders, and mileage between maintenance for the Brevi Bus and three baseline buses. The most

relevant comparison is between the Brevi Bus and International MFV Bus 31, as they have relatively similar accumulated miles. The miles between maintenance of the Brevi Bus is about half that of Bus 31. Reasons for maintenance included vehicle inspection, fluid level check, oil change, repair due to failure, or complaints from drivers. The mileage between oil changes of the Brevi Bus and Bus 31 was similar, at 5,099 and 5,890 miles respectively. WVU attempted to collect more detailed maintenance records for the Brevi Bus prototype and baseline buses, but the success of the data collection process was limited by the paper records inconsistency of records and the manual filing process.

Table 3-2 *Summary Maintenance Statistics for Ride Solution Buses*

Bus No.	Bus	Date Range	Total Work Orders	Total Mileage	Mileage/ Service Order
20	International MFV	07/2009-03/2012	188	81,604	434.1
21	GM RTS	01/2005-03/2012	266	93,248	350.5
31	International MFV	01/2011-08/2011	25	20,396	815.8
60	Brevi Bus	07/2011-02/2012	37	17,671	477.6

Altoona Testing of Second Brevi Bus Prototype

The Surface Transportation and Uniform Relocation Assistance Act (STURAA) of 1987 established a requirement for all new model transit buses to be tested prior to purchase with federal funds [5]. The Bus Research and Testing Center operated by the Penn State Larson Transportation Institute in Altoona, Pennsylvania, tests buses for maintainability, reliability, safety, performance, structural integrity and durability, fuel/energy economy, noise, brake performance, and emissions [6]. The data from all the tests are compiled into a test report made available to the manufacturer to provide information during the procurement process. There are no minimum performance standards for the tests nor are the tests rated “pass” or “fail.” Prior to purchasing a bus, transit agencies requesting federal funding must obtain a copy of the report for the specific bus model to be purchased using federal funds. The report is considered confidential until the manufacturer gives permission to publish it or until such time as the manufacturer responds to a procurement bid by an FTA-funded recipient.

The second Brevi Bus prototype bus built by Ride Solution was submitted for testing at the Altoona Bus Testing Center in 2012 but was withdrawn from the test program prior to completing the full battery of tests. Manufacturers can withdraw a bus from testing at their discretion. As the Brevi Bus was withdrawn from the testing program, the test report was never released by the manufacturer and was not made publicly available. Therefore, WVU was unable to obtain a copy of the test report or publish any findings from the Altoona testing. The Brevi Bus was never resubmitted for follow-up testing.

Brevi Bus Program Continuation Struggles

In 2012, Ride Solution experienced a significant shortfall in operational funding from the State of Florida. As a result, Ride Solution laid off all shop personnel who were involved in the fabrication and assembly of additional Brevi Bus prototypes and suspended fabrication of two prototype buses; additional Brevi Bus prototypes were not built. Ride Solution also implemented reductions in administrative staff, reducing their ability to collect and maintain operational data records on the Brevi Bus program. Due to the cutbacks in Ride Solution technicians and administrative staff, WVU was unable to acquire substantial operational data from the Brevi Bus program.

Outcomes from Ride Solution Brevi Bus Program

The Brevi Bus was specifically designed to address the unique vehicle requirements of rural transit providers:

- *Accessibility for mobility impaired and handicapped passengers* – Small community and rural transit agencies may have a high percentage of physically-challenged passengers. Vehicles need to have a low floor and a convenient loading ramp for wheelchairs and for passengers who have difficulty traversing steps. The Brevi Bus featured a low floor design.
- *Flexible seating arrangements* – Small community transit agencies may need to accommodate a very high number of wheelchair passengers on some occasions. Many small transit agencies provide door-to-door service for older adult and mobility-impaired passengers between their homes and physician offices, grocery stores, and other retail stores. Consequently, the interior and seating arrangements of the buses must also be able to accommodate rider parcels and packages. The Brevi Bus had specially-designed fold-up seats that easily and quickly allow for five forward-facing wheelchair positions as required.
- *Maneuverability* – Small community and rural transit agencies need a vehicle that has a capacity to carry 20–30 passengers, but the vehicle must be able to maneuver narrow, poorly- maintained streets and roads to provide service to very near the front door of passenger residences. The Brevi Bus was designed to transport 26 passengers and maneuver sharp corners such as those found in some trailer parks common in the Ride Solution service area. It also had a low and narrow profile to adapt to the service environment.
- *High ground clearance* – Poorly-maintained roads in many rural counties and communities require vehicles with a high ground clearance. The Brevi Bus was designed with minimal front and rear overhangs for traversing hilly, washed-out roads with steep approach and departure angles.
- *Low original cost* – The Brevi Bus was estimated to cost $250,000–$300,000, which was less than many comparable vehicles on the market.

- *Ease of maintenance* – Small transit agencies have limited maintenance shop resources, including limited training for their mechanics and limited spare parts storage. The entire engine and transmission of the Brevi Bus were mounted on a cage or stand that slid as a unit on rollers into and out of the vehicle, which allowed good access for maintenance.
- *Durability and a long service life* – One of the most common complaints about small transit vehicles is durability. As most small transit vehicles on the market are light- and medium-duty cutaways and body-on-chassis vehicles, durability and service life are lower than purpose-built heavy-duty transit buses. The Brevi Bus featured a medium-duty truck chassis and powertrain, stainless steel structure, and composite body for increased durability and long life.

Designing and manufacturing a completely new transit bus is a highly ambitious undertaking, particularly for a transit agency with no prior vehicle design and manufacturing experience or vehicle manufacturing equipment and tooling. Although the prototype Brevi Bus conceptually fulfilled most of the desirable vehicle requirements and features for rural transit applications, the prototype vehicle lacked the workmanship, reliability, and durability afforded by an established vehicle OEM. There were some attempts by the Brevi Bus team to recruit an OEM manufacturer to take the prototype design to production, but an arrangement did not materialize.

WVU intended to report the results of the Altoona testing of the second prototype Brevi Bus. However, the prototype vehicle was unable to complete the testing protocol at the Altoona Bus Testing and Research Center and was withdrawn from the testing program. A test report was never publicly released, and WVU researchers were not able to draw any conclusions from the Altoona test program.

This demonstration program also highlighted the difficulties associated with capturing operational and maintenance data from a small transit operator. Small rural transit agencies, some of which are operated by county governments, senior citizen centers/organizations, and independent contractors, operate with lean administrative and maintenance staffs. Such agencies often lack the financial and manpower resources to keep rigorous operational and maintenance records and often do not possess sophisticated commercial operating and maintenance tracking software. WVU struggled to acquire adequate operation and maintenance records for the Ride Solution buses, rendering a data collection protocol similar to that used by the NREL Transit Bus Evaluations programs unworkable. WVU was able to collect only anecdotal information through conversations with Ride Solution administrators and mechanics.

Southeast Area Transit

Transit Agency Profile

Southeast Area Transit (SEAT) provides local transit bus service in a rural setting consisting of eight towns and two cities in a southeastern county of New London, Connecticut. SEAT is a local government agency comprising the towns of East Lyme, Griswold, Groton, Lisbon, Montville, New London, Norwich, Stonington, and Waterford, a service area that covers 3,250 square miles. SEAT receives approximately 70% of its operating revenue from the State of Connecticut but is not a State agency. It operates a flag-stop service along 17 routes with reduced service on weekends and contracts with the Eastern Connecticut Transportation Consortium to provide complementary ADA paratransit service for those who live within ¾ mile of these routes but are unable to use fixed-route services [7].

The 17 fixed routes operated by SEAT include longer corridor-based services and shorter local routes operating within one municipality. The New London Union Station Intermodal Center and the Norwich Intermodal Transportation Center serve as major hubs for the SEAT system, with each serving as a key transfer location, where six or seven routes come together and "pulse," arriving and leaving on the hour to facilitate passenger connections [7]. New London and parts of Norwich and Groton represent the core of the SEAT service area due to the clustering of jobs and population in proximity. Waterford also has areas with high or moderate demand. Several boroughs and key activity centers outside these communities also demonstrate relatively high or moderate transit demand. However, these locations are geographically isolated from other areas of high demand [7]. The service area consists primarily of paved roads suitable for 29–40-ft heavy-duty transit buses.

SEAT operates a fleet of 31 buses consisting primarily of heavy-duty 29-, 35-, and 40-ft buses. ADA paratransit service is provided using five gasoline-powered cutaway buses on Ford E450 chassis. At the time of data collection, the heavy-duty fleet consisted of diesel-powered buses. SEAT was exploring the development a bus rapid transit (BRT) service in its rural transit setting and was considering the purchase of diesel-hybrid electric buses for use in the BRT service. SEAT had not previously operated hybrid electric buses in its fleet.

BRT is a bus-based service designed to provide fast, comfortable, and cost-effective services with features similar to a light rail or metro system. Because it resembles a light rail system, BRT is more reliable and convenient and faster than regular bus services by avoiding the causes that that typically slow regular bus service, such as traffic and passenger queuing onboard the bus to pay their fare. BRT accomplishes these efficiencies through use of dedicated lane and busways, stations typically aligned to the center of the road, off-board fair collection, and fast and frequent operations.

Five essential features define BRT:

- *Dedicated right-of-way* – Bus-only lanes that make for faster travel and ensure that buses are never delayed due to mixed traffic congestion.
- *Busway alignment* – Center-aligned bus lanes or bus-only corridors that keep buses away from busy curbsides where cars are parking, standing, and turning.
- *Off-board fare collection* – Fare collection at stations instead of on the bus, which eliminates the delay cause by passengers waiting to pay on board.
- *Intersection treatments* – Prohibiting traffic turning across a bus lane, which reduces delays caused by crossing traffic; prohibiting crossing traffic is the most important measure for moving buses through intersection.
- *Platform-level boarding* – Stations that are level with the bus for quick and easy boarding, which facilitates fully-accessible boarding for wheelchairs, passengers with disabilities, strollers, and carts with minimal delays.

A 2015 comprehensive operations analysis of SEAT services also identified BRT-type improvements for the route connecting New London and Norwich that could potentially provide fast, frequent service and attract new riders. Recommended improvements included transit signal priority to maintain green traffic signals for buses, queue jump lanes at intersection to improve flow of buses, designation of limited key stops with branded passenger shelters, and designated berths in New London and Norwich [7].

Vehicle Technology Descriptions

SEAT's bus fleet is funded with 80% FTA capital grants and 20% State of Connecticut capital grants. The workhorse buses in SEAT's flag-down fixed-route service are 29-, 35- and 40-ft heavy duty diesel-powered buses. At the time of data collection, the fleet consisted of 2004 and 2006 model year Gillig low-floor 29-ft buses and 2003 and 2005 model year New Flyer low-floor 35- and 40-ft diesel-powered buses. The Gillig buses included ADA wheelchair ramps at the front door and bike racks on the front of the bus. The New Flyer buses were equipped with wheelchair ramps at the rear doors and bike racks on the front of the bus.

The current active bus fleet consists of the following:

- *Nine 2007–2008 New Flyer low-floor 30- and 40-ft clean diesel (Cummins-powered) buses with particulate filters and DOC catalysts*. The buses are equipped with wheelchair ramp and two wheelchair positions. The 30-ft buses seat 29 passengers, and the 40-ft buses seat 38 passengers. The buses are equipped with GFI Cents-A-Bill fare boxes, Apollo security cameras, Motorola two-way radios, Syncromatics GPS, automatic

passenger counters, and two-position front-mounted bike racks. These buses were purchased through a State of Connecticut Bus contract [8].

- *Two 2013 Gillig low-floor BRT diesel hybrid-electric 35- and 40-ft buses*. The hybrid-electric buses are equipped with Cummins diesel engines and BAE Systems series hybrid-electric drive systems. The 35-ft bus seats 32 passengers, and the 40-ft bus seats 39 passengers. The buses are equipped with a wheelchair ramp, two wheelchair positions, GFI Fastlane fare boxes, Apollo security cameras, Motorola two-way radios, Syncromatics GPS, automatic passenger counters, and two-position front-mounted bike racks. One 35-ft bus and one 40-ft bus were purchased as options on the LANTA (Allentown, PA) bus contract. The hybrid-electric buses were originally intended for service to Bradley Airport, which was not implemented [8].
- *Eleven 2018 New Flyer Xclesior 35- and 40-ft clean diesel buses (Cummins-powered) buses with particulate filters and SCR catalysts*. The 35-ft bus seats 29 passengers, and the 40-ft bus seats 36 passengers. The buses are equipped with a wheelchair ramp, two wheelchair positions, GFI Fastlane fare boxes, Apollo security cameras, Motorola two-way radios, Syncromatics GPS, automatic passenger counters, and two-position front-mounted bike racks. The buses were purchased through the State of Connecticut Bus contract [8].
- *Four Gillig 29-ft (Cummins-powered) clean diesel buses with particulate filters and SCR catalysts*. The buses seat 26 passengers and have two wheelchair positions, a wheelchair ramp, GFI Fastlane fare boxes, Apollo security cameras, Motorola two-way radios, Syncromatics GPS, automatic passenger counters, and two-position front-mounted bike racks. The buses were purchased through the State of Connecticut Bus contract [8].
- *Five 2016 Ford E450 Coach & Equipment Phoenix gasoline-powered cutaway buses used for ADA paratransit demand-response service*. The buses seat 12 passengers with 4 wheelchair positions and are equipped with a wheelchair lift, Diamond Dropboxes, Apollo security cameras, and Motorola two-way radios. They were purchased as option on the Greater Hartford Transit District bus contract.

Hybrid-Electric Transit Bus Technology and Efficiency Benefits

SEAT was considering the purchase of diesel hybrid-electric transit buses for use in a BRT-type service on certain routes within its regional service area. It ultimately purchased two hybrid-electric transit buses. Fuel consumption is the main direct cost element of an urban transit fleet, and hybrid-electric transit buses have the potential to reduce operating costs of providing transit service. They are powered by a diesel internal combustion engine and an electric drive motor that uses energy stored in batteries. The power supplied by the electric drive system enables engine downsizing. Hybrid-electric buses employ

regenerative braking, with energy normally lost during braking captured by the electric propulsion system and stored in the propulsion batteries for reuse. Energy from the propulsion batteries can also power accessory loads (electrification of mechanical accessory systems) and reduce engine idling when stopped. All of these features lead to greater vehicle efficiencies [9]. Manufacturers offering diesel hybrid-electric buses in the North America Market include ENC, Gillig, MCI, New Flyer, and Nova Bus. BAE Systems and Allison Transmissions, Inc., are the primary suppliers of the hybrid-electric drive systems used in hybrid-electric buses sold in the U.S. [9].

There are multiple possible arrangements of the engine and electric motor in a hybrid-electric vehicle (HEV). The two primary propulsion systems found in heavy-duty transit buses are series hybrid architecture and power-split hybrid architecture. A series HEV typically consists of an engine directly connected to an electric generator (or alternator). Power from the generator is sent to the drive motor and/or energy storage batteries according to their needs. There is no mechanical coupling between the engine and drive wheels. The electric drive motor provides the entire drive force using energy from the energy storage device and/or the engine, or both [10]. BAE Systems was the primary manufacturer providing series hybrid-electric drive systems sold through bus OEMs in North America. Table 3-3 summarizes advantages and disadvantages of series hybrid-electric architectures.

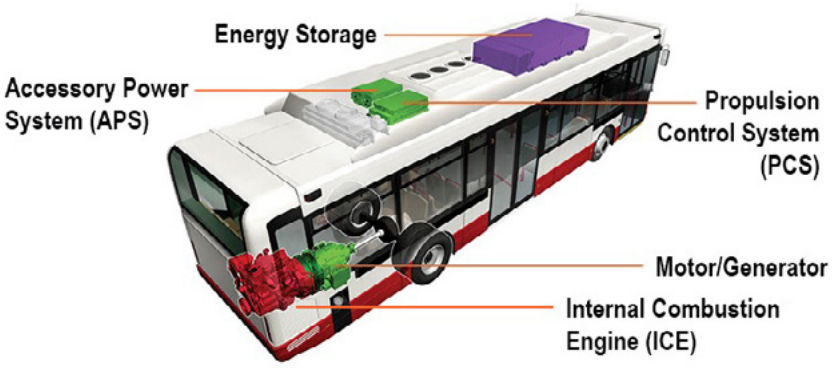


Figure 3-7 *BAE Systems HybriDrive® Series-E Hybrid-Electric Bus components [11]*

Table 3-3 *Advantages and Disadvantages of Series Hybrid-Electric Drive System*

Advantages	Disadvantages
Engine configuration relatively easy and simple to control.	Most suited to city-type driving only.
Engine able to operate in region of its peak efficiency more often than in conventional vehicles.	Energy from IC engine converted twice (mechanical to electrical to mechanical), leading to significant energy conversion loses.

Advantages	Disadvantages
Engine more efficient at modest speed and high load, which results in superior fuel efficiency.	Requires large traction motor, as is only source of propulsion.
Allows optimization of engine technology.	Requires generator and associated cost and weight.
Can reduce severe transient load demands on engine, which leads to lower emissions.	Requires high storage capacity battery if engine downsized.
Has excellent dynamic performance at low-speed acceleration.	Requires full-size engine if battery does not have high storage capacity.

In a parallel hybrid-electric drive system, both power sources (engine and electric motor) are coupled mechanically to the vehicle's wheels. The motor may be coupled to the wheels either through the transmission (pre-transmission parallel design) or directly to the wheels after the transmission (post-transmission parallel). Each has its advantages. A pre-transmission motor is required to operate over a smaller speed range than a post-transmission motor, and it could effectively deliver more torque to the rear wheels at low speed. However, a post-transmission motor offers higher efficiency in transmitting power to the drive wheels and a greater efficiency in recapturing regenerative braking energy [10]. Pre- and post-transmission parallel hybrid drive configurations are not common in heavy-duty transit buses.

The series-parallel configuration combines the advantages of both series and parallel hybrid-electric drive trains by incorporating two electric motors and one or more planetary gear arrangements. In these architectures, two of the rotating mechanical components are linked electrically by motors/generators to form a continuously variable transmission (CVT). Part of the power is transmitted mechanically and part is transmitted electrically. Either or both motors may exchange energy with the energy storage system, and either may at different times serve as drive motors or generators depending on the configuration and control algorithm. Control of a series-parallel system is more complex but greater freedom is provided to manage the engine speed and torque as functions of vehicle speed and power demand [10]. The H 40/50 EP ™ Series hybrid-electric drive system was a series-parallel hybrid-electric transmission manufactured by Allison Transmissions, Inc., and sold through bus OEMs in North America and elsewhere in 2018 in a series-parallel configuration referred to as a split-parallel or 2-mode system. The H 40/50 EP ™ transmission employs multiple planetary systems, two motor/generators, clutches, and brakes to provide multiple operating modes. This enables the 2-mode hybrid transmission to achieve improved fuel efficiency and performance over a wider range of vehicle speeds. Table 3-4 summarizes the advantages and disadvantages of series-parallel hybrid-electric drive systems [10].

Table 3-4 *Advantages and Disadvantages of Series-Parallel Hybrid System Architecture*

Advantages	Disadvantages
Offers flexibility in engine operation.	Design is complex
Provides freedom in managing engine speed and torque vs. vehicle speed and power demand.	Control is complex.
Can offer high fuel efficiency and reduced emissions.	

Powertrain simulation results indicate that both parallel and series hybrid systems can offer fuel economy benefits up to 45% over conventional buses [12–15]. Results from experimental assessments vary. Hallmark et al. [16] reported an average 11.8% higher fuel economy (mi/gal) of three hybrid-electric buses compared to two conventional diesel buses on-road testing in Iowa. Merkisz and Pielecha [17] found that the fuel consumption of a hybrid-diesel bus was 15–18% lower than a corresponding conventional one, depending on traffic conditions in Poznan, Poland. Zhang et al. [18] observed that diesel hybrid-electric buses tested in Beijing consumed 29% less fuel compared to conventional diesel buses. However, the authors also reported a 50% increase in the hybrid bus fuel consumption when average speed dropped from 15 mph to 9 mph and an offset of consumption benefits when the air conditioning was enabled. This finding is very important, as urban buses are mostly employed in routes of low speeds and often with the air-conditioning on.

The driving cycle is known to affect the fuel consumption of both hybrid-electric and conventional transit buses. Numerous studies have been conducted to characterize the effects of duty-cycle on fuel consumption and emissions of transit buses. Wayne et al. [19] measured the fuel economy of conventional diesel and hybrid-electric buses over 16 driving cycles on a chassis dynamometer. Figure 3-8 shows the fuel economy of the two 2006 model year Cummins ISM-powered diesel buses. Fuel economy was the highest on the Commuter Cycle (5.84 mi/gal) from the second bus, and the same bus on the NYBus Cycle exhibited the lowest fuel economy (1.54 mi/gal). Figure 3-9 shows the fuel economy of two 2006 hybrid-electric transit buses equipped with Allison E^P 40 hybrid drive systems. Fuel economy of the hybrid-electric buses was also high on the high-speed cycles and low on the low-speed cycles. The NYBus Cycle exhibited the lowest fuel economy, and the ETC-Urban, CSHVC, and Commuter cycles showed high fuel economy.

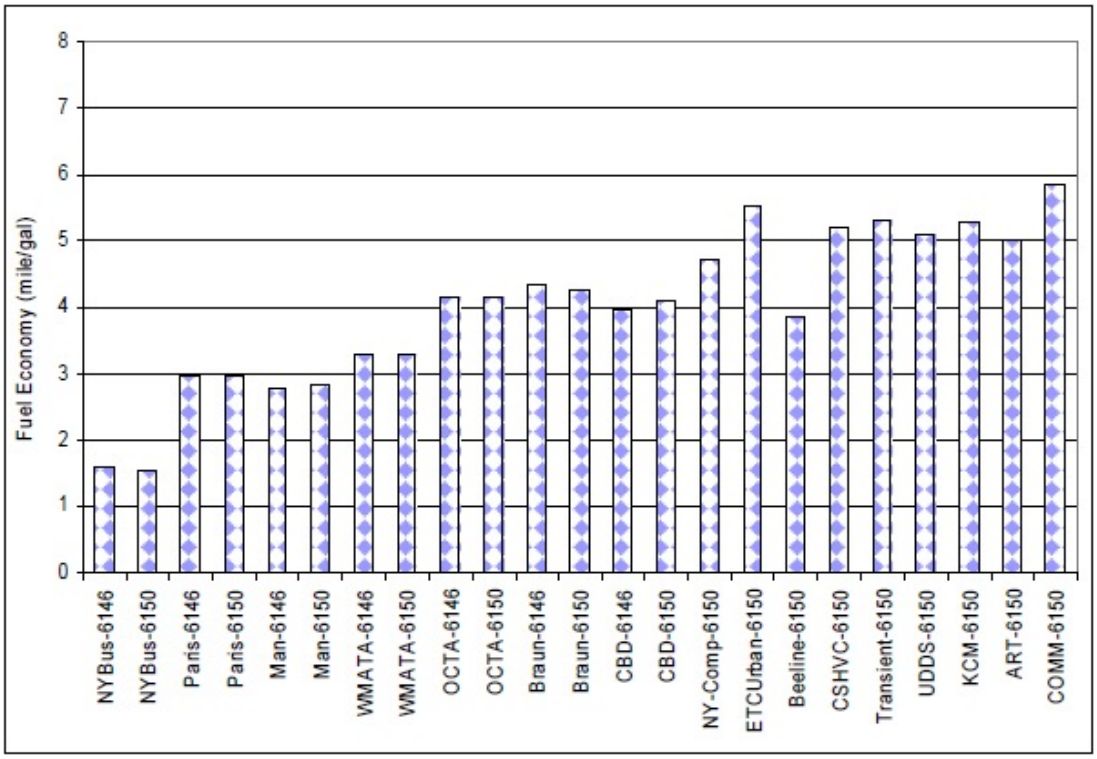


Figure 3-8 *Cycle-averaged fuel economy of Cummins power diesel transit buses [19]*

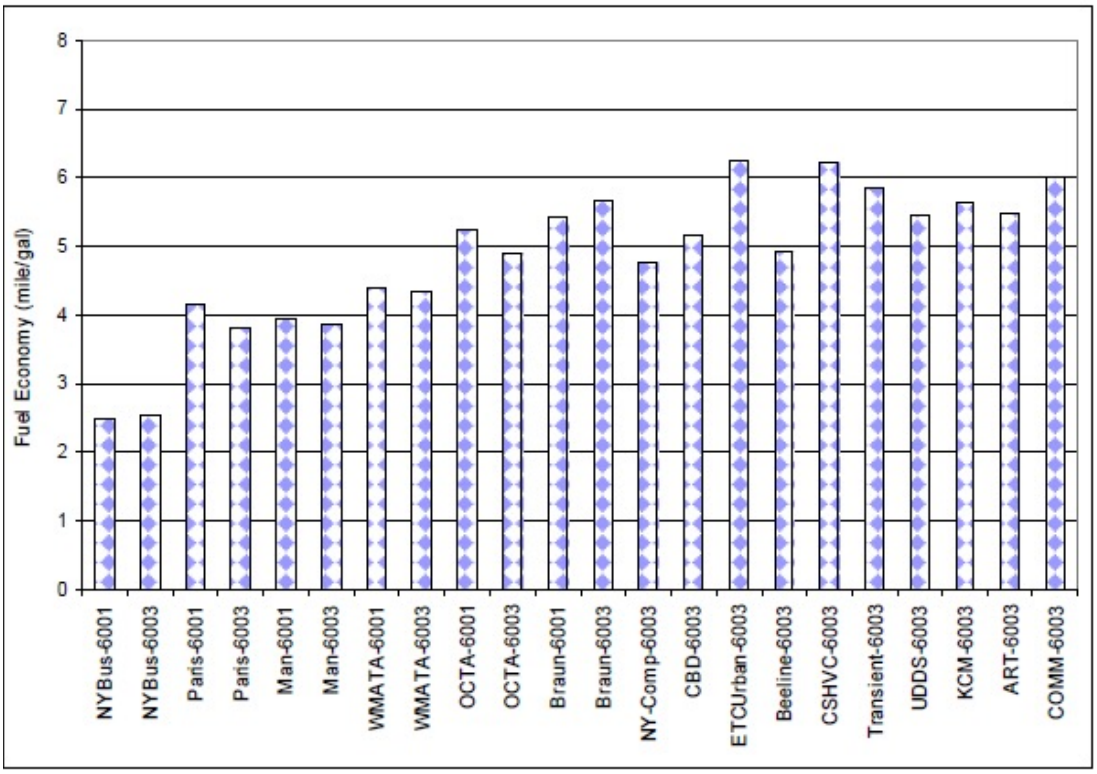


Figure 3-9 *Cycle-averaged fuel economy of Allison E^P 40 diesel hybrid-electric transit buses [19]*

Fuel economy was the highest on the ETC-Urban Cycle (6.25 mi/gal) from the second bus, and the first bus on the NYBus Cycle exhibited the lowest fuel economy (2.48 mi/gal). It was observed that hybrid-electric diesel buses exhibited an approximate 25% fuel economy advantage over the Cummins ISM diesel buses. However, the fuel economy advantage was more distinct and higher in the low-speed cycles with frequent stops and a high percentage of idle. For example, hybrid buses, on average, showed about 60%, 39%, and 22% fuel economy advantage over Cummins ISM diesel buses on the NYBus, Manhattan, and OCTA cycles, respectively. The high-speed cycles with low percentages of idle and fewer stops per mile offered less advantage for regenerative braking.

Average driving cycle speed is commonly used to characterize the impact of duty cycle on fuel consumption and exhaust emissions. Based on these same data combined with in-use data, Clark et al. [10] proposed correlations for the fuel economy of conventional diesel and diesel hybrid-electric transit buses as functions of average cycle speed. Data on chassis dynamometer fuel economy for diesel buses (Cummins ISM engine) at WMATA are plotted against average cycle speed for 16 cycles in Figure 3-10. These data were fitted with a parabolic line to provide a trend against average operating speed. The line was not forced through the origin, even though zero speed should imply zero mpg. The authors assumed that that a certain percentage of fuel economy is lost due to air conditioner or heating load, and that there also is a possible fuel economy loss from terrain. A correction factor was applied to account for these effects. In Figure 3-10, the solid line represents the final diesel bus in-use fuel economy performance. It was created by reducing the overall fuel economy curve by 26% from the chassis data (dotted line). A parabolic curve represented by the equation $y=-0.0032x^2+0.2143x+0.9726$, shown in were used in Figure 3-10 was applied by Clark et al. [10] to predict diesel bus fuel economy from the average speed for life cycle cost modeling.

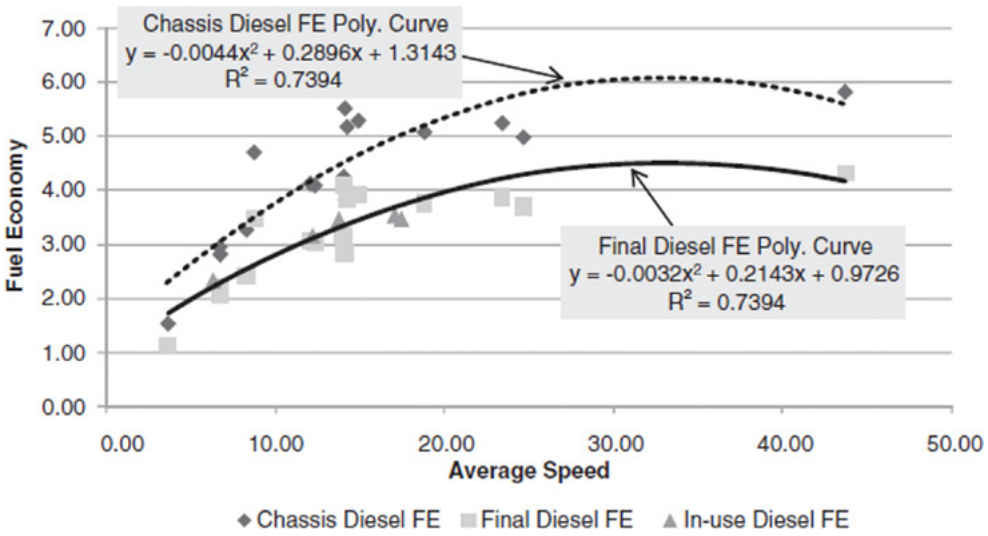


Figure 3-10 *Diesel bus fuel economy data and parabolic trend lines [10]*

Clark et al. [10] applied the same methodology to derive a relationship for diesel hybrid-electric fuel economy as a function of average cycle speed, as shown in Figure 3-11. For the hybrid bus case, a reduction percentage of 24.5% was found and applied to the chassis dynamometer data. The authors used a parabolic curve represented by the equation y=-0.0033x2+0.20263x+0.1-7985 to predict diesel hybrid-electric bus fuel economy. The authors compared their predicted fuel economy to in-use results derived from fueling records at four transit agency sites. Table 3-5 shows the predicted and in-use fuel economy with average cycle speed and the in-use and predicted hybrid-electric fuel economy advantage over conventional diesel buses.

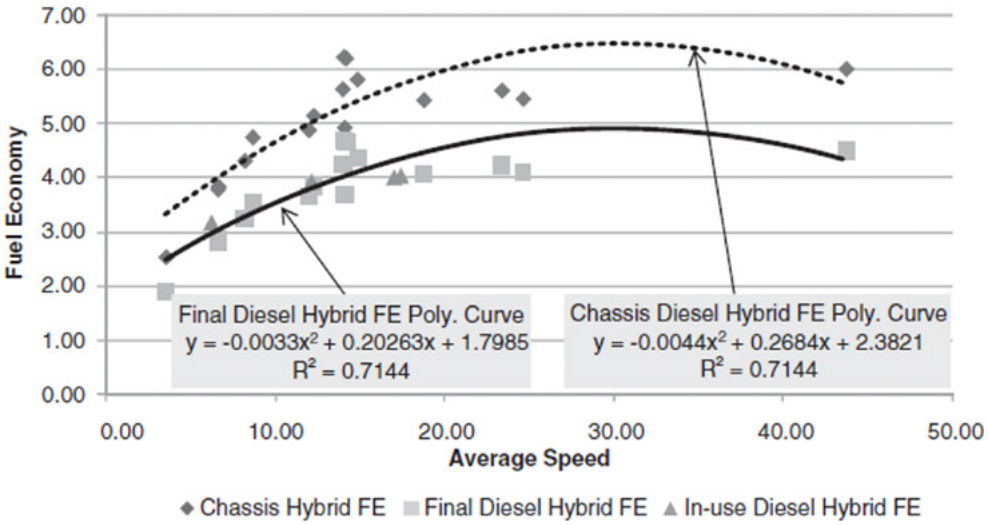


Figure 3-11 *Diesel hybrid bus fuel economy data and parabolic trend lines [10]*

Table 3-5 *Comparison of In-Use and Predicted Fuel Economy and Hybrid Electric Advantage [10]*

	Average Speed (mph)	In-Use FE (mpg)	Correlation FE (mpg)	Difference (%)
NYCT	6.35	3.19	2.95	-7.5
KC Metro	12.25	3.96	3.78	-4.5
WMATA – Montgomery	17.10	4.04	4.29	6.3
WMATA – Landover	17.50	4.07	4.33	6.4
	In-Use FE: Hybrid to Diesel		**Correlation FE: Hybrid to Diesel**	
NYCT	48%		34%	
KC Metro	27%		22%	
WMATA – Montgomery	14%		16%	
WMATA – Landover	16%		16%	

It is well known that vehicle energy usage is closely linked to the operational duty cycle. O'Keefe et al. [20] derived four metrics from the energy equation to characterize the sameness between vehicle duty cycles and assess a duty

cycle's suitability for hybrid vehicle usage. Duty cycles typically consist of second-by-second values of speed (and, in some cases, road grade) and are created to provide a concise, repeatable sequence of vehicle operation for chassis dynamometer performance and emissions testing. Duty cycles are intended to represent actual operation of the vehicle in a target application. In heavy-duty applications, cargo weight, road surface, route type, and vocational load (such as air conditioning in transit applications) can vary dramatically overtime [20]. An effective duty cycle must account for more than just driving speed as a function of time.

The tractive power required to move a vehicle over a roadway surface is the summation of the power required to overcome aerodynamic drag, rolling resistance, vehicle inertia, and gravitational potential energy. The tractive force is given by the classic road load equation:

$$F_{road} = \frac{1}{2} \cdot \rho \cdot C_D.FA \cdot v^3 + RRC_0 \cdot m_{veh} \cdot g \cdot v + m_{veh} \cdot v \cdot \frac{dv}{dt} + m_{veh} \cdot g \cdot \frac{dh}{dt}$$

where ρ is air density, C_D is the aerodynamic drag coefficient, FA is the frontal area of the vehicle, RRC_0 is the rolling resistance of the tires on the road surface, m_{veh} is the mass of the vehicle, g is the acceleration of gravity, v is vehicle velocity and *h* is elevation. Based on the road load equation, O'Keefe et al. [20] derived three metrics to characterize a duty cycle.

Characteristic acceleration measures the inertial work to accelerate or elevate a vehicle per unit mass per unit distance. It is the positive part of specific kinetic energy and potential energy per unit distance associated with moving a vehicle over a duty cycle [20]. Characteristic acceleration can be calculated for an entire duty cycle as:

$$\tilde{a} = \frac{\sum_{j=1}^{N-1} positive\left(\frac{1}{2} \cdot \left(v_{j+1}^2 - v_j^2\right) + g \cdot \left(h_{j+1} - h_j\right)\right)}{D}.$$

where ã is the characteristic acceleration, j is a sample time counter, N is the total number of time increments in the duty cycle, and D is the distance traveled over the duty cycle [20]. The characteristic acceleration reduces to the classis acceleration for linear speed increase over constant grade.

Aerodynamic speed (or, more accurately, the square of the aerodynamic speed) measures the ratio of the overall average cubic speed to the average speed. It is directly linked to the impact of aerodynamics on vehicle fuel usage [20]. Aerodynamic speed of a duty cycle is defined as:

$$v_{aero}^2 = \frac{\sum_{j=1}^{N-1} \overline{v_{j,J+1}^3} \cdot \Delta t_{j,j+1}}{D}.$$

Hybrid advantage can be defined as the percent reduction in fuel consumption of a hybrid-electric vehicle over a conventional vehicle:

$$HA = \left(1 - \frac{SFC_{HEV}}{SFC_{CV}}\right) \cdot 100\%.$$

where SFC is the specific fuel consumption. O'Keefe et al. [20] related hybrid advantage to characteristic acceleration and aerodynamic speed:

$$HA \cong \frac{\eta_{regen}}{C_{aero} \cdot \frac{v_{aero}^2}{\tilde{a}} + \frac{C_{rolling}}{\tilde{a}} + 1}$$

where η_{regen} is the regenerative braking energy capture and redeployment efficiency,

$$C_{aero} = \frac{\frac{1}{2} \cdot \rho \cdot C_D \cdot FA}{m_{veh}}$$

and

$$C_{rolling} = RRC_0 \cdot g$$

The third duty cycle metric defined by O'Keefe et al. [20] is the kinetic intensity, defined as

$$ki = \frac{\tilde{a}}{v_{aero}^2}$$

the inverse of which appears in the equation for hybrid advantage. Kinetic intensity relates well to a hybrid-electric vehicle's hybrid advantage in cases when idle fuel usage and vocational loads are small compared to the fuel usage for propulsion [20]. As the kinetic intensity of the duty cycle increase, the hybrid advantage increases. The relationship between hybrid advantage and kinetic intensity based on limit data presented by O'Keefe et al. is shown in Figure 3-12.

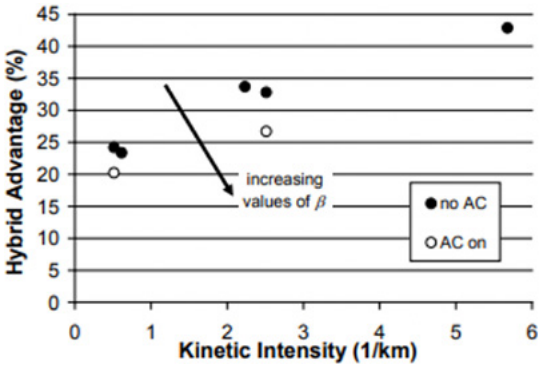


Figure 3-12 *Relationship between kinetic intensity and hybrid advantage [20]*

The final duty cycle metric proposed by O'Keefe et al. relates idle and vocational fuel consumption to the fuel consumed for tractive effort:

$$\beta \cong \frac{\frac{E_{fuel,other}}{m_{veh} \cdot D}}{C_{aero} \cdot v_{aero}^2 + C_{rolling} + \tilde{a}}.$$

Sandoval [21] modeled the fuel economy and emissions of conventional diesel and diesel hybrid-electric transit buses based on analysis of chassis dynamometer data from conventional and diesel-hybrid electric buses over 16 standard chassis dynamometer test cycles. The model used cycle average speed excluding idle and percentage of idle characteristic acceleration as inputs and predicted fuel economy, carbon dioxide CO_2 emissions and oxides of nitrogen NO_X emissions. Recognizing that percentage idle and characteristic acceleration may not always be available, the author developed correlations relating these parameters to average cycle speed excluding idle and subsequently used these correlations to model fuel economy using only average speed as an input. Sandoval also applied his models to determine the Hybrid Advantage [20] as a function of average speed and kinetic intensity, as shown in Figures 3-13 and 3-14, respectively.

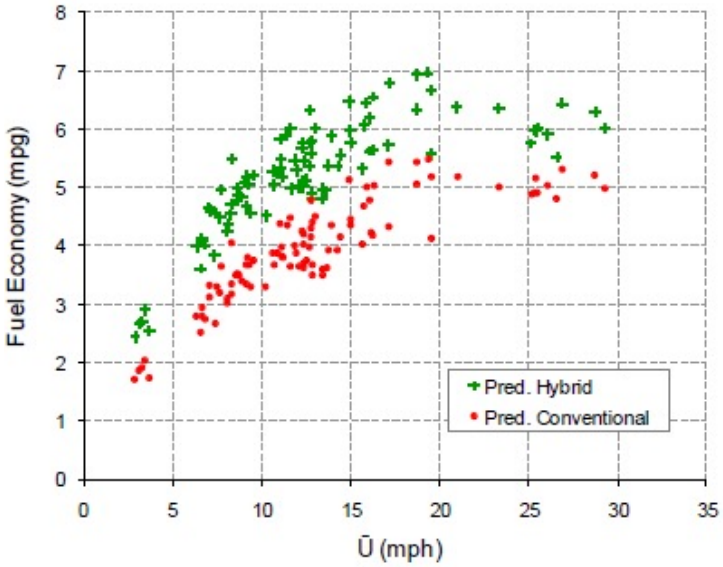


Figure 3-13 *Predicted conventional diesel and diesel hybrid-electric transit buses [21]*

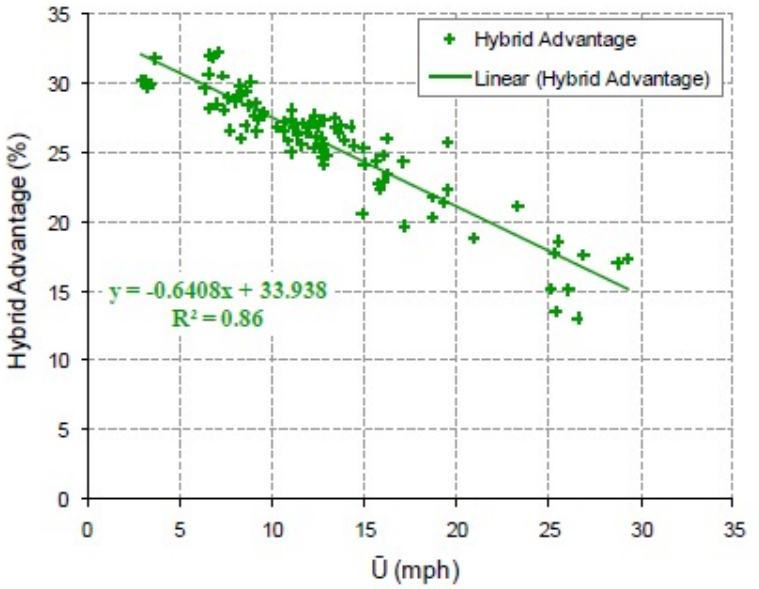


Figure 3-14 *Hybrid Advantage as a function of average speed [21]*

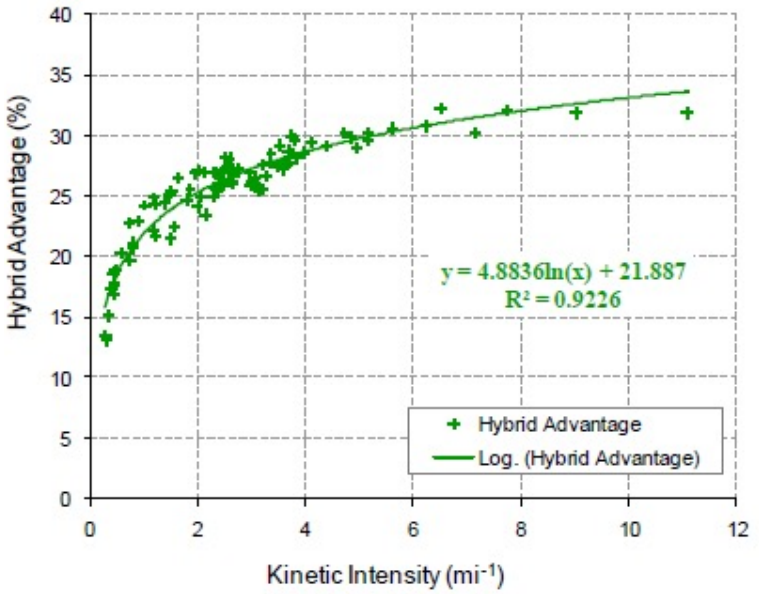


Figure 3-15 *Hybrid Advantage as a function of kinetic intensity [21]*

Vehicle Activity Characterization of Southeast Area Transit Routes

Hybrid-electric buses offer potential fuel cost savings compared to conventional diesel-powered buses as well as reduced exhaust emissions. The hybrid fuel economy advantage varies with duty cycle. WVU installed dataloggers on SEAT

buses to collect vehicle activity data on the 12 SEAT bus routes and processed the data to determine the cycle statistics listed in Table 3-6.

Table 3-6 *Characteristics Used to Determine Hybrid Advantage [20]*

Characteristic	Value
Regeneration Efficiency (η_{regen})	35%
Air Density (ρ)	1.2 kg/m^3
Drag Coefficient (C_D)	0.8
Vehicle Mass (m_{veh})	14515 kg
Frontal Area (FA)	8 m^2
Tire Rolling Resistance Coefficient (RRC_0)	0.0065
Gravitational Acceleration (g)	9.81 m/s^2
$C_{aero}\left(\frac{\frac{1}{2}\cdot\rho\cdot C_D\cdot FA}{m_{veh}}\right)$	0.000265
$C_{rolling}\ (RRC_0\cdot g)$	0.063765

Vehicle Activity Characterization of Southeast Area Transit Routes

Hybrid-electric buses offer potential fuel cost savings compared to conventional diesel-powered buses as well as reduced exhaust emissions. The hybrid fuel economy advantage varies with duty cycle. WVU installed dataloggers on SEAT buses to collect vehicle activity data on various SEAT bus routes. Data were collected from a total of 83 trips over 11 different SEAT bus routes, including 8 weekday and 3 weekend bus routes. These data included GPS data (speed, altitude, etc.) and bus data (vehicle speed, engine speed, throttle position, etc.). The collected data were processed to determine typical individual trip statistics including distance, duration, average speed, and stops per mile.

There was some difficulty in using GPS data, as it included noise and error arising from varying numbers of satellites fixed and intentionally-induced GPS noise. This is illustrated in Figure 3-16, which includes both GPS velocity data (mi/hr) and ECM broadcast vehicle speed data (km/hr). When ECM speed data indicate that the vehicle is stopped (0 mph), the GPS velocity data indicate a non-zero varying positive speed. As a result, the ECM speed data must be used for input to the modeling algorithms of O'Keefe [20]. For altitude data, which are required to calculate characteristic acceleration ($\tilde{a}$), there were no readily-alternate options to using the GPS altitude data.

$$\tilde{a} = \frac{\sum_{j=1}^{N-1} positive\left(\frac{1}{2}\cdot\left(v_{j+1}^2 - v_j^2\right) + g\cdot\left(h_{j+1} - h_j\right)\right)}{D}$$

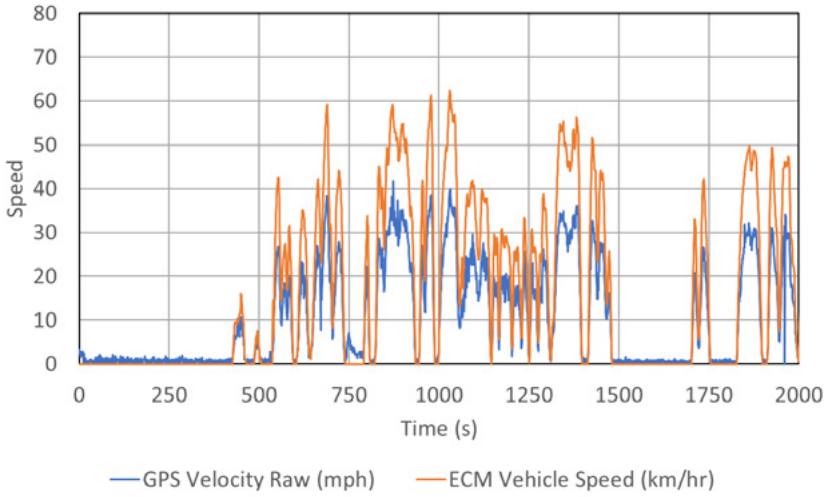


Figure 3-16 *Vehicle speed as recorded using GPS data and from vehicle ECM*

Using GPS altitude data is problematic in calculating instantaneous parameters such as characteristic acceleration, as it has noise intentionally embedded from the GPS system and error from satellite fixes. This is illustrated in Figure 3-17, which shows ECM vehicle speed data and corresponding GPS altitude data. Variations in altitude when the vehicle was at a stop (e.g., 0–400 seconds) cannot be accurate, as they show variation when the bus elevation is not changing. Although the noise in GPS altitude data would result in erroneous instantaneous characteristic acceleration values, the numerator of the O'Keefe model is a sum of the instantaneous values, and the random noise will be eliminated assuming the net elevation error is zero or near-zero.

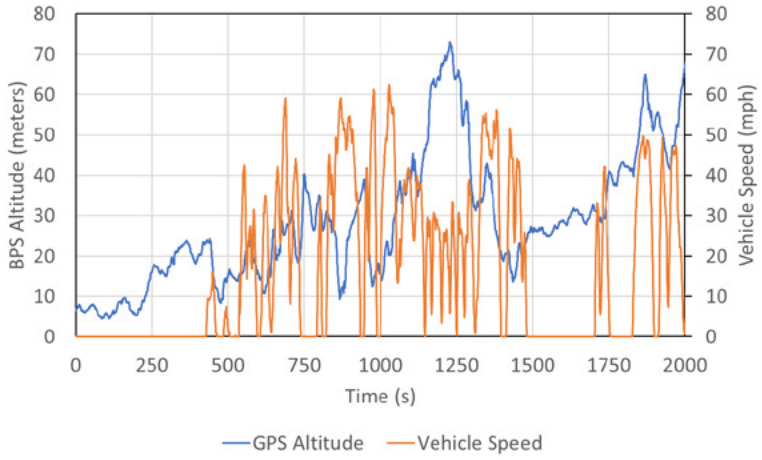


Figure 3-17 *Vehicle altitude reported by GPS datalogger and vehicle speed from ECM (note varying altitude during periods where vehicle not in motion)*

Although speed and altitude data from each trip can be processed to determine characteristic acceleration, aerodynamic speed, and kinetic intensity independently of vehicle characteristics, the methodology presented in O'Keefe requires the use of vehicle parameters to determine HA. SEAT data were processed using the same vehicle parameters used by O'Keefe, as those values were reasonably comparable to those for the SEAT buses, which allowed comparison with route/cycle-specific hybrid advantage values they obtained. Table 3-7 shows the duty cycle statistics derived from the SEAT routes.

Table 3-7 *Southeast Area Transit Bus Route Duty Cycle Statistics*

Route	Round Trips	Total Miles	Average Speed (mph)	Stops per mile	Characteristic Acceleration (m/s^2)	Aerodynamic Speed (m^2/s^2)	Kinetic Intensity (km^{-1})
1	4	199.7	16.6	1.2	0.294	185.4	1.59
3	3	246.2	19.4	0.6	0.361	218.9	1.65
5	8	171.4	14.5	1.2	0.281	102.3	2.75
5W	6	129.6	14.4	1.5	0.320	129.6	2.47
6	10	149.8	10.9	2.3	0.345	94.5	3.65
6W	6	99.3	11.3	2.0	0.342	96.8	3.54
7	7	130.8	12.9	2.1	0.305	128.9	2.36
11	3	292.8	14.8	1.3	0.339	150.8	2.25
11W	8	187.5	15.3	1.1	0.304	127.1	2.39
12	8	139.7	10.7	2.3	0.361	89.8	4.03
12W	8	125.8	10.5	2.0	0.386	109.0	3.54
14	9	174.9	12.3	1.9	0.344	112.7	3.06

Table 3-8 shows the diesel and hybrid fuel economy derived from average speed using the C15 [10] methodology (curve fits of Figures 3-11 and 3-12) and the HA calculated using the three methodologies previously described:

$$HA\ (C15) = \frac{FE_{hybrid} - FE_{diesel}}{FE_{diesel}}$$

$$HA\ (O'Keefe) \cong \frac{\eta_{regen}}{C_{aero} \cdot \frac{v_{aero}^2}{\tilde{a}} + \frac{C_{rolling}}{\tilde{a}} + 1}$$

$$HA\ (Sandoval) = 4.8836\ ln(ki) + 21.887$$

Note that, for consistency, the Sandoval correlation was transformed to use kinetic intensity with units of kph^{-1} rather than mph^{-1}.

Table 3-8 *Diesel and Hybrid-Electric Bus Fuel Economy and Hybrid Advantage Derived from Different Models*

Route	Diesel Fuel Economy (10)	Hybrid Fuel Economy [10]	Hybrid Advantage (C15)	Hybrid Advantage (O'Keefe [20])	Hybrid Advantage (Sandoval [21])
12 (Weekend)	2.86	3.56	24.2%	28.2%	27.2%
12	2.90	3.59	23.8%	28.2%	27.1%
6	2.93	3.62	23.4%	27.8%	26.9%
6 (Weekend)	2.98	3.66	22.9%	27.8%	26.7%
14	3.13	3.79	21.3%	27.5%	26.0%
11	3.44	4.07	18.3%	26.8%	24.5%
5 (Weekend)	3.40	4.03	18.8%	26.8%	24.7%
11 (Weekend)	3.51	4.13	17.8%	26.5%	24.1%
7	3.20	3.86	20.6%	26.5%	25.7%
5	3.40	4.04	18.7%	26.5%	24.7%
3	3.92	4.49	14.3%	26.2%	21.5%
1	3.65	4.25	16.6%	25.3%	23.3%
OCTA	3.13	3.79	21.3%	24.8%	26.0%

HA values calculated using the C15 methodology were significantly lower than those found using methodologies of Sandoval and O'Keefe. There was general correlation among the three methodologies examined for the highest-ranking routes, but the correlation deteriorated for the lower ranked routes. The data used in the regression analysis of Sandoval (Figure 3-16) include data points where a cycle with a kinetic intensity of 1 mph^{-1} had a higher hybrid advantage than a cycle with kinetic intensity of 2 mph^{-1} but the regression line use to predict hybrid advantage from kinetic intensity would indicate that the 2 mph^{-1} cycle had a higher hybrid advantage than the cycle with a kinetic intensity of 1 mph^{-1}.

HA, as calculated directly from logged SEAT bus data using the methodology of O'Keefe, was over a relatively small range, from a high of 28.2% for Route 12 (weekday and weekend) to a low of 25.3% for Route 1. This indicates that, for the SEAT routes, there may be little advantage to selective deployment of hybrid buses given the relatively minor benefits realized. However, for a transit fleet with more varied routes, selective hybrid deployment using this methodology would provide greater benefit.

Outcomes from SEAT Diesel Hybrid-Electric Bus Program

SEAT purchased two 2013 model year low-floor BRT diesel hybrid-electric heavy-duty buses. The buses are series hybrid- electric buses with Cummins engines, diesel particulate filters, SCR catalyst, and a BAE series hybrid drive. During the project, the scope of the BRT service changed. The hybrid-electric buses were planned to provide service to Bradley Airport, but that service was not implemented.

Unlike Ride Solution and Greater New Haven Transit District, SEAT provides fixed-route service in a rural setting featuring primarily paved roads. The service area is suited for 29–40-ft heavy-duty conventional buses. SEAT's fleet consists primarily of 29-, 35-, and 40-ft buses. SEAT also provides ADA paratransit service using five gasoline-powered cutaway buses on Ford E450 chassis. Procurement resources, such as APTA procurement guidelines, are better established in the heavy-duty bus chassis market, and heavy-duty buses experience fewer durability issues than medium-duty cutaway and body-on-chassis buses.

Hybrid-electric propulsion technologies for heavy-duty buses are well established, making it reasonably easy to implement hybrid-electric buses into a fleet that had historically operated heavy-duty non-hybrid diesel buses. Hybrid-electric buses use the same diesel engine and exhaust aftertreatment technologies as their non-hybrid diesel counterparts.

Greater New Haven Transit District

Transit Agency Profile

The Greater New Haven Transit District (GNHTD) is a municipal corporation established to provide a variety of transportation services and is one of 11 regional transit districts in Connecticut [22]. GNHTD provides direct transportation ADA transit service and Regional Rides Program service to passengers in the Greater New Haven region. GNHTD transit programs are funded by FTA, the Connecticut Department of Transportation, municipality community dues, and fares paid by program users. GNHTD provides ADA paratransit service in the municipalities of East Haven, Hamden, New Haven, North Branford, North Haven, Orange, West Haven, and Woodbridge and limited ADA service in Ansonia, Branford, Cheshire, Derby, Guilford, Madison, Meriden, Milford, Seymour, Shelton, Wallingford, and Waterbury. It also provides Regional Rides Program service for work, medical, and adult daycare Monday through Saturday and for shopping Tuesday and Thursday in Bethany, Branford, East Haven, Hamden, North Branford, North Haven, Orange, Wallingford, West Haven, and Woodbridge. Service is available within ¾ mile of the fixed-service routes, excluding express and commuter routes.

The GNHTD technology demonstration project was initially conceived as an advanced hydrogen fuel battery-dominant hybrid vehicle program on a 40-ft bus platform. While executing the project, GNHTD, which primarily provides paratransit services, recognized that a 40-ft bus platform was not appropriate for its operation. At the time, GNHTD operated 59 body-on-chassis vehicles in paratransit service; the vehicle inventory included 8 Ford E450 body-on-chassis and 51 Ford E-350 body-on-chassis vehicles. Based on the type of services GNHTD provided, the project evolved towards small transit vehicles. GNHTD and the State of Connecticut had a strong commitment to hydrogen fuel, and GNHTD was in the process of installing a hydrogen fueling facility.

GNHTD investigated developing a hydrogen-powered hydraulic hybrid vehicle in partnership with Eaton by retrofitting the hydraulic hybrid drive system into an existing gasoline-powered vehicle and then proceeding to a hydrogen-fueled internal combustion engine powerplant. GNHTD had a feasibility study done that showed promise for this technology in their application. It also had experience with an Ebus battery-electric bus that had a 95% pull-out rate but found battery replacement costs prohibitive. As a second potential technology, GNHTD also explored a hydrogen fuel cell-powered transit bus in partnership with Ebus. The goal of the GNHTD demonstration project was to prove the validity and commercial viability of an environmentally-friendly hydrogen fuel transit bus system.

Vehicle Technology Descriptions

GNHTD ultimately conducted a pilot demonstration of two hydrogen-powered 22-ft buses—a hydrogen fuel cell-powered plug-in hybrid-electric bus manufactured by Ebus and a Ford E-350 cutaway bus powered by a spark ignition hydrogen internal combustion engine made available through a leasing agreement with Ford Motor Company.

Through an FTA grant to develop one hydrogen fuel cell-powered plug-in hybrid electric bus and hydrogen fueling infrastructure in the New Haven area, GNHTD purchased a 22-ft Ebus battery-dominant fuel cell electric bus (FCEB), shown in Figure 3-18. The FCEB featured a Ballard PEM Mark 9, a 19.3 kW fuel cell power system, a SAFT nickel-cadmium 50 kWh energy storage system, and an Ebus plug-in hybrid propulsion system and power electronics. The Ebus FCEB could seat 20 passengers and 1 wheelchair and was designated to serve as a shopping shuttle for older adults; it was not used to provide regular door-to-door service. The project also included construction of a hydrogen fueling station with a 24-hour hydrogen generating capacity of 10 kg/day at 5,000 psi, developed by Avalence.

Figure 3-18 *GNHTD fuel cell plug-in hybrid-electric transit bus manufactured by Ebus*

The Ebus FCEB experienced significant maintenance issues, resulting in very low service availability. Over a one-year period, the bus was operated in regular duty service only 16 times. Issues resulting in removal from service included problems with hydrogen leaks (8 occurrences), software (4 occurrences), air compressor (4 occurrences), chiller (4 occurrences), diagnostics/troubleshooting (3 occurrences), wiring (3 occurrences), controller (3 occurrences), lack of hydrogen fuel (1 occurrence), PC board (1 occurrence), and battery charger (1 occurrence). GNHTD maintenance personnel interviewed by WVU researchers reported the following issues that contributed to the low service availability:

- Failure of some parts combined with long lead time to procure replacement parts. Maintenance technicians reported that Ebus often did not have the needed spare parts in stock and had to order from component manufacturers before shipping them to GNHTD.
- Frequent failure of control software.
- Difficulty in diagnosing the powertrain, including problems with the fuel cell, energy storage system, and powertrain control system. Factors contributing to the difficulty diagnosing problems included:
  - Insufficient knowledge and experience of GNHTD maintenance technicians in diagnosing and maintaining the fuel cell and hybrid electric powertrain systems.
  - Lack of a local dealer to provide service and support for mechanical problems.
  - Lack of detailed diagnostic manuals for maintenance technicians to follow.
  - Problems with bad electrical connectors. GNHTD technicians were advised by Ebus to shake or unplug and reconnect the connectors to establish the correct connection.
  - Four-hour time zone difference between Connecticut and California, making it difficult to communicate with the manufacturer.
  - In a few cases, systems removal from the bus and shipment back to the manufacturer in California for diagnostics and service.
  - Longer learning curve for maintaining the FCEB. There was a need for more training on the unique fuel cell and hybrid-electric powertrain systems.
- Ebus' lack of experience in fuel cell-powered hybrid vehicle operation at the time of the demonstration; only four vehicles were in service under the Ebus early FCEB development.
- GNHTD fueling station still being under construction, so bus had to be fueled at a hydrogen station owned by Proton 20 miles from GNHTD. Due to low maximum speeds, the Ebus had to travel to and from the fueling station on local roadways.

- Incomplete planned safety upgrades to the GNHTD maintenance facility to accommodate hydrogen-fueled vehicles. Maintenance was being performed outdoors. At the time, comprehensive guidelines and State safety codes did not exist, hampering discussions with the local fire department and fire marshal and hampering development of engineering plans and specifications for maintenance facility upgrades. This highlights the need for easily-available technical specifications, safety information, and guidance documents and for small transit operators planning implementation of alternative fuels and powertrain technologies.

Tables 3-9 and 3-10 show operational data provided to WVU by GNHTD during the year that WVU tracked the operation of the fuel cell hybrid electric transit bus. Due to the very limited availability for regular enough data was not available to draw reasonable conclusions related to the energy efficiency, operating costs and reliability of the FCEB compared to gasoline powered buses performing the same service.

Table 3-9 *Operational Data for GNHTD Fuel Cell Hybrid-Electric Bus*

Month	Number of Days of Service	Number of Passengers Served	Mileage	Hydrogen Consumed (GGE)	Cost of Electricity Consumed ($)
March	5	35	331	10.255	367.23
April	0		26	2.165	383.21
May	6	219	190	18.365	351.25
June	2	28	83	Missing data	Missing data
July					
August					
September	5	64	352	6.98	727.57
October	Out of service due to fuel cell air pump issues				

GNHTD maintenance technicians and drivers also provided input about challenges encountered operating an older adult shopping shuttle service using vehicles that are available on the market:

- *Accessibility for mobility-impaired and handicapped passengers* – GNHTD cited concerns about the liability posed by the safe operation of wheelchair lifts and the challenges raised by ever-increasing combined weight of mobility-impaired passengers and their powered wheelchairs. Small community and rural transit agencies may have a high percentage of physically-challenged passengers. Vehicles need to have a low floor and a convenient loading ramp for wheelchairs and for passengers who have difficulty traversing steps.

- *Flexible seating arrangements* – small community transit agencies may need to accommodate multiple wheelchair passengers on some occasions.
- *Onboard storage for customers, packages, and groceries* – operation of a shopping shuttle requires unique storage to safely and securely transport rider packages and grocery bags.

Table 3-10 *Operational Data for Gasoline-Powered Bus Providing Same Service as GNHTD Fuel Cell Hybrid-Electric Bus*

Month	Number of Days of Service	Number of Passengers Served	Mileage	Hydrogen Consumed (GGE)	Fuel Economy (mi/GGE)
April	8	78	592	110.9	5.33
May	15	222	992	189.5	5.23
June	17	226	870	212.5	4.09
July					
August					
September	14	184	1038	233.6	4.44
October	15	218	1222	194.3	
	Out of service due to fuel cell air pump issues				

Outcomes from GNHTD Fuel Cell Hybrid-Electric Bus Program

GNHTD provides services similar to those provided by Ride Solution in Palatka and most small rural transit agencies throughout the US. It provides direct transportation ADA transit service and Regional Rides Program service to passengers to transport riders to and from public services such as Medicare offices, doctor offices, shopping centers etc. As with many rural transit providers, GNHTD stated that the small transit vehicles available on the market lack features needed to provide transit service in rural areas with a high number of older adult and mobility-impaired passengers. These desirable features include:

- *Accessibility for mobility-impaired and handicapped passengers* – vehicles with low, flat floors and convenient loading ramps for wheelchairs and for passengers who have difficulty traversing steps are preferred to vehicles with wheelchair lifts. GNHTD operators expressed concerns with liability and safety associated with use of wheelchair lifts and stated that increasing weights of passenger and powered wheelchairs push the weight capacities of available lifts.
- *Flexible seating arrangements* – GNHTD provides door-to-door service for older adult and mobility-impaired passengers between their homes and physician offices, grocery stores, and other retail stores. Currently available small transit vehicles can accommodate only one or two wheelchairs.

Flexible storage solutions are also needed to transport rider groceries and packages when shopping shuttle services are provided.

- *Maneuverability* – door-to-door transit service requires vehicles with a tight turning radius, short overhangs, and large approach and departure angles.
- *Durability and a long service life* – a common complaint about small transit vehicles is durability. As most small transit vehicles on the market are light- and medium-duty cutaways and body-on-chassis vehicles, durability and service life are lower than purpose-built heavy-duty transit buses.

Discussions with GNHTD leadership, maintenance technicians, and drivers reinforced the theme voiced by most transit operators interviewed by WVU researchers—the currently available small transit vehicles do not fully meet the needs for providing transit service in rural areas with high ridership by older adult and mobility-challenged populations.

The experience at GNHTD also highlights the challenges posed by adoption of early-stage alternative propulsion technologies. Like large urban transit agencies, some small transit agencies want to reduce their environmental impact by incorporating alternative fuels and energy-efficient, low-emission powertrain technologies. Some transit agencies may be required to meet state and local environmental mandates or may be pressured by their citizens, customers, and boards to reduce their environmental footprint. These are laudable pursuits. Small transits also seek to take advantage of federal, state and municipal grants to improve energy efficiency and reduce environmental impacts.

Adoption of alternative fuels and advanced propulsion technologies often present significant challenges, including construction of major fueling infrastructure, renovation of maintenance facilities (particularly for gaseous fuels), training of maintenance personnel and drivers, increased troubleshooting and diagnostic challenges, and initial reliability problems. These challenges are amplified for early-stage technology demonstration projects. GNHTD's hydrogen fuel demonstration project consisted of a TRL 6 demonstration characterized by engineering/pilot-scale field testing and design shakedown of one or two prototype buses in actual transit service. In a TRL 6 demonstration, manufacturers typically assist in operation and handle all maintenance while introducing transit staff to the technology. Frequent breakdowns are common as the new technology is validated in the normal revenue environment.

GNHTD experienced significant maintenance and reliability issues with the Ebus fuel cell hybrid-electric bus that severely limited the availability of the FCEB for operational service. Several factors contributed to the struggles encountered in the GNHTD advanced technology demonstration:

- At the time of the demonstration, fuel cell electric buses were still in a relatively early stage of development. Design integration of the fuel cell power system and battery-dominant hybrid-electric drive system was still evolving.
- OEM personnel were not stationed on site to provide diagnostic support and assist with maintenance of the prototype buses.
- The manufacturer had produced only a small number of prototypes of this bus design.
- The distance between GNHTD and the manufacturer based in California made troubleshooting support difficulty.
- The low volume of buses manufactured to date made availability of replacement parts problematic, leading to long lead times for replacement parts.

Recommendations for Implementation of Advanced Technologies in Small Transit

Small rural transit operators often have good justification to implement energy-efficient and environmentally-friendly vehicle technologies into their transit fleet. When selecting alternative vehicle technologies, small transit agencies should consider the following recommendations:

- Select more mature technologies that have reached TRL 7–9. CNG and propane are well-developed internal combustion engine fuel options. Hybrid-electric powertrain technology is proven, and battery-electric propulsion is quickly approaching full commercialization. Vehicle and propulsion technologies in the early stages of development can present substantial challenges in maintenance, reliability, and training and often require significant engineering support to achieve successful implementation into a fleet. Small transit operators may not have onsite engineering personnel with extensive experience in these experimental technologies. Relying solely on support from the vehicle manufacturer or propulsion system integrator can present difficulties related to timely troubleshooting and repairs, which can cause extended periods when the demonstration vehicles are not available for service.
- Select vehicles and propulsion systems manufactured by well-established manufacturers and powertrain integrators. There is a well-developed market for 30-ft and larger CNG, hybrid-electric and battery-electric buses. Offerings in the less-than-30-ft market are still extremely limited. There are fewer advanced powertrain technology options in the small transit vehicle market compared to the heavy-duty transit bus market. For example, early hybrid-electric, battery-electric, and fuel cell-electric technology development and demonstration tended to involve partnerships with

established heavy-duty bus manufacturers. Far fewer technology development projects involved medium- and light-duty transit vehicles. Smaller manufacturers may be challenged in providing the close support needed during the demonstration and early deployment phases of new vehicle and propulsion technologies.

- Retrofitting existing gasoline and diesel-powered buses may be a viable option. Select a well-established integrator that offers fully commercialized solutions.
- Onsite OEM technical support during the start-up period is crucial for success. In many of the technology demonstrations involving hybrid-electric, battery-electric, and fuel cell-electric heavy-duty buses, the bus OEM often provides onsite engineering and maintenance personnel who perform troubleshooting and maintenance of the advance technology buses while training the permanent transit agency mechanics and technicians. The availability of OEM engineers and technicians facilitates troubleshooting and maintenance activities. In many advanced technology demonstrations at small and rural transit agencies, it is not feasible for the manufacturer to provide onsite support staff.

Section 4

Small Transit Vehicle Availability, Features, and Procurement

Peterson [1] identified common issues that inhibit the small transit vehicle industry from reaching peak efficiency—quality and reliability concerns with the available small transit vehicles; high maintenance costs; widely varying procurement policies, procedures, and guidelines at State and local levels; production fluctuations stemming from demand uncertainties; the relatively small size of individual orders; and the large number of competitors in the market. Many of these issues persist today. The second objective of the Advance Small Transit Vehicle Technology Study was to assess the current state of the small transit vehicle industry and provide recommendations to improve the features, durability, and procurement processes of transit vehicles used to provide transit services in rural communities. WVU researchers conducted in-person and telephone interviews with multiple small transit agencies to discuss the challenges associated with currently available small transit vehicles, potential improvements in vehicle features and offerings to better serve the needs of small rural transit operators, procurement process challenges and potential improvements faced by small transit providers, and tools and resources that could assist small transit providers with the vehicle procurement process.

Mountain Line Transit Authority

Transit Agency Profile

The Monongalia County Urban Mass Transit Authority (dba Mountain Line Transit Authority) provides public transit service to Morgantown, WVU, and Monongalia County. Mountain Line provides service on 24 routes within the Greater Morgantown area and the surrounding communities of Westover, Star City, Cheat Lake, Granville, Osage, Cassville, Laurel Point, Arnettsville, Crown, Everettesville, Opekiska, Booth, Wadestown, Cassville, New Hill, Core, Pentress, Blacksville, Wana, and Wadestown. Through a financial partnership with WVU, Mountain Line provides free bus service to University faculty, staff, and students with a WVU ID. Free service is also provided to high school students who enroll in the High School Ride Free Sponsorship Program and to Monongalia County residents age 60 or older through a partnership with Senior Monongalians [23]. Based on the 2018 National Transit Database (NTD) [24] transit agency profile, Mountain Line served a population of 91,576 over a service area of 293 square miles, including the municipality of Morgantown with a population of 70,350 and occupying 37 square miles. Service consumption in 2018 was 1,008,556 unlinked trips, comprising 1,255,561 annual vehicle revenue miles and 68,785 annual revenue vehicle hours. In 2018, Mountain Line expended $4,848,452 in operating funds, consisting of $421,204 in fare revenues, $2,285,156 in local funds, $0 in State funds, and $2,142,092 in federal funds. Capital expenditures totaled $1,284,836, including $1,272,792 of local funds and $12,044 of federal funds.

Types of Service

Fixed-Route

Fixed-route-only service is provided on a limited number of routes serving the WVU campus. On these routes, buses stop only at designated permanent stops, as flag service is impractical on the campus.

Deviating Fixed-Route

Deviating fixed-route service constitutes most of Mountain Line's service. On these routes, passengers may flag the bus or request a stop at any safe location along the routes. Deviating fixed-route buses are accessible to all individuals and provide for pre-arranged deviations from the fixed route up to ¾ mile to pick up patrons at a location of their choosing. To request a deviation, an applicant must submit a Deviation Request Form for consideration. An operations supervisor is dispatched to the desired location to determine the best service route and any obstacles that might prevent the bus from accessing the location. Once a deviation is approved, service to that location is provided indefinitely to any passenger requesting it regardless of whether the passenger has a disability or not. The deviating service allows riders to call for a pick-up as little as 15 minutes before the desired trip. The deviated service is limited only by the ability to get the bus to the desired location and to safely turn the bus to return to the fixed route. Although alternate vehicle assignments to accommodate a deviation are possible, such substitutions are rare due to the capacity requirements of the route.

Inter-City

The Mountain Line Grey Line provides inter-city service connecting the north central West Virginia towns of Morgantown, Fairmont, and Clarksburg with Waynesburg, Washington, and Pittsburgh, Pennsylvania, and the Pittsburgh International Airport. Reservations are required for Grey Line service, and passengers can check baggage up to 50 lb and carry on one small bag of 25 lb or less.

Fleet Demographics, Desirable Vehicle Features and Limitations

In 2018, the Mountain Line bus fleet consisted of 34 vehicles, including cutaway buses and heavy-duty 29–35-ft buses, as shown in Table 4-1.

Table 4-1 *Mountain Line Transit Bus Fleet [24]*

MY	Manufacturer	Model	Type	Length	Seated Capacity	Standing Capacity	Number in Fleet	Modes
2009	Elkhart Coach	ECII	Cutaway	23	10	15	1	DR /MB
2011	Elkhart Coach	ECII	Cutaway	23	15	15	2	DR /MB
2000	Freightliner	Trolley	HD Bus	32	29	45	2	MB
2009	Gillig	Low Floor	HD Bus	35	31	30	7	MB
2010	Gillig	Low Floor	HD Bus	29	26	52	3	MB
2011	Goshen Coach	GCII	Cutaway	32	26	26	1	MB
2011	Goshen Coach	GCII	Cutaway	24	34	25	1	MB
2014	Gillig	Low Floor	HD Bus	35	32	64	4	MB
2014	Gillig	Low Floor	HD Bus	29	26	52	1	MB
2015	Elkhart Coach	ECII	Cutaway	25	21	31	9	MB
2018	Elkhart Coach	ECII	Cutaway	28	22	22	3	MB

DR – Demand Response, MB – Bus

WVU researchers met with the Mountain Line General Manager to discuss the type and characteristics of transit vehicles that are best suited for use in Mountain Line's service, durability and reliability of available vehicles, shortcomings and limitations of vehicles available in the market, and desirable features that could improve the utility of available transit vehicles.

Cutaway Buses

Light-duty cutaway buses are best suited for serving the rural areas within Mountain Line's service area. Mountain Line identified the following positive features of cutaway buses:

- Rated for 125,000 miles and a three-year service life.
- Twice the rated mileage and service life of buses.
- Reasonable prices, at approximately $75,000 per vehicle.
- Economical to replace in the event of premature failure of significant maintenance problems or extensive accident damage.
- Easily maintained and repaired gasoline engine, adequate parts and maintenance support available through local dealerships.
- Buses built on OEM Ford or International chassis that are well-supported through local dealerships.
- Buses seat 8–10 passengers, are well-sized for providing deviated service in rural parts of Mountain Line service area.
- Can be equipped with ADA lift.
- Adequate ground clearance for road conditions and terrain in service area.

Shortcomings of the cutaway buses include:

- No low floor or level loading capability with acceptable ground clearance for navigating local terrain and road conditions.
- Require stairs to ADA lift for boarding.
- Limited passenger capacity given gross vehicle weight restrictions. Buses do not have enough passenger capacity for many Mountain Line routes, which limits their use, which forces Mountain Line to use larger buses on many routes that include rural areas and limits the ability to provide route deviations in areas where passenger capacity dictates the need for larger vehicles.
- Softer ride suspensions desirable for passenger comfort.
- Spinner chains desirable in winter climates but are not always available given the suspension selection (i.e., spinner chains cannot be combined with air-ride suspensions).

Heavy-Duty Buses

Heavy-duty 29–35-ft buses are best suited for Mountain Line routes in Morgantown, Westover, Star City, and outlying areas consisting of primarily paved roads. Positive features of the heavy-duty buses include:

- 400,000 mile, 10-year service life for 30-ft buses; 425,000, 12-year service life for 30–35-ft buses.
- Higher seating capacity.
- Ground level loading or kneeling capability.
- Stainless steel chassis and aluminum body panels reduce corrosion issues and decrease maintenance.
- Panels are easily replaced in case of accidental damage.
- Highly customizable. Mountain Line provides highly detailed custom specification when procuring new heavy-duty buses.

Shortcomings of the heavy-duty buses cited by Mountain Line include:

- Limited engine options.
- Complexity of exhaust aftertreatment technology.
- Frequent exhaust aftertreatment system failures.
- Limited warranty on exhaust aftertreatment systems.
- Cleaning, service, and replacement of exhaust diesel particulate filters and exhaust gas recirculation (EGR) components are significant maintenance cost item.

Medium-Duty Body-on-Chassis Buses

Medium-duty body-on chassis buses are not a good fit for Mountain Line's service needs and are being phased out of the bus fleet. Body-on-chassis buses may be considered in future for niche applications but are not a priority vehicle option going forward. Limitations of the body-on-chassis buses include:

- Inadequate passenger capacity to service urban and suburban routes.
- Too large to navigate roads and terrain on rural routes.
- Higher maintenance and repair costs compared to heavy-duty and cutaway buses.

Durability and Reliability of Existing Transit Vehicle Offerings

Mountain Line cited very few recurring durability or maintenance issues with their cutaway buses. The following durability and maintenance issues were raised regarding their heavy-duty buses:

- Emissions and aftertreatment system failure on heavy-duty diesel buses are the leading durability problem across all vehicle types.
- Cummins is the only engine OEM option available.
- Local service routes do not produce enough exhaust temperatures to promote regeneration of DPF aftertreatment systems.
- Only one engine model works reasonably in local transit service due to low exhaust temperatures.
- High rate of EGR system failures and problems.
- Cleaning and replacement of DPF is costly.
- Engines in heavy duty buses require replacement at ~220,000 miles.
- Replacement engines have 5-year warranty, which should offset costs of next replacement should engines fail prior to 12-year vehicle service life.
- If engine is replaced again prior to 12-year retirement, then Mountain Line may keep buses beyond the 12-year replace interval.

Alternative Propulsion Technologies

Mountain Line had previous experience with lean- burn natural gas-fueled vehicles that were fueled at local public natural gas fuel stations. However, the natural gas buses were sold when the public natural gas stations closed due to low utilization. CNG buses are not a viable option due to lack of refueling infrastructure and prohibitive cost of constructing dedicated natural gas fueling infrastructure for the fleet. Mountain Line is interested in battery-electric bus technologies and believes that believes that battery-electric buses may be a viable option for Mountain Line Transit within a 5- to 10-year horizon. Mountain Line is not currently considering hybrid-electric bus technologies.

Vehicle Procurement Processes and Challenges

Mountain Line Transit purchases both heavy-duty and cutaway transit buses. It develops its own custom detailed vehicle specification for the heavy-duty buses it purchases and meets with OEM engineers at the vehicle manufacturer facility to go over specifications in detail. Mountain Line has sought consultation and guidance on developing heavy-duty bus procurement specifications from Kanawha Valley Regional Transit (KRT) (Charleston, WV) and Tri-State Transit Authority (Huntington, WV). KRT and Tri-State have a longer history of heavy-duty vehicle procurements. Mountain Line has cooperated with KRT, Tri-State, and other WV transit agencies on joint vehicle procurements. Mountain Line staff are familiar with the APTA Bus Procurement Guidelines [3] and other APTA resources but typically do not use default APTA vehicle specification templates when developing RFPs for heavy-duty bus purchases.

Mountain Line receives funding through the FTA 5311 Rural Transit Assistance Program, and procurement of its cutaway buses is funded through the program, which is coordinated by the State of WVDOT and undertaken through the State Procurement process. Vehicle specifications for the cutaway buses have been developed over time through collaboration with the WVDOT and other WV transit operators. These specifications are a compromise of the requirements for multiple transit providers. Mountain Line staff review and provide input into the procurement specifications for vehicles procured through WVDOT, but there is far less ability for customization of cutaway buses.

Preston County Senior Citizens, Inc.

Transit Agency Profile

Preston County Senior Citizens, Inc., dba Buckwheat Express, provides deviated fixed-route and non-emergency medical public transportation service to residents throughout Preston County under the Enhanced Mobility of Seniors & Individuals with Disabilities, Section 5310: West Virginia Section 5310 Seniors and Individuals with Disabilities Program and Formula Grants for Rural Areas – 5311 as well as medical transportation with Medicaid reimbursement managed by MTM (Medical Transportation Monitoring). Based on its 2018 NTD [24] transit agency profile, Buckwheat Express serves a population of 34,000 over a service area of 650 square miles. Service consumption in 2018 was 32,694 unlinked trips, comprising 202,153 annual vehicle revenue miles and 16,780 annual revenue vehicle hours. In 2018, Buckwheat Express expended $653,219 in operating funds, consisting of $20,940 in fare revenues, $90,717 in local funds, $187,961 in State funds, and $353,601 in federal funds. Capital expenditures totaled $291,556, including $58,311 of state funds and $233,245 of federal funds.

Types of Service

Deviated Fixed-Route

Buckwheat Express provides service on four routes:

- Kingwood–Morgantown–Terra Alta service operates Monday through Friday and connects with Mountain Line Transit in Morgantown.
- South Preston Loop operates only on Tuesdays, serving Kingwood, Tunnelton, Denver, Fellowsville, Newburg, Authurdale, and Reedsville.
- West Preston Loop operates only on Fridays, serving Kingwood, Reedsville, and Masontown.
- Service from Kingwood to Bruceton Mills, Newburg, Rowlesburg, and Tunnelton on Monday, Tuesday, Thursday, and Friday.

On these routes, passengers may flag the bus or request a stop at any safe location along the deviated fixed routes. Route deviations up to ¾ mile for off-route pickup can be arranged by calling one day in advance.

Non-Emergency Medical Transportation

Buckwheat Express provides door-to-door non-emergency medical transportation for doctor and dentist appointments, diagnostic testing, or recurring therapy by reservation. The medical transport segment provides non-emergency transportation to "local" hospitals (Garret County [MD], Clarksburg, Morgantown, Bruceton, etc.) in addition to doctor offices and other medical facilities. Medical transport must be arranged through MTM–transportation brokers and will pick up customers at any location within Preston County. There are no location constraints for Medicaid/Medicare medical transport. Medical transport is typically provided by a dedicated medical transport vehicle (minivan or SUV); it is rarely provided by a transit vehicle running a regularly-scheduled route.

Fleet Demographics, Desirable Vehicle Features, and Limitations

In 2018, the Buckwheat bus fleet consisted of 25 vehicles comprising medium-duty buses, cutaway buses, passenger vans, minivans, and 4-wheel drive utility vehicles, as shown in Table 4-2.

Table 4-2 *Buckwheat Express Transit Fleet [24]*

MY	Type	Length	Seated Capacity	Number in Fleet	Modes
2017	Bus	29	18	2	DR
2017	Bus	23	22	1	MB
2017	Bus	23	22	1	MB
2010	Bus	29	26	2	MB
2007	Bus	29	24	2	MB
2016	Cutaway	23	12	1	DR
2015	Cutaway	23	15	1	DR
2015	Cutaway	23	15	1	MB
2010	Cutaway	23	14	1	DR
2010	Cutaway	23	14	1	MB
2009	Cutaway	23	14	1	MB
2014	Van	18	10	2	DR
2008	Van	18	10	3	DR
2018	Minivan	12	7	1	DR
2017	Minivan	12	5	1	DR
2012	Minivan	12	7	1	DR
2017	SUV	12	5	1	DR
2010	SUV	15	7	1	DR
2008	SUV	17	5	1	DR

DR – Demand Response, MB – Bus

WVU researchers met with the Buckwheat Express Operations Manager to discuss the type and characteristics of transit vehicles that are best suited for use at Buckwheat Express, durability and reliability of available vehicles, shortcomings, and limitations of vehicle available in the market, desirable features that could improve the utility of available transit vehicles and the vehicle procurement process.

Buckwheat Express primarily uses gasoline-powered high-top vans and cutaway buses to provide its deviated fixed-route service. Except for the limited number of diesel-powered 29-ft buses used on routes in Kingwood, all Buckwheat Express transit vehicles are gasoline-powered and built on Ford, GM, or Dodge chassis.

Cutaway Buses

Buckwheat Express is generally satisfied with the vehicles purchased. Essential or desirable features of the cutaway buses include:

- Adequate ground clearance to navigate rural roadways.

- Short overhangs and tight turning radius to navigate tight roads, and driveways.
- Destination signs and strobe lights.
- Air-ride suspension.
- ADA lifts with adequate lifting capacity for increasingly heavy passengers and powered wheelchairs and scooters.

Most routes are serviced by 14–15 passenger cutaway buses effectively meet requirements in terms of ground clearance, tight turning radius, short overhangs, and maneuverability. Many locations have very limited space for vehicle navigation, which favors vehicles with shorter wheelbases. The Buckwheat Express service area is characterized by hilly terrain, which results in bus routes that include points with unusually high approach/departure/breakover angles that can cause issues with low-floor vehicles. As powertrains and components for the cutaway buses are typically derivatives of commercially available light-truck products (Ford, Chevrolet/GMC, Dodge, International), they are available from local service locations. Adequate dealer support is typically available locally for maintenance and repairs that are not undertaken in- house; this also reduces the difficulty in troubleshooting powertrain issues.

The two-wheel drive vehicles provide adequate traction in most weather conditions in which the vehicle operate. The dual rear tires often provide adequate traction to safely navigate the winter driving conditions under which transit service operates. Chains are not used for inclement weather, as services are suspended when road conditions are not suitable (snow, ice). Typically, service is suspended when county schools are closed due to inclement weather, but this is not exclusive (e.g., schools may be open, but roads may still be unsuitable for public transit vehicles). All cutaway buses are ADA lift-equipped, and the lifts currently provide adequate capability for loading and unloading mobility challenged passengers.

No major shortcomings of the cutaway buses were identified. Buckwheat Express drivers are observing an increasing trend in the weight of mobility challenged passengers as well as the powered wheelchair and scooter equipment that passengers use. ADA lifts with greater weight capacities will likely be needed in the future. Cutaway buses equipped with diesel engines have the disadvantage of limited space and accessibility to perform maintenance. Diesel engines are not cost-effective considering the additional capital cost, maintenance cost, and payback period.

Durability and Reliability of Existing Transit Vehicle Offerings

Buckwheat Express reported general satisfaction with the durability and reliability of the current vehicle offerings and identified no major reliability issues with its current vehicles.

- Buckwheat Express experienced some problems with galvanic corrosion between aluminum bus bodies and steel chassis components.
- Every active transit vehicle undergoes a routine maintenance inspection every two weeks.
- Buckwheat Express typically performs all vehicle maintenance at its own dedicated maintenance facilities, including most powertrain and chassis maintenance and repairs.
- Maintenance technicians rely on local Ford dealerships for powertrain-n and chassis-related warranty repairs.
- There are no local service facilities for bus bodies and HVAC systems, and it is not feasible to have warranty repairs on bus bodies and HVAC performed by OEM dealerships. Body and HVAC system repairs must be performed by transit agency personnel parts and labor costs are reimbursed under the vehicle warranty coverage.
- Technical support to facilitate body and HVAC system repairs can sometime be a challenge.
- The rural transit community relies heavily on cooperation and support from other transit operators to troubleshoot and resolve maintenance problems.

Alternative Propulsion Technologies

Buckwheat Express does not currently own any buses with alternative fuel or propulsion systems. Currently, it has no interest in alternative propulsion technologies due to lack of supporting fueling infrastructure and lack of mechanic training and experience with such technologies.

Maintenance Training

WVDOT offers annual maintenance training for ADA wheelchair lifts and ramps, and maintenance training is offered almost every year, usually in September, providing an opportunity for drivers to learn how to do preventive maintenance on wheelchair lifts/ramps or tie downs and to discuss any problems they are having with their vehicles with WVDOT staff and manufacturer representatives. Agencies are highly encouraged to attend this training; however, training is limited only to lifts and ramps and does not cover general vehicle maintenance.

Vehicle Procurement Processes and Challenges

Vehicle procurements are administered through WVDOT. State vehicle purchases often include vehicles for multiple agencies. Buckwheat Express staff have limited input into the vehicle technical specifications on joint procurements administered by WVDOT; specifications usually involve some compromise between the requirements and features requested by multiple agencies participating in the joint procurement. The vehicle technical

specifications for cutaway buses have evolved over time through collaboration with WV DOT and rural transit operators throughout the state.

Recommendations for Improvement in Vehicle Procurement Process

- *Communications* –Buckwheat Express observed that communication between WVDOT and Buckwheat Express regarding vehicle procurement can be improved. New vehicles typically arrive "unannounced" with no description/specifications provided by the WVDOT beforehand. The transit agency often does not know what type of vehicle it is scheduled to receive before it arrives; the agency would prefer to have a detailed description of new vehicles before they arrive on site. Buckwheat Express has received new transit vehicles that were not equipped with destination signs and strobe lights upon delivery, which it attributes to miscommunication during the vehicle specification process.
- *Vehicle preferences* – Buckwheat Express prefers that WVDOT procure vehicles from the same manufacturer year-to-year to reduce costs associated with changing part lines and additional costs associated with training and tooling for an unfamiliar manufacturer.
- *Mechanic and technician training* – Availability of mechanic training is an issue with new vehicle procurements. Training of mechanics and technicians on new model vehicles is not common. Training from the body companies on structural and HVAC system maintenance is not readily available or cost-effective. There is a need for programs at the State and federal levels that will assist with and provide funding for technician and mechanic training at small rural transit operators.
- *Diagnostic equipment* – Acquisition of diagnostic scanners and tools is not typically included in vehicle procurement; the transit agency must purchase these tools from its own local budgets. Procurement of new diagnostic equipment that may be required to service new vehicles should be part of vehicle procurement.

Central West Virginia Transit Authority

Transit Agency Profile

Central West Virginia Transit Authority dba Centra, headquartered in Clarksburg, provides fixed-route and ADA complementary paratransit service in Harrison, Adamston, Hartland, Annmore, Bridgeport, Despard, Northview, Nutter Fort, Shinnston, Stealey, West Milford, and Salem as well as service to University Hospital Center and the Charles Pointe mixed-use commercial, residential, and recreational community [25]. Service to Fairmont, Morgantown, Charleston, and Pittsburgh is provided via transfer to Mountain Line's Greyline service and I-Ride 79 service provided by Barons Bus, Inc. Based on the 2018 NTD [24] transit

agency profile, Centra's service consumption in 2018 included 272,928 unlinked trips, comprising 633,573 annual vehicle revenue miles and 40,860 annual revenue vehicle hours. In 2018, Centra expended $2,727,231 in operating funds, consisting of $203,734 in fare revenues, $1,976,912 in local funds, and $525,000 in federal funds. Capital expenditures totaled $291,556, including $58,311 of State funds, $233,245 of federal funds, and $21,585 in other funds. Capital expenditures totaled $136,876, including $27,375 of state funds and $109,501 of federal funds.

Types of Service

Fixed-Route

Centra provides fixed-route service which runs on a regular schedule with no deviation aside from those to "request only" locations, including WV Works (WV Temporary Assistance for Needy Families), WV Junior College, Cambridge Place office park, and Bridgeport Manor nursing care facility.

ADA Complementary Paratransit Service

Centra offers ADA complementary paratransit demand-response service for eligible passengers with disabilities. Eligibility is determined according to criteria established by the ADA.

Fleet Demographics, Desirable Vehicle Features, and Limitations

In 2018, the Centra bus fleet consisted of 25 vehicles, comprising 29-ft medium-duty body-on-chassis buses, 23-ft cutaway buses, and passenger vans, as shown in Table 4-3. The largest buses operated by Centra transit are Freightliner diesel-powered body-on-chassis buses. These buses are also high-floor, with ADA-lifts. The cutaway buses are gasoline-powered buses on Ford E-10 and F550 chassis and seat 12–15 passengers; they do not feature low floors or level loading capability but are ADA lift-equipped.

Table 4-3 *Central West Virginia Transit Authority Fleet [24]*

MY	Type	Length	Seated Capacity	Number in Fleet	Modes
2017	Bus	29	18	2	MB
2015	Bus	29	33	2	MB
2015	Bus	29	25	6	MB
2013	Bus	29	24	2	MB
2010	Bus	29	28	2	MB
2000	Bus	29	24	1	MB
2017	Cutaway	23	15	1	DR/MB

MY	Type	Length	Seated Capacity	Number in Fleet	Modes
2016	Cutaway	23	12	1	MB
2014	Cutaway	23	15	1	MB
2014	Cutaway	23	15	1	DR
2012	Cutaway	23	15	1	DR
2017	Van	16	9	1	DR
2014	Van	18	10	3	DR
2011	Van	18	10	1	DR

Essential or desirable vehicle features include the following:

- Adequate ground clearance to navigate rural roadways.
- Short overhangs and tight turning radius to navigate tight roads, and driveways.
- Air-ride suspension; leaf spring suspensions tend to fail due to poorly-maintained roads.
- Traction control, desirable due to the winter weather conditions; traction control systems coupled with dual wheels tends to provide adequate traction. Spinner chains are not used because they conflict with the air-ride suspension system. Centra suspends service during weather condition that would require tire chains.
- ADA lifts with adequate lifting capacity for increasingly heavy passengers and powered wheelchairs and scooters.

Shortcomings of available cutaway buses identified by Centra staff include:

- Ford E-10 cutaway buses have poor visibility for drivers.
- Video surveillance systems are of poor quality; video systems are essential for liability reasons.
- Better HVAC systems for the buses; a significant number of passenger complaints are related to HVAC issues. Common complaints are that buses are not cool enough. The State RFP for 23-ft cutaways does specify BTU capacity of the cooling system.
- Strength of the tie-downs for wheelchairs in cabins is not adequate given increasing size and weight of powered wheelchairs and passengers.
- At times, no adequate passenger capacity (ridership typically surges at first of month).
- Need for better quality driver seats; current seats wear too easily and cannot comfortably accommodate larger drivers.

- ADA lifts currently have adequate capacity, but passenger and powered wheelchairs are increasing in weight. Lift platforms are sometimes too small to accommodate the size of some powered wheelchairs.

Durability and Reliability of Existing Transit Vehicle Offerings

Centra maintenance staff cited several durability issues with the cutaway buses used in their service:

- Water leaks are a significant issue. Water infiltration can occur in hidden areas and go unnoticed until significant damage occurs. The plywood floors in the buses can rot due to water infiltration.
- Electrical systems in the buses are complex and sometime suffer damage due to chaffing where wiring passes through bulkheads and body panels.
- Most reliability issues are associated with bus bodies and body manufacturers.
- HVAC systems have reliability issues. The maintenance supervisor mentioned that aluminum components in the AC were problematic compared to older copper components (more susceptible to cracking).
- It is important to maintain uniformity of bus manufacture in subsequent procurements for consistency of parts inventories.
- Destination signs become detached due to rough road conditions.
- Bus bodies are not adequately designed to endure the twisting imposed by terrain in rural areas.
- Framework in bodies is constructed of light gage 1–1.5-inch tubing.
- For buses built on Ford E-10 and F550 chassis, there are adequate service dealers in the local areas to support vehicle repair and maintenance and parts are easy to obtain.

Alternative Propulsion Technology

Centra transit has no previous experience with alternative propulsion technologies and no immediate plans to pursue them. Alternative fuel technologies are not feasible due to lack of refueling infrastructure.

Vehicle Procurement Processes and Challenges

All vehicle purchases at Centra are handled through the WVDOT Division of Public Transit. Purchases of transit vehicles are undertaken through the State procurement process. The Division of Public Transit determines when buses at Centra will be replaced. State vehicle purchases often include vehicles for multiple agencies. Centra staff have limited input into vehicle technical specification on joint procurements administered by WVDOT. Specifications usually involve some compromise between the requirements and features requested by multiple agencies participating in the joint procurement. Vehicle

technical specifications for cutaway buses have evolved over time through collaboration with WV DOT and rural transit operators throughout the state.

Recommendations for Improvement in Vehicle Procurement Process

- *Communications* – Procurement staff from the WV DOT Division of Public Transit should meet with the transit agencies to discuss needs and experiences with previous vehicles prior to making purchasing decisions.
- *Mechanic and technician training* – Centra staff observed that very few training programs are available. None of the available training offered through the Division of Public Transit includes training on vehicle maintenance. No training is available for the bodies or electrical and HVAC systems on cutaway and body-on-chassis vehicles. Previously, some training was available from Cummins on diesel engines used in larger body-on-chassis buses, and training sessions were offered on HVAC, bus bodies, and ADA lifts; these training are no longer available.
- *Diagnostic equipment* – Diagnostic tools and equipment are not included in vehicle purchases; Centra must purchase diagnostic tools and equipment using local funds.

Section 5 Vehicle Procurement Specifications

Purchases of small- to medium-size cutaway and body-on-chassis buses for small and rural transit agencies, including those funded through federal funding sources, are typically made through state department of transportation contracts. The contracts are awarded through solicited bids, with the bus companies proposing vehicle(s) and costs based on requirements defined in the solicitation.

APTA publishes Standard Bus Procurement Guidelines for heavy-duty transit buses [3] that outline a standardized RFP for a negotiated bus procurement contract including vehicle technical specifications. The Guidelines were developed from a cross-section of representatives from the public and private sectors of the public transit industry with the goal of creating common RFP and Vehicle Technical Specification (VTS) templates that transit agencies can modify to reflect State and local regulations and requirements. Standardization leads to consistency of interpretation and should reduce the effort required to develop RFP and VTS documents, resulting in fewer contract disputes during the contracting process.

The APTA Guidelines do not address small light- and medium-duty minivans, vans, cutaway buses, and body-on-chassis buses commonly used by small transit agencies that provide public transit in rural areas. Unlike purchases of large buses, where detailed guidance on the purchase process and on bus technical specifications are available through the APTA Guidelines, fewer resources are available to small transit providers to guide the development of technical specifications for small- to medium-size cutaway and body-on-chassis buses. As a result, small- to medium-size cutaway bus specifications vary markedly from state to state.

An objective of this project was to review procurement processes, vehicle procurement solicitations, and vehicle specifications to identify opportunities for standardization that could lead to the development of technical specification templates for cutaway and body-on-chassis buses such as those in the APTA Standard Bus Procurement Guidelines for 30–60-ft heavy-duty transit buses. WVU reviewed vehicle technical specifications from California [26, 27], Florida [28], Iowa [29], Kentucky [30], New Hampshire [31], New York [32], Ohio [33], Michigan [34], and West Virginia [35, 36]. Specifications varied widely, ranging from general guidance provided by Ohio to highly-detailed specifications provided by Michigan and California. Specification for similar buses, equipment, and vehicle systems varied substantially.

To encourage the development of standardized vehicle technical specifications and procurement guidance, a set of vehicle technical specifications was developed for cutaway buses based on the publicly-available specifications

cited above. The specifications, provided as an addendum in this report, include several alternative descriptions for vehicle systems, components, and features and can serve as a starting point for future development of a procurement guidance document for small transit vehicles like the APTA Standard Procurement Guidelines for heavy-duty transit buses [3].

Section 6

Conclusions

Morgantown PRT System Upgrades

WVU's PRT System is an automated people mover system in Morgantown that connects the WVU Downtown, Evansdale, and Health Sciences campuses and the Morgantown CBD. WVU used $414,700 of FTA funding from this grant and $251,000 of local cost-share funding to replace aging boilers in two guideway heating boiler plants. This involved removal of the existing boilers, installation of a new roof to accommodate the taller height of the replacement boilers, interior preparations, fabrication of the new boilers, and installation. Building modification and boiler installation were performed by Pine Hollow Construction. FTA funds in the amount of $414,700 were expended to purchase the new boilers, and WVU expended $253,000 of local cost-share to pay for removal of the existing boilers, building modifications, and installation of the new boilers.

Advanced Small Transit Vehicle Study

Vehicle Features for Rural Transit Applications

Rural transit applications have unique vehicle requirements that are not fully addressed by the vehicles currently available on the market. These features include the following:

- *Accessibility for mobility impaired and handicapped passengers* – Small community and rural transit agencies may have a high percentage of physically-challenged passengers. Vehicles need to have a low floor and a convenient loading ramps for wheelchairs and for passengers who have difficulty traversing steps. The Brevi Bus featured a low-floor design.
- *Flexible seating arrangements* – Small community transit agencies may need to accommodate a very high number of wheelchair passengers on some occasions. Many small transit agencies provide door-to-door service for older adult and mobility-impaired passengers between their homes and physician offices, grocery stores, and other retail stores. Consequently, the interior and seating arrangements of the buses must also be able to accommodate rider parcels and packages. The Brevi Bus had specially-designed fold-up seats that easily and quickly allowed for five forward facing wheelchair positions as required.
- *Maneuverability* – Small community and rural transit agencies need a vehicle that has the capacity to carry 20–30 passengers and that can maneuver narrow, poorly-maintained streets and roads to provide service to very near the front door of passenger residences. The Brevi Bus was designed to transport 26 passengers and maneuver sharp corners such

as those found in some trailer parks common in the Ride Solution service area. It had a low and narrow profile to adapt to the service environment.

- *High ground clearance* – Poorly-maintained roads in many rural counties and communities require vehicles with a high ground clearance. The Brevi Bus was designed with minimal front and rear overhangs for traversing hilly, washed-out roads with steep approaches and departure angles.
- *Low original cost* – The Brevi Bus was estimated to cost $250,000–$300,000, which was less than many comparable vehicles on the market.
- *Ease of maintenance* – Small transit agencies have limited maintenance shop resources, including limited training for their mechanics and limited spare parts storage. The entire engine and transmission of the Brevi Bus were mounted on a cage or stand that slid as a unit on rollers into and out of the vehicle and allowed good access for maintenance.
- *Durability and long service life* – A common complaint about small transit vehicles is durability. As most small transit vehicles on the market are light- and medium-duty cutaways and body-on-chassis vehicles, durability and service life are lower than purpose-built heavy-duty transit buses. The Brevi Bus featured a medium-duty truck chassis and powertrain, stainless steel structure, and composite body for increased durability and long life.

The Brevi Bus prototype developed at Ride Solution in Palatka was specifically designed to address these unique vehicle requirements of rural transit providers. The Brevi Bus, which was built on a modified medium-duty Freightliner truck chassis, featured a unique drive train arrangement that enabled a flat, low floor arrangement similar to the low-floor design of heavy-duty low-floor transit buses. The low-floor design allowed for use of a loading ramp, eliminating the need for a wheelchair lift, and greatly enhanced accessibility for mobility-impaired passengers. The Brevi Bus prototypes were designed and manufactured by Ride Solution with the assistance of FTA funding. As a prototype vehicle not built by a commercial vehicle manufacturer, the Brevi Bus encountered reliability problems that needed to be addressed through further design and manufacturing refinement. Ride Solutions originally intended to build 10 vehicles but due reductions in local funding, only two vehicles were completed. There were attempts by the Brevi Bus team to recruit an OEM manufacturer to take the prototype design to production, but an arrangement did not materialize.

Despite the reliability issues encountered in the early prototypes and the difficulty in attracting an OEM manufacturer, the Brevi Bus concept addressed many desirable features for rural transit vehicles and shortcomings of existing vehicles available in the market. Further vehicle development based on the Brevi Bus design could dramatically improve upon the features of current vehicle offerings.

Reliability and Durability of Currently-Available Vehicles for Small and Rural Transit

Transit managers interviewed by WVU cited several common shortcomings with currently-available cutaway and body-on-chassis buses. Two common issues included lack of low-floor or level-loading capability with acceptable ground clearance for navigating local terrain and road conditions and the need for lifts to load passengers who use manual and powered wheelchairs. Another common shortcoming is the trade-off between passenger capacity and maneuverability. Smaller cutaway buses that have the maneuverability and ground clearance to navigate the roads and terrain often do not have adequate passenger capacity, and larger body-on-chassis buses with higher passenger capacity lack the maneuverability to service the rural areas. Several transit managers stated that available HVAC systems lacked the capacity to provide adequate cooling for passenger comfort.

Common maintenance and durability complaints about currently available vehicles include the following:

- Galvanic corrosion occurs between aluminum bus bodies and steel chassis components.
- Water leaks are a significant issue. Water infiltration can occur in hidden areas and go unnoticed until significant damage occurs. The plywood floors in the buses can rot due to water infiltration.
- Electrical systems in the buses are complex and sometimes suffer damage due to chaffing where wiring passes through bulkheads and body panels.
- Bus bodies are not adequately designed to endure the twisting imposed by terrain in rural areas. The framework in the bodies is constructed of light gage 1–1.5-inch tubing.
- Strength of tie-downs for wheelchairs in cabins is not adequate given increasing size and weight of powered wheelchairs and passengers.
- HVAC systems have reliability issues. Maintenance supervisors mentioned that aluminum components in ACs are problematic compared to older copper components (more susceptible to cracking).

Most reliability issues were associated with bus bodies and HVAC systems. There typically are no local service facilities for bus bodies and HVAC systems, and it is not feasible to have warranty repairs on bus bodies and HVAC performed by OEM dealerships. Body and HVAC system repairs must be performed by transit agency personnel, although the parts and labor costs are reimbursed under the vehicle warranty coverage. Technical support to facilitate body and HVAC system repairs can sometimes be a challenge. There is a need to improve the reliability and durability of the bodies and HVAC systems of currently-available vehicles on the market.

Advanced Propulsion Technologies in Rural Transit Applications

There is frequently a desire on the part of local governments and transit boards to integrate advanced propulsion technologies into transit fleets to reduce the carbon footprint and environmental impacts and to improve energy efficiency. Available propulsion technologies include alternative fuels such as CNG, propane, biodiesel, ethanol, and hydrogen (for combustion as an internal combustion engine fuel) as well as hybrid-electric and battery-electric buses and fuel cell-electric vehicles. Integration of a new fuel or propulsion technologies into an existing transit vehicle fleet presents several challenges:

- *Availability or installation of charging and fueling infrastructure* – For alternative fuels including CNG, propane, and hydrogen, installation of a refueling station represents a significant financial investment. In some instances, municipal refueling infrastructure may be available. In these instances, the round-trip distance between the transit depot and fueling facility compared to vehicle range must be considered. Installation of charging equipment and charging facilities may also require a significant financial investment as well as upgrade of the electric infrastructure feeding the transit property. Installation of chargers at the maintenance depot represents the most cost-effective alternative for small electric vehicle fleets.
- *Construction or modification of maintenance facilities* – Introduction of gaseous fuels typically requires that maintenance facilities be upgraded due to the flammability of gaseous fuels. Modification can include replacing light fixtures, modifying ceiling designs to prevent accumulation of gaseous fuel, or constructing separate maintenance facilities for the gaseous fueled buses.
- *Unique vehicle maintenance requirements* – Small transit providers often rely on local OEM dealerships for powertrain maintenance. Alternative fuel and advanced propulsion vehicles have unique maintenance requirements that local OEM dealership maintenance departments may not be able to support. Onsite mechanics will require specialized training and specialized diagnostic equipment and tools to maintain alternative-fueled, hybrid-electric, and battery-electric vehicles. Adequate manufacturer support in the form of technical support and timely delivery of parts is also an important consideration. Alternative-fueled and advanced technology vehicle should be purchased from well-established OEMs that can provide close technical support and adequate inventory of spare parts.
- *Vehicle range* – The distance that an alternative-fueled or battery-electric vehicle can travel must be considered. Fueling and charging facilities for advanced technology vehicles will often only be available at the maintenance depot. Transit vehicles providing paratransit service often

travel long distances through rural areas, and vehicles must have adequate range to meet the service demands.

When considering integration of advanced propulsion technologies, rural transit agencies should favor technologies that have reached technology readiness levels 7–9. Hybrid-electric propulsion is a well-established technology both in heavy duty transit and light duty personal transportation. Hybrid electric vehicles are relatively easy to integrate into and existing transit fleet. Hybrid-electric vehicle can use existing gasoline or diesel fueling infrastructure and generally do not require battery charging infrastructure. OEM dealerships that sell hybrid-electric vehicles should be equipped to provide powertrain maintenance. Hybrid-electric vehicles can provide improved fuel efficiency compared to conventional internal combustion engine vehicles. CNG- and propane-fueled internal combustion engine vehicle are also mature technologies. Many school bus fleets employ propane- or CNG-fueled buses. Although propane and CNG buses may require some specialized fuel system maintenance, maintenance of the internal combustion engine is similar to maintenance of conventional gasoline or diesel engines and typically requires only a modest investment in specialized diagnostic tools. Battery-electric buses have also reached a stable level of maturity in the heavy-duty bus market. Battery-electric bus demonstration projects conducted by NREL [37–42] indicate maintenance costs that are similar to or below those of internal combustion engine vehicles. Hydrogen fuel cell buses and hydrogen internal combustion engine buses represent a more challenging technology to implement in small rural transit operations.

Vehicle Procurement Process

The purchase of transit vehicles for rural transit is eligible for funding through the Chapter 53, Section 5311, Formula Grants for Rural Areas program. Under this program, FTA funds 80% of capital projects including vehicle purchases, and procurements often are executed by state departments of transportation that develop and distribute vehicle technical specifications and requests for quotes and execute procurement contracts on behalf of small and rural transit providers. Rural transit providers contacted by WVU reported that they typically have limited input into the development of vehicle specifications, RFPs, and vehicle procurement schedules. Specifications usually involve some compromise between the requirements and features requested by multiple agencies participating in a joint procurement and may not fully address the needs of individual transit agencies. Transit managers observed that state procurement departments should communicate with transit providers about the strengths and shortcomings of existing vehicles prior to making new vehicle purchases.

Vehicle Technical Specifications

Purchases of small- to medium-size cutaway and body-on-chassis buses for small and rural transit agencies, including those funded through federal funding sources, are typically made through state DOT contracts. Unlike purchases of large buses, where detailed guidance on the purchasing process and bus technical specifications are available through the APTA Standard Bus Procurement Guidelines, fewer resources are available to small transit providers to guide the development of technical specifications for small- to medium-size cutaway and body-on-chassis buses. As a result, small- to medium-size cutaway bus specifications vary markedly from state to state. To encourage the development of standardized vehicle technical specifications and procurement guidance, a set of vehicle technical specifications was developed for cutaway buses. The specifications, provided as an addendum to this report, include several alternative descriptions for vehicle systems, components, and features and can serve as a starting point for future development of a procurement guidance document for small transit vehicles similar to the APTA Standard Procurement Guidelines for heavy-duty transit buses [3].

Section 7

Suggested Future Work

APTA's Standard Bus Procurement Guidelines for heavy-duty transit buses [3] outline a standardized RFP for a negotiated bus procurement contract, including vehicle technical specifications; however, they do not address small light- and medium-duty minivans, vans, cutaway buses, and body-on-chassis buses commonly used by small transit agencies that provide public transit in rural areas. Specifications included in RFPs for small and rural transit vehicle are developed by state DOTs and vary widely from state to state. Standardization of vehicle specifications would reduce the effort required to develop RFP and VTS documents, resulting in fewer contract disputes during the contracting process. Standardization would also benefit manufacturers of cutaway and body-on-chassis buses for small transit applications.

WVU researchers developed a draft vehicle technical specification template based on review of multiple state specification documents. This template is intended to serve as a starting point for the development of a set of formal vehicle procurement guidelines for small transit vehicles. The current template addresses only cutaway buses; a similar template should be developed for body-on-chassis buses. The next step is for a transit industry trade group such as APTA or CTAA to develop standard bus procurement guidelines for small transit vehicles that are similar to the APTA Standard Bus Procurement Guidelines for heavy-duty transit buses [3] based on the template developed through this project.

Appendix A Technology Readiness Level Guideline

Table A-1 *Technology Readiness Levels for Advanced Technology Bus Commercialization [43]*

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Deployment	TRL 9	Actual system operated over full range of expected conditions	Technology is in final form. Deployment, marketing, and support begin for first fully commercial products.
Technology Demonstration/ Commissioning	TRL 8	Actual system completed and qualified through test and demonstration	Last step in true system development. Demonstration of limited production of 50–100 buses at small number of locations. Beginning transition of all maintenance to transit staff.
	TRL7	Full-scale validation in relevant environment	Major step up from TRL 6 by adding larger numbers of buses and increasing hours of service. Full-scale demonstration and reliability testing of 5–10 buses at several locations. Manufacturers begin to train larger numbers of transit staff in operation and maintenance.
	TRL 6	Engineering/pilot-scale validation in relevant environment	First tests of prototype buses in actual transit service. Field testing and design shakedown of 1–2 prototypes. Manufacturers assist in operation and typically handle all maintenance. Begin to introduce transit staff to technology.
Technology Development	TRL 5	Laboratory scale, similar system validation in relevant environment	Integrated system tested in laboratory under simulated conditions based on early modeling. System integrated into early prototype or mule platform for some on-road testing.
	TRL 4	Component and system validation in laboratory environment	Basic technological components integrated into system and begin laboratory testing and modeling of potential duty cycles.
Research to Prove Feasibility	TRL 3	Analytical and experimental critical function and/or proof of concept	Active research into components and system integration needs. Investigate what requirements might be met with existing commercial components.
Basic Technology Research	TRL 2	Technology concept and/or application formulated	Research technology needed to meet market requirements. Define strategy for moving through development stages.
	TRL 1	Basic principles observed and reported	Scientific research and early development of concepts.

Acronyms and Abbreviations

AC	air conditioning
ADA	Americans with Disabilities Act
APS	accessory power system
APTA	American Public Transportation Association
ART	arterial test cycle
ATC	automatic train control
BRT	bus rapid transit
BTU	British thermal unit
CNG	compressed natural gas
CO_2	carbon dioxide
CVT	continuously variable transmission
DOT	Department of Transportation
DPF	diesel particulate filter
ENC	Eldorado National Corporation
FCEB	fuel cell electric bus
FTA	Federal Transit Administration
GNHTD	Greater New Haven Transit District
GPS	global positioning system
HA	Hybrid Advantage
HVAC	heating ventilation and air conditioning
ICE	internal combustion engine
KC Metro	King County Metropolitan Transit
KRT	Kanawha Valley Regional Transit
MCI	Motor Coach Industries
MTM	Medical Transportation Monitoring
NO_X	oxides of nitrogen
NREL	National Renewable Energy Laboratory
NYCT	New York City Transit
OEM	original equipment manufacturer
PCS	propulsion control system
PRT	Personal Rapid Transit
regen	regenerative braking
RRC_O	rolling resistance coefficient
SEAT	Southeast Area Transit
STURAA	Surface Transportation and Uniform Relocation Act
VCCS	vehicle control and communication system
VMT	vehicle miles traveled
WMATA	Washington Metropolitan Transit Administration
WVU	West Virginia University

References

[1] D. Peterson (2007). Small transit vehicle industry study, North Dakota State University, Fargo, DP-181. https://www.ugpti.org/resources/reports/details.php?id=568, accessed March 4, 2019.

[2] Federal Transit Administration (FTA). National Transit Database. https://www.transit.dot.gov/ntd, accessed June 18, 2018.

[3] American Public Transportation Association (APTA) (2013). APTA Standard Bus Procurement Guidelines. https://www.apta.com/resources/reportsandpublications/Pages/BusParatransit.aspx.

[4] Eudy, L., and Chandler, K. (2010). Fuel cell transit bus evaluations: Joint evaluation plan for the U.S. Department of Energy and the Federal Transit Administration, National Renewable Energy Laboratory, Golden CO, NREL/TP-5600-49342-1. https://www.nrel.gov/docs/fy11osti/49342-1.pdf, accessed March 2019.

[5] FTA. Program History. https://www.transit.dot.gov/research-innovation/program-history, accessed June 14, 2019.

[6] Penn State College of Engineering. Bus Research and Testing Center. https://www.altoonabustest.psu.edu/index.aspx, accessed June 14, 2019.

[7] Nelson\Nygaard Consulting Associates & ASG Planning (2015). SEAT bus study. https://southeastareatransitdistrict.com/wp-content/uploads/2019/01/SEAT-Final-Report-110115_reduced.pdf, accessed July 9, 2019.

[8] Southeast Area Transit District (SEAT). https://southeastareatransitdistrict.com, accessed July 9, 2019.

[9] APTA (2017). APTA Clean Propulsion Resource Guide. http://www.apta.com/resources/reportsandpublications/Documents/2017%20APTA%20Clean%20Propulsion%20Resource%20Guide_20170710.pdf, accessed June 27, 2018.

[10] Clark, N.N., Zhen, F., Wayne, W. S., Schiavone, J. J., Chambers, C., Golub, A. D., and Chandler, K. L. (2009). Assessment of hybrid-electric transit bus technology, TCRP Report 1073-4872. https://www.nap.edu/catalog/22983/assessment-of-hybrid-electric-transit-bus-technology

[11] BAE Systems, Inc. BAE Systems HybriDrive Series-E: Electric Power and Propulsion. http://www.hybridrive.com/series-e.php, accessed June 1, 2018.

[12] Hu, X.S., Murgovski, N., Johannesson, L., and Egardt, B. (2013). Energy efficiency analysis of a series plug-in hybrid electric bus with different energy management strategies and battery sizes,. *Appl. Energy*, 111, 1001-1009.

[13] Lajunen, A. (2014). Energy consumption and cost-benefit analysis of hybrid and electric city buses. *Transportation Research Part C-Emerging Technologies*, 38, 1-15.

[14] F. Millo, F., Rolando, L., Fuso, R., and Zhao, J.N. (2015). Development of a new hybrid bus for urban public transportation. *Appl. Energy*, 157, 583-594.

[15] Xiong, W., Zhang, Y., and Yin, C. (2009). Optimal energy management for a series–parallel hybrid electric bus. *Energy Conversion and Management*, 50(7), 1730-1738.

[16] Hallmark, S.L., Wang, B., and Sperry, R. (2013). Comparison of on-road emissions for hybrid and regular transit buses. *J Air Waste Manag Assoc*, 63(10), 1212-20.

[17] Merkisz, J., and Pielecha, J. (2010). Emissions and fuel consumption during road test from diesel and hybrid buses under real road conditions. *2010 IEEE Vehicle Power and Propulsion Conference*, 1-3 September 2010, 1-5.

[18] Zhang, S.J., et al. (2014). Real-world fuel consumption and CO_2 emissions of urban public buses in Beijing. *Appl. Energy*, 113, 1645-1655.

[19] Wayne, W. S., Clark, N.N., Khan, A.S., Gautam, M., Thompson, G.J., and Lyons, D.W. (2008). Regulated and non-regulated emissions and fuel economy from conventional diesel, hybrid-electric diesel, and natural gas transit buses. *J. Transp. Res. Forum.*, 47(3), 105-125. https://EconPapers.repec.org/RePEc:ags:ndjtrf:206966.

[20] O'Keefe, M.P., Simpson, A., Kelly, K.J., and Pedersen, D.S. (2007). Duty cycle characterization and evaluation towards heavy hybrid vehcile applications. Presented at 2007 SAE World Congress and Exhibition, Detroit, MI.

[21] Sandoval, J.A. (2011). Study of transit bus duty cycle and its influence on fuel economy and emissions of diesel-electric hybrids, Ph.D. dissertation, West Virginia University. https://search.proquest.com/pqdtglobal/docview/894245940/70A61475040D4074PQ/1?accountid=2837.

[22] Greater New Haven Transit District. http://www.gnhtd.org/, accessed October 17, 2019.

[23] Mountain Line Transit Authority. http://www.busride.org/, accessed February 18, 2020.

[24] FTA. National Transit Database. https://www.transit.dot.gov/ntd, accessed February 18, 2020.

[25] Centra, Central West Virginia Transit Authority. https://www.centrabus.com/, accessed May 29, 2020.

[26] Vehicle Specification and Bid Requirements for Medium Duty Transit Bus (2005).

[27] RFP No. 13-03, Request for Proposals for Joint Procurement of Cutaways, Minivans, Large Cutawayns and Low Floor Cutaways (2015).

[28] (TRIPS-15-CA-RFP, Standard Cutaway Chassis Type Transit Vehicles Request for Proposal TRIPS-15-CA-RFP (2015).

[29] Spec. No. 4148 176-LDB-09, Cutaway Van Chassis Light Duty Accessible Transit Composite/Fiberglass Buses (2009).

[30] Invitation for Bids (2014).

[31] Vehicle Specification New Hampshire Department of Transportation Medium/Heavy Duty Low Flow Transit/Paratransit Cutaway Buses Class 4/5 (2017).

[32] Contract No. PC67313, Consent to Assignment Post Assignment Contract No. PC67795 (2017).

[33] Vehicle Catalog & Selection Guide.

[34] Specificationfor Small Class of Buses, Class I - 5 years/150,000 Miles (minimim); Class II - 7 Years/200,000 Miles I (minimum) of Non-lift and Lift Transit Buses with Alternate Seating (2016).

[35] Solicitation No. BVH419, Solicitation for Passenger Cutaway Bus (2013).

[36] RFP No. MCUMTA2017-4, Contract Documents and Specification for Cutaway Buses (2017).

[37] Eudy, L., and Jeffers, M. (2017). Foothill Transit battery electric bus demonstration results: Second report. National Renewable Energy Laboratory, Golden CO, Report NREL/TP-5400-67698. https://www.nrel.gov/docs/fy17osti/67698.pdf, accessed August 21, 2017.

[38] Eudy, L (2017). Foothill Transit battery electric bus evaluation. National Renewable Energy Laboratory. https://www.nrel.gov/transportation/fleettest-electric-foothill.html, accessed October 24, 2017.

[39] Eudy, L., and Jeffers, M. (2018). Foothill Transit Agency Battery electric bus progress report - Data period focus: Jan 2018 through Jun 2018. National Renewable Energy Laboratory, Golden CO, NREL/PR-5400-72207. https://www.nrel.gov/docs/fy19osti/72207.pdf, accessed June 2, 2021.

[40] Eudy, L., and Jeffers, M. (2018). Foothill Transit Agency battery electric bus progress report - Data period focus: Jul 2018 through Dec 2018. National Renewable Energy Laboratory, Golden CO, NREL/PR-5400-72209, May 2019. https://www.nrel.gov/docs/fy19osti/72209.pdf, accessed June 2, 2021.

[41] Eudy, L., and Jeffers, M. (2019). Foothill Transit Agency battery electric bus progress report - Data focus period: Jan 2019 through Jun 2019, National Renewable Energy Laboratory, Golden CO, NREL/PR-5400-73516, October 2019. https://www.nrel.gov/docs/fy20osti/73516.pdf, accessed June 2, 2021.

[42] Eudy, L., and Jeffers, M. (2020). Foothill Transit Agency battery electric bus progress report - Data period focus: Jan 2020 through June 2020. National Renewable Energy Laboratory, Golden CO, NREL/PR-5400-76259, December 2020. https://www.nrel.gov/docs/fy21osti/76259.pdf, accessed June 2, 2021.

[43] Eudy, L., Prohaska, R., Kelly, K., and Post, M., Foothill Transit battery electric bus demonstration results. National Renewable Energy Laboratory, Golden CO, Report NREL/TP-5400-65274, January 2016. https://www.nrel.gov/docs/fy16osti/65274.pdf, accessed August 21, 2017.

Addendum 1: Sample Vehicle Technical Specifications Template for Cutaway Transit Buses

The American Public Transportation Association (APTA) publishes Standard Bus Procurement Guidelines for heavy-duty transit buses. These guidelines outline a standardized Request for Proposal (RFP) for a negotiated bus procurement contract including vehicle technical specifications. The APTA Bus Procurement Guidelines were developed from a cross-section of representatives from the public and private sectors of the public transit industry with the goal of creating common RFP and Vehicle Technical Specification (VTS) templates that transit agencies can modify to reflect state and local regulations and requirements. Standardization leads to consistency of interpretation and should reduce the effort required to develop RFP and VTS documents resulting in fewer contract disputes during the contracting process.

The APTA Standard Bus Procurement Guidelines do not address small light- and medium-duty minivans, vans, cutaway buses, and body-on-chassis buses commonly used by small transit agencies that provide public transit in rural areas. Purchases of small- to medium-size buses for small and rural transit agencies, including those funded through federal funding sources are typically made through state department of transportation contracts. The contracts are awarded through solicited bids; bus companies propose vehicle(s) and costs based on requirements defined in the solicitation. No standardized RFP and VTS templates currently exist for small transit vehicles. Consequently, vehicle technical specifications and RFPs vary substantially from state to state, which complicates the procurement process for both transit providers and vehicle manufacturers and vendors. The use of standard specifications for commonly-used transit vehicles will improve the ability of the prepared procurement contracts that contain all necessary requirements and incorporate best available practices.

This document provides an outline to facilitate the development of vehicle technical specifications for cutaway buses for use in rural transit and paratransit applications and a starting point to spur the development of standardized vehicle specifications for other types of rural transit buses including minivans, vans, and body-on-chassis buses. The template was developed by reviewing and combining publicly-available technical specifications for cutaway buses from multiple states and includes several alternative specifications that can be used to develop a vehicle specification package for a specific bus procurement. Specifications from Florida and Michigan were cited heavily because they were representative of many state documents and contain adequate detail without being excessive.

How to Use this Document

This cutaway vehicle specification template includes sample specifications taken from various public cutaway vehicle procurement RFPs. For each section of the specification, one or more alternative descriptions are presented that indicate different levels of detail in the specification. Users can edit the document to delete alternatives not selected. Alternatively, descriptions can be copies from this document into a vehicle specification document. Transit agencies will need to modify this document by choosing among the alternatives presented in each section and by customizing the specifications to reflect state and local regulations, laws, and vehicle requirements, deleting rows associated with alternatives not selected. However, modifications should be made such that they will maintain the structural integrity of the document. The numbering of unused sections should be maintained and accompanied by the notations “not used” or “reserved.”

Table of Contents

1 General Requirements

1.1 Vehicle Types

Alternative 1

This Proposal shall consider any available cutaway chassis that the manufacturer is capable of building. Proposal shall include GVWR and GAWR along with the body length and seating capacity.

Source: Florida Department of Transportation [1]

Alternative 2

These specifications set forth the minimum requirements for a two-axle, transit class commercial non-lift bus or a paratransit type commercial bus equipped with a commercial wheelchair lift. The body shall be mounted on a commercial or recreational vehicle (RV) chassis [2]. Buses in these specifications shall be defined by the following classes:

1. Small Class One: Minimum 11,500 GVWR; 5 Years/150,000 Miles
2. Small Class Two: Minimum 15,200 GVWR; 7 Years/200,000 Miles

The Small Class of buses must be capable seating a minimum of 11 adult forward facing passengers or an alternate capacity of ambulatory adult passengers and wheelchair passengers.

The vendor shall be responsible for certifying that all buses delivered:

1. Shall not exceed the GVWR of the chassis as bid (determined by engineering calculated loaded vehicle axle weights),
2. 20 passenger single wheelchair securement area buses shall not exceed 21' 11" in length measured bumper to bumper excluding the energy absorbing portion of the bumper (distance of travel allowed for compression of the bumper without body deformation).

Source: Michigan Office of Passenger Transportation [2]

2 Standard and Optional Equipment

Alternative 1

Shuttle Bus Package shall include the following:

1. Chrome Appearance.
2. Transmission Oil Cooler.
3. Auxiliary Rear Heat Provisions.
4. Tilt-Wheel.
5. Cruise-Control.

No Standard Features shall be deleted. Each Proposal shall include a list of all Standard Features, Safety and Security Features and Accessibility Features to be provided as standard equipment. The vendor shall list Optional Features available and their related pricing.

Source: Florida Department of Transportation [1]

2.1 Vehicle Identification and Labeling

Alternative 1

Chassis serial number, body number, axle ratio, gross vehicle weight rating (GVWR), seating capacity and paint codes shall be imprinted on a permanent decal(s) or stamped on a metal plate(s) and affixed in the driver's area of the bus (location to be approved by the State).

Source Michigan Office of Passenger Transportation [2]

2.2 Prototype Vehicle

Alternative 1

The first bus produced under this agreement shall be considered the “prototype” bus. After inspection of this vehicle, (Insert Transit Agency Name) reserves the right to clarify production build methods that are not specifically addressed in the technical specifications. Subsequent manufactured vehicles shall include all changes as standard in production.

Source: Florida Department of Transportation [1]

3 Regulatory Requirements

Alternative 1

The contractor shall comply, and the proposed vehicle conform to all applicable federal, state, and local regulations.

3.1 Federal Motor Vehicle Safety Standards

Alternative 1

The proposed vehicle(s) must meet applicable requirements of 49 CFR Part 571: Federal Motor Vehicle Safety Standards.

3.2 Federal Motor Carrier Safety Regulations

Alternative 1

The proposed vehicle(s) must meet applicable requirements of 49 CFR Part 393: Federal Motor Carrier Safety Regulations.

3.3 Air Pollution and Emissions Standards for New Vehicles

Alternative 1

The proposed vehicle(s) shall meet with the requirements of 40 CFR Part 85, Control of Air Pollution from Mobile Sources, and 40 CFR Part 86, Control of Emissions from New and In-Use Highway Vehicles and Engines.

3.4 Americans with Disabilities Act

Alternative 1

The proposed vehicle(s) shall meet the requirements of 49 CFR Part 38: Americans with Disabilities Act (ADA), Accessibility Specifications for Transportation Vehicles, Subpart B: Buses, Vans, and Systems.

3.5 Fuel Economy

Alternative 1

Any proposed vehicle(s) with capacity for 12 persons or less, including the driver, must comply with 40 CFR Part 600: Fuel Economy and Greenhouse Gas Exhaust Emissions of Motor Vehicles.

Source: Florida Department of Transportation [1]

Alternative 2

{Reserved}

3.6 Bus Testing Program

Alternative 1

The proposed vehicle(s) must have passed any testing required by 49 CFR 665: Bus Testing and the proposer must submit FTA bus test reports.

The successful bidder will be required to provide all results of testing accomplished under the final rules issued by the Federal Transit Administration, 49 CFR Part 655 Bus Testing Program. The tests include the evaluation of maintainability, reliability, safety, performance, structural integrity, fuel economy and noise. The successful bidder shall provide all reports related to the buses as specified in §665.11 and § 665.13.

3.7 Natural Gas Fueled Vehicles

Alternative 1

Proposed vehicle(s) must meet standards of National Fire Protection Agency (NFPA)_52: Vehicular Natural Gas Fuel Systems Code.

Alternative 2

{Omit section if not applicable}

3.8 State/Local Regulations

{This section is reserved for applicable state and local regulatory requirements.}

4 Build Quality

4.1 Workmanship

Alternative 1

The machining, welding, fabrication and finishing of the delivered vehicles must meet the highest standards of accepted vehicle manufacturing practices.

Alternative 2

1. Workmanship throughout the vehicle shall conform to the highest standards of accepted commercial practice and shall result in a neat and finished appearance.
2. The complete vehicle(s) must be of substantial and durable construction in all respects.
3. All sub-components must be installed per the sub-component manufacturer's standard mounting/installation/operations instructions.
4. Any deviations on component mounting/installation/operations procedure must be approved in writing by the sub-component manufacturer and **{insert procuring agency name}** prior to installation.

Source Florida Department of Transportation [1]

Alternative 3

1. All labor employed in both the manufacturing and assembly processes of the bus purchased shall be to the highest industry standards.
2. The entire bus shall be within all established engineering tolerances set by all parties involved in the design and production of the bus.
3. All added components shall be installed and positioned according to the component manufacturer's installation procedures which shall be available upon request.

Source: Michigan Office of Passenger Transportation [2]

4.2 Welding

Alternative 1

Procedures and materials used in welding the vehicles shall meet American Society for Testing and Materials (ASTM) and American Welding Society (AWS) standards. Welds must be ground, and carbon steel welds must be primed with a corrosion inhibiting primer and painted.

Alternative 2

1. Welding procedures and materials shall be in accordance with standards of the American Society of Testing Materials and the American Welding Society.
2. Welds not meeting these standards will be rejected. Rejection will result in the total replacement of sub-floor assemblies and/or cage assemblies.
3. All exterior skin side welded surfaces shall be ground smooth and be free of unfriendly surfaces as part of the standard production process.
4. All welds shall be inspected for quality and subject to online inspection.
5. All welding shall be performed using MIG welding machines utilizing Argon gas.

6. All steel body/floor structure shall be coated rust inhibiter primer for corrosion protection and to prevent rust.
7. Proposer shall describe their corrosion prevention process and products utilized in application to vehicle and submit with proposal for this RFP.

Source: Florida Department of Transportation [1]

Alternative 3

1. All welding procedures used throughout the construction of the bus, including materials, qualifications, and training of personnel, shall be in accordance with the standards of the American Society for Testing and Materials (ASTM) and the American Welding Society (AWS).
2. Contact surfaces of all material to be welded shall be clean, and free of grease, paint, rust, and scale.
3. After welding, all rough edges and surfaces on parts shall be ground smooth and coated with a corrosion inhibiting primer and paint.

Source Michigan Office of Passenger Transportation [2]

4.3 Fasteners

Alternative 1

1. All fasteners used in the vehicle shall be backed by a Certificate of Quality by the manufacturer and have been found to be in accordance with all SAE and ANSI specifications.
2. Screws, bolts, nuts, washers, rivets, and other fasteners used to construct the vehicle shall be appropriately sized for their application.
3. Fasteners that have the potential to be exposed to the elements, including fasteners used in the interior of the vehicle that may be exposed to tracked in snow/ice melting substances (sodium chloride/salt, calcium chloride, etc.), must be made of a corrosion resistant material (e.g. stainless steel, plastic) or treated (hot-dip galvanized, plated) with rust-resistant material.

4.4 Finishing

Alternative 1

1. Surfaces and edges of all parts, components and accessories shall be new. All exposed surfaces and edges shall be smooth, free from burrs and other projections and shall be neatly finished.
2. The exhaust system, drive line and any subcomponent installed underneath the vehicle shall not be primed.

4.5 Sub-components

Alternative 1

All sub-component units including but not limited to wheelchair lift, restraint systems, passenger seating, event data recorders, alternators, air conditioning, and any other subcomponent installed by the bus manufacturer shall be installed per the sub-component manufacturer's installation instructions. All subcomponent manufacturer Installation Instructions must be submitted prior to the first bus being delivered from this contract.

Source: Florida Department of Transportation [1]

5 Chassis

Alternative 1

1. The chassis shall have a pre-delivery inspection performed by a representative of the chassis manufacturer before the bus manufacturing process begins. A copy of the completed pre-delivery inspection form shall accompany the bare chassis and accompany the bus during manufacturing as part of the build order.
2. All standard or optional chassis equipment to be included shall be as advertised by the manufacturer and factory installed and shall not consist of substitute or aftermarket equipment. Optional chassis equipment not available from the factory may be dealer installed.
3. The chassis shall meet the following minimum requirements.
    a. Class I - Chassis shall have one front axle with single wheels and one rear axle with dual wheels. It shall have a driver and passenger OEM door with co-pilot seat, or it shall have a driver OEM door without a co-pilot seat.
    b. Class II - Commercial rated chassis shall be the highest Gross Vehicle Weight Rating (GVWR) available for the wheelbase and shall have one front axle with single wheels and one rear axle with dual wheels.

Source Michigan Office of Passenger Transportation [2]

5.1 Chassis Alterations

Alternative 1

Any modifications between the front and rear suspension mounts to lengthen the OEM chassis must be accompanied by engineering analyses that assures the proposed vehicle GVWR is not reduced.

Alternative 2

1. Cutting of the chassis to increase or decrease the length of the chassis to increase the GVWR will not be permitted. This will be verified through serial number checks.
2. Any proposal to modify the chassis shall include a detailed description and drawings of frame insert section.
3. Rear frame extensions shall be butt-welded with a continuous weld and shall exceed the requirements of the chassis manufacturer. A 4" x 12" x 1/4" steel plate shall be installed and welded with a continuous weld around the entire circumference of the plate and bolted.
4. Re-certification of the chassis OEM GVWR and GAWR is not allowed. Any vehicle that exceeds the OEM GVWR and/or GAWR will not be accepted.
5. The rear overhang, measured from the center of the rear axle to the outer edge of the rear bumper, cannot exceed 1/3 of the overall vehicle length.

Source: Florida Department of Transportation [1]

Alternative 2: **(Source Florida Department of Transportation [1])**

5.2 Wheelbase

Alternative 1

The minimum wheelbase shall be 138 inches (small class I) and 158 inches (small class II) suing the wheelbase for each of the specified bus lengths which will provide proper approach and departure

angles, proper handling, and proper ride characteristics. Maximum rear overhang shall not exceed 1/3 bus overall length.

Source: Michigan Office of Passenger Transportation [2]

5.3 Weight

Alternative 1

1. The GVWR and front/rear GAWR of the proposed vehicle shall not exceed the OEM chassis ratings.
2. The four-corner unladen weight of the vehicle, with a full tank of fuel, shall be measured using a certified scale and provided with the proposal.
3. A four-corner weight distribution engineering analysis for the proposed vehicle using 150 lbs. for the driver and ambulatory passengers and 300 lbs. for each mobility aid passenger and a full tank of fuel must be provided.
4. The weight at an individual wheel/wheelset shall not exceed 50% of the associated axle GAWR when fully loaded.
5. The "as built" weight certification shall provide the following information:
    a. VIN of the bus
    b. Manufacturer
    c. Body Serial Number
    d. A description (type) of the bus
    e. Date of certification
    f. The number of ambulatory passenger capacity including driver
    g. The number of wheelchair positions
    h. Four-wheel weight distribution of the actual completed weight of the bus including all attachments
    i. Four-wheel weight distribution of the weight of the ambulatory passengers including driver
    j. Four-wheel weight distribution of the weight of the wheelchairs
    k. Four-wheel weight distribution of the weight of the Fuel
    l. Four-wheel weight distribution of the total weight of the vehicle
    m. Weight analysis must have signature and title of person submitting it.

Source Florida Department of Transportation [1]

Alternative 2

The GVWR and front/rear GAWR of the proposed vehicle shall not exceed the OEM chassis ratings.

1. Class One Vehicles
    a. Front Axle Rating – 3,700 lb. minimum
    b. Rear Axle Rating – 7,800 lb. minimum
    c. Chassis GVWR – 11,500 lb. minimum
2. Class Two
    a. I-Beam Front Axle Rating – 4,600 lb. minimum

b. Rear Axle Rating – 9,450 lb. minimum
c. Chassis GVWR – 14,200 lb. minimum

5.4 Alignment

Alternative 1

The bus shall have a four-wheel alignment at final point of inspection, just prior to delivery to the transit agency. A copy of the work order indicating the camber, caster, and toe-in settings at time of final inspection shall be provided with the bus at delivery. All axle alignment required.

5.5 Dimensions

Alternative 1

The following linear dimensions for the proposed vehicle(s) must be provided:

1. Wheelbase
2. Overall Length
3. Width
4. Height
5. Wheel Track
6. Height to front/rear bumper
7. Ground Clearance
8. Approach angle
9. Departure angle
10. Breakover angle

6 Engine

Alternative 1

The proposed vehicle must be equipped with an engine that, when coupled with the transmission and driveline, meets minimum gradeability specifications. These minimum gradeability specifications are meant to ensure that the proposed vehicle, while fully loaded, can maintain minimum speeds while ascending roads with various slopes/grades.

Alternative 2

The maximum time for the vehicle to reach 30 mph shall not exceed 8 seconds and the vehicle shall be capable of maintain a sustained speed of 40 mph on a 2.5% grade and a sustained speed of 10 mph on a 10 percent grade.

Source: Federal Transit Administration [3]

6.1 Gasoline

Alternative 1

Gasoline engine shall be manufacturer's standard for this size bus considering components and accessories proposed. The proposed engine must give satisfactory performance over terrain

encountered in **{insert state or municipality name}** with maximum passenger load. Manufacturer shall propose engine horsepower and torque.

Source: Florida Department of Transportation [1]

Alternative 2

1. Class One Vehicles

   Gasoline V8 or V10, fuel injected, 330cid, 5.4L minimum.

2. Class Two Vehicles

   Gasoline V8 or V10, fuel injected, 415cid, 6.8L minimum.

Source: Michigan Office of Passenger Transportation [2]

6.2 Diesel

Alternative 1

Diesel engine shall be manufacturer's primary option for this size bus considering components and accessories proposed. The specified engine must give satisfactory performance over terrain encountered in **{insert state or municipality name}** with maximum passenger load. Manufacturer shall propose engine horsepower and torque.

Source: Florida Department of Transportation [1]

Alternative 2

Engine shall be certified to operate on-highway and be equipped with a Cummins (or equal) in-line ISB 6.7L turbocharged diesel engine supplied by the chassis manufacturer. The engine shall be equipped with a 120-volt AC/1000-watt freeze plug block heater. The block heater socket receptacle shall be mounted below the driver's door. The engine shall also be equipped with a Webasto Coolant Heater – Thermo 350 or equal.

Source: New Hampshire Department of Transportation [4]

6.3 Alternative Fuels

Alternative 1

1. Liquefied Petroleum Gas (LPG) or Compressed Natural Gas (CNG): The bus shall accept liquefied petroleum gas (LPG) or compressed natural gas (CNG) application if required for fleet compliance by federal Environmental Protection Agency (EPA) alternate fuel application guidelines. The engine/chassis shall include a gaseous fuel preparation package and the cylinder heads shall have hardened valve seats. All LPG and CNG conversions shall maintain OEM powertrain warranties.
2. On buses ordered with alternate fuels options (LPG, CNG, etc.) auxiliary heater systems installed shall meet the same specifications for the systems operating on gasoline. All heated air models shall have a 12-volt heater booster pump installed in the coolant line forward of the first rear heater. Additional equipment needed for auxiliary heater shall be included in the option. Suggested sources: Bergstrom 863040.

Source: Michigan Office of Passenger Transportation [2]

Alternative 2

An Alternative Fuel Engine, which is the manufacturer's standard for this size bus considering components and accessories proposed, **{may/must}** be provided as an alternative fuel option. The specified engine must give satisfactory performance over terrain encountered in **{insert state or municipality name}** with maximum passenger load. Manufacturer shall propose engine horsepower and torque.

1. A service and parts manual shall be provided that specifies all gaseous fuel components along with tank removal and installation methods and any special tool that may be required. The manual must state that the fuel tank must be grounded prior to servicing the system and include a grounding procedure.
2. The DNG/LPG fuel system maximum system pressure and working pressure shall be specified in the installation documentation.
3. Heat shields shall be added for all fuel components located withing 8 inches of the exhaust system. Fuel handling components must be isolated at least 8 inches from unshielded heat sources or at least 3 inches from shielded heat sources.
4. Gaseous fuel fill and de-fuel ports shall be in the normal fueling location.
5. An interlock switch shall be provided to prevent starting the vehicle while fueling or de-fueling.
6. All gaseous fuel lines and fittings shall be stainless steel or flex tubing approved for use with CNG at 3600 psi or LPG a 300 psi and meet current NFPA 52 and 58 guidelines. Fuel lines and fittings must be:
    a. Be routed away from and not attached to items that are likely to move during normal vehicle operation.
    b. Be routed so that they will not be affected by the deformation or displacement of adjacent components during a crash.
    c. Be routed inboard of the frame rales and above the plan of the lower frame flange (except for the connection to the filler port).
    d. Have adequate flexibility to avoid rupture or disconnection during crash situations.
    e. Be routed away from sharp objects and be retained adequately to prevent movement into or against such objects.
    f. Be clear of moving suspension components.
    g. Avoid exposure to road debris and undercoating.
    h. Be properly grommeted where they pass through panels.
7. When CNG/LPG fuel tanks are mounted outside of the OEM frame rails, and addition crash barrier structure must be provided to surround the tanks. This structure must be equal or exceed the section modulus and material strength of the OEM frame rail
8. CNG fuel thanks shall be a minimum Type III aluminum and carbon fiber construction with a twenty year live that complies with NGV2-2007 and FMVSS 304 regulations. Stainless steel dust and gravel shields must protect the tanks and valves. The tanks shall have a production data no more than 24 months prior to the date of vehicle delivery.
9. A methane detection system shall provide audible and visual alarms to the driver when methane fumes exceed the specified threshold greater than 20% and disable the fuel system when

methane fumes exceed the specified threshold greater than 50%. The power supply for the methane detector shall be separate from the chassis.

10. In the event of conflicting standards, NFPA 52 and 58 take precedence.

Source: Florida Department of Transportation [1]

Alternative 3

When available the 6.8L engine shall be OEM gaseous prepped. The system shall be installed by Engine Systems Manufacturers approved installers.

1. A minimum of 27-gallon gasoline equivalent capacity in three 3600 psi tanks shall be installed between the frame rails of the chassis.
2. CNG fuel thanks shall be a minimum Type III aluminum and carbon fiber construction with a twenty year live that complies with NGV2-2007 and FMVSS 304 regulations. Stainless steel dust and gravel shields must protect the tanks and valves. Type IV tanks are acceptable if installed within the frame rails. The tanks shall have a production data no more than 24 months prior to the date of vehicle delivery.
3. All fitting and hoses must be stainless steel or flex tubing approved for use with CNG at 3600 psi.
4. All lines must be supported with split block high pressure retaining devices and or rubber insulated line clamps approved for use with CNG at 3600 psi.
5. All fasteners shall be grade 8 fasteners.
6. Dust and gravel shields must be installed to protect tanks and valves.
7. The gaseous fuel system shall include:
    a. NGV-2 3600 psi rated fill receptacle.
    b. Electronic tank shut off valves.
    c. Exterior fuel pressure gauge.
    d. Locking fuel door.
    e. Lockout switch for fuel filler door to prevent starting with fuel door open.
8. A Kidde Aerospace & Defense (or equal) automatic fire sensing and suppression system (AFSS) complete with detectors, control panel, manual activation switch and engine compartment and battery compartment battery compartment methane detection system shall be included. The AFSS shall detect fires in protected areas. Upon detection the AFSS shall immediately activate and audible and visual alarm in the operator's area. After a 15 second delay, the AFSS shall shutdown the vehicle engine and discharge extinguishing agent into the protected areas. The vehicle operator shall have the ability to extend or terminate the engine shutdown and extinguisher discharge delay. The completed AFSS shall be tested and certified by Kidde Aerospace & Defense and a certification report shall be provided.

Source: California Joint Procurement [5]

6.4 Engine Fast Idle

Alternative 1

1. A fast-idle system shall be installed which will automatically increase the engine speed (RPM) to approximately 1500 RPM on gasoline engines and 1200 RPM on Optional diesel engines.

2. Include a Gateway Module capable of being actuated either by driver, a voltage sensor, an air conditioner, an air compressor command, or a low coolant temperature command.
3. This fast speed idle shall engage only when the vehicle is in Park and the parking brake applied.
4. Suggested source: Inter-motive Advanced Fast Idle Systems (AFIS) or approved equal.

Source: Florida Department of Transportation [1]

Alternative 2

1. The engine shall be equipped with fast idle control which includes manual and automatic control features.
2. Fast idle shall not activate unless the transmission control is in park (P).
3. The control system shall have a manual switch, volt sensor, an indicator light, and activate automatically from voltage sensors.
4. The system shall automatically deactivate when bus is shifted into gear and when the bus foundation brakes are applied.
5. Suggested source: Chassis manufacturer's equipment, Gateway by Intermotive Products, Penntex Model PX-HI-(mod no) with time out module, Vortec MD30-2500.

Source: Michigan Office of Passenger Transportation [2]

Alternative 3

1. A fast-idle system shall be installed.
2. The fast-idle system must be able to automatically increase engine speed to 1,500 rpm on gasoline engines and 1,200 rpm on diesel engines.
3. The fast-idle system must activate when vehicle voltage drops below 12.5 volts, the chassis air conditioning is commanded on, or when the coach air conditioning (non-OEM) is turned on.
4. A manual switch shall be located convenient to the driver to engage the system.
5. The fast-idle system shall engage only when the vehicle is in park and the vehicle is not in motion (must sense vehicle movement).
6. Suggested source: Intermotive Hi-Lok.

Source: California Joint Procurement [5]

6.5 Engine Cover and Trim

Alternative 1

The engine cover shall be insulated from engine heat, engine noise, and road noise. Additional equipment, including flooring, added to the engine cover area shall not interfere with removal/installation of the engine cover.

7 Radiator and Cooling System

Alternative 1

1. The cooling system shall have an extra cooling capacity radiator (aluminum or copper core), water pump, pulley, and clutch-type fan with coolant recovery system with a factory installed coolant filter (heavy duty system installed by chassis manufacturer).

2. Cooling system shall be winterized with 50/50 mixture (minimum) of permanent antifreeze and distilled water or a factory premix (minimum -35oF freezing point).
3. Coolant integrity shall be maintained throughout the manufacturing process to ensure that the coolant, including additives, in the delivered bus is equal to the coolant installed at the chassis OEM factory.
4. All cooling system hose connections in the engine compartment shall use constant tension spring loaded band clamps (Breeze Constant-Torque®, Clampco Products Inc., Oetiker that automatically adjust for thermal expansion and contraction to control leakage.
5. Radiator removal instructions and estimated removal time shall be furnished with first bus to each agency.

Source: Michigan Office of Passenger Transportation [2]

8 Fluids

Alternative 1

Fluids shall be checked and filled from inside front hood where application allows. Engine oil fill/check, transmission oil fill/check, and coolant fill/check shall be located for easy access per approval at pilot model inspection. All fluids shall be at proper levels at delivery.

9 Exhaust System

Alternative 1

1. The vehicle shall be equipped with a heavy duty, corrosion resistant exhaust system which meets or exceeds FMVSS and EPA noise level and exhaust emission requirements.
2. Heavy-duty OEM type exhaust hangers shall be standard equipment and shall be bolted to the frame. All hanger U-bolt thread orientation must be directed sideways.
3. All altered exhaust joints shall be welded with a continuous weld. Any exhaust system extensions shall be of the same material as the OEM exhaust system.
4. The exhaust system must be installed to provide maximum ground clearance and departure angle at the rear of the bus.
5. The exhaust tailpipe shall terminate at the left rear corner of the bus flush with the rear bumper.
6. Galvanized heat shielding shall run between the exhaust system and the floor of the vehicle, at a minimum, this shield shall meet OEM Up-Fitter Guide requirements or approved equal.

10 Fuel Tank

Alternative 1

1. Fuel tank capacity shall be the largest size available for each chassis. Fuel tank capacity shall be minimum for the following chassis/buses:
    a. Small Class I: 40 gallons.
    b. Small Class II: 55 gallons
2. Fuel fill shall not extend beyond the exterior surface of the bus and may have the fuel cap set in a recess like a Ford OEM unit.

3. Fuel fill shall be on the street (left) side of the bus.

Source: Michigan Office of Passenger Transportation [2]

11 Transmission

Alternative 1

Minimum four speed automatic transmission incorporating OEM installed air-to oil type auxiliary transmission oil cooler and filler extension neck for adding fluid.

Source: California Joint Procurement [5]

Alternative 2

A heavy-duty, minimum 4-speed, automatic, overdrive transmission, with tow/haul mode, and the most extreme duty cycle available from OEM, compatible with the engine specified, shall be standard. Gross input power, gross input torque and rated input speed shall be compatible with the engine specified.

Source: Florida Department of Transportation [1]

Alternative 3

The electronically controlled transmission shall be a minimum, heavy-duty, five-speed automatic cooled by an "H.D. transmission oil cooler" in series with radiator cooler or equal (cooler capacity to match GVWR of bus). The transmission shall have an external spin-on type filter. Suggested source: Allison Transmission 1000 or 2000 series or Ford Torqshift matched to the electronic engine and chassis.

Source: Michigan Office of Passenger Transportation [2]

12 Drive Shaft

Alternative 1

1. The drive shaft shall be OEM.
2. Protective metal guards of sufficient strength for the drive shaft shall be provided to prevent a broken shaft from striking the floor of the buss, the ground, or contact any brake line.
3. The guards shall be OEM chassis equipment (preferred) or may be installed by the chassis manufacturer and shall be secured properly.
4. For each drive shaft section, the protective metal guard shall be located within ¼ of the length of the shaft and behind the forward U-joint. The bottom portion of the hoop shall be no more than three (3) to four (4) inches from the outer surface of the drive shaft.
5. The drive shaft guards shall conform to 49 CFR.
6. Manufacturer shall provide a detailed description of the guard(s) proposed.

13 Differential

Alternative 1

1. Heavy-duty rear axle with full floating axles.

2. Gear ratio shall allow buses to travel approximately 65 miles M.P.H. loaded, maximize fuel economy, and not exceed manufacturer's recommended engine operating R.P.M.
3. Axles shall be marked if synthetic oil is used.

Source Michigan Office of Passenger Transportation [2]

14 Axles

Alternative 1

Axles shall be manufacturer's standard. Axle must be load rated for the GVWR of the size bus involved.

15 Suspension

Alternative 1

1. Suspension shall be manufacturer's standard but, must incorporate add on components that enhance ride comfort and prevent vehicle "listing".
2. Proposer must provide product description along with their proposal.
3. Final product must be load rated for the GVWR of the size bus involved.
4. OEM standard shocks and leaf springs shall be proposed.

Source: Florida Department of Transportation [1]

Alternative 2

1. The chassis shall be equipped with a heavy-duty tapered leaf (parabolic) spring or coil spring front suspension to match the specified front gross axle weight rating.
2. The chassis shall be equipped with a heavy-duty rear suspension fitted with a rubber shear spring suspension that works in conjunction with the OEM chassis leaf spring suspension to match the specified gross axle weight rating. The added suspension shall consist of a spring carrier assembly, a frame hanger assembly, a cross-member tube assembly, and a carrier spring assembly, shall be installed in place of the original spring hanger and shackle assembly. The frame hanger must bolt into the existing Original Equipment Manufacturer (OEM) spring hanger holes in the frame. The added suspension system must not alter the OEM gross axle weight rating.
3. The chassis shall have the most heavy-duty gas filled shock absorbers front and rear available from the chassis manufacturer. The shock absorbers performance must be matched to the bus GVWR.
4. The chassis shall have heavy duty OEM suspensions stabilizers if available.

Source: Michigan Office of Passenger Transportation [2]

16 Power Steering/Tilt Wheel

Alternative 1

Chassis shall be equipped with power steering and a tilt wheel steering column. The steering column shall be adjustable for various up and down positions of the steering wheel. The steering gear shall be a full hydraulic power assist type.

17 Brakes

17.1 Service Brakes

Alternative 1

The vehicle must be equipped with dual hydraulic power-assisted brake system with disc-type brakes on the front wheels and drum or disc-type brakes on the rear wheels.

Source: California Joint Procurement [5]

Alternative 2

1. The foundation brakes shall be a power-actuated hydraulic split system of a four-wheel disc type with a three channel anti-lock braking system. The system shall be the heaviest-duty available for stop and go operation.
2. The brake system shall include a red brake warning lamp in the instrument cluster that lights when the parking brake is on, when a front or rear hydraulic failure occurs, or when brake fluid is low in the reservoir and act as a low brake warning system.

Source: Michigan Office of Passenger Transportation [2]

Alternative 3

1. Brakes should be capable of stopping a fully loaded vehicle at a deceleration rate equivalent to a 22-foot stop from a speed of 20 miles per hour.
2. The brake performance shall be demonstrated using a VC-4000 Brake Meter that records acceleration, speed, brake efficiency and stopping distance.
3. The brake performance shall be tested on level asphalt in dry conditions with 150 lbs. in each seat position and 250 lbs. in each wheelchair position to simulate maximum passenger capacity.
4. The driver shall accelerate to 22 mph and apply heavy and constant pressure to the service brake until the vehicle comes to a complete stop as quickly as possible without skidding.
5. The VC-4000 Brake Meter will calculate the 20-mph stopping distance.
6. The test shall be repeated a minimum of 3 times.
7. The vehicle fails the test if it fails to stop all 3 times from 20 miles per hour in 22 feet or the brakes fade or overheat during the test.

Source: Florida Department of Transportation [1]

17.2 Parking Brake

Alternative 1

A foot operated parking brake shall be supplied with a warning light on the dashboard.

California Joint Procurement [5]

Alternative 2

The heaviest-duty parking brake available from the chassis manufacturer. The parking brake shall be rebuildable and reparable by a trained technician.

Source: Michigan Office of Passenger Transportation [2]

Alternative 3

1. The vehicle must be equipped with a parking brake that can hold the fully loaded vehicle stationary on a paved road clear of snow/ice with a 25% grade (15-degree incline).
2. Parking brake function shall be demonstrated in both the forward (front of vehicle facing down the incline) and rearward (front of vehicle facing up the incline) on a ramp with a verified angle of 15 degrees with 150 lbs. in each seat position and 250 lbs. in each wheelchair position with tires in good condition and a minimum of ¼ tank of fuel.
3. The vehicle must remain stationary with parking brake fully set and transmission in neutral for 30 minutes.
4. Wheel chocks are to be placed 2 inches behind the rear tires to prevent the vehicle from rolling freely down the incline.
5. The vehicle fails the test if more than 1 inch of movement occurs in either direction or the brakes display any signs of slippage during the test.
6. The system shall incorporate a warning light on the instrument panel to indicate when the parking brake is applied.

Source Florida Department of Transportation [1]

17.3 Wheelchair Lift Interlocks

Alternative 1

Interlocks must be incorporated such that the wheelchair lift cannot operate unless the vehicle parking brake is engaged, and the transmission is in the park position and that the vehicle transmission cannot be shifted out of park unless the wheelchair lift is properly stowed. Interlock system shall comply with the requirements of Section 47.6.1. These interlocks must comply with ADA and FMVSS requirements.

18 Wheels and Tires

Alternative 1

1. Wheels shall be matching **{specify diameter and width if desired i.e. 16.0”x 6.0”}** steel disc wheels, hub piloted type, 8-hole flange nut style.
2. The combined rated load compacity of the wheels shall equal or exceed the GVWR of the vehicle.
3. Wheels shall have all stainless steel or all brass valve stems or 1½” in length retained by threaded nuts fitted with stainless steel, steel or brass caps and an inner air seal. Rear dual wheels shall have a brass valve extension installed and secured to the outside on each set of rear wheels to check and fill air pressure.
4. All tires shall be of equal size and rating, OEM steel-belted all-season tubeless radial ply tires.
5. Tires shall be the largest size available from the chassis manufacturer to meet the GVWR.
6. A spare tire mounted on the same type wheel assembly shall be provided as standard equipment.
7. Suggested sources: goodyear, Michelin XZA, Unisteel.

19 Body Structure and Exterior Panels

19.1 Metal Rollover Frame, Cage-type Construction

19.1.1 Body Structure

Alternative 1

1. The bus shall have a heavy-duty, unit-body structure.
2. The rollover frame/cage shall be constructed of gauge #16 steel, 0.060" or equal, minimum.
3. The body structure shall be made of durable steel or aluminum construction insulated against electrolysis between dissimilar metals, and adequately reinforced at all joints and points of stress.
4. The body structure must comply with the FMVSS 220 rollover protection test.
5. All body and floor structural members shall be Gas Metal Arc Welded (GMAC) or equal. A MIG welding system is acceptable provided it meets the requirements of this specification.
6. Each contractor shall provide certification that the bus meets the FMVSS 220 rollover protection test as bid.
7. The bus shall be designed to withstand road shocks, stop, and start operations, seasonal weather and road extremes, and other conditions found in transit bus service.
8. The body shall be securely fastened to the chassis frame structure using uniform attachment consisting of strategically placed rubber isolators/cushions consistent with cab/chassis isolators/cushions with connector bolts that permit body flexing independent of chassis flexing.
9. Roof, side, front, and back panels shall be secured to the body vertical and horizontal frame members, and when fastened to the floor structural members, result in a permanent, fully integrated structural unit adequately reinforced at all points where stress concentration may occur.
10. The wall structure shall be bolted to the floor with grade 8 bolts to provide adequate stability in the event of a non-static rollover event.
11. The body floor sub-frame assembly, including lower skirt reinforcements, shall be, at a minimum, gauge number 14 (0.075" thickness) galvanized steel, or gauge number 16 stainless steel, or gauge number 12 aluminum, or gauge number 14 steel treated a with corrosion resistant coating. All body floor sub-frame assembly shall meet the 480-hour salt spray test per ASTM procedure B-117, with no structural detrimental effects to normally visible surfaces. Certification of compliance with this requirement shall be published by an independent company.
12. Wheel wells shall have minimum yield strength of gauge number 14 (0.075" thickness) galvanized steel, gauge number 16 (0.060" thickness) stainless steel, or gauge number 12 (0.10" thickness) aluminum properly welded or secured with approved corrosion resistant fasteners to the floor structure.
13. The entire body cage and frame including floor structure shall be properly coated with a corrosion resistant coating or a non -water permeable primer/paint.
14. All components treated to resist corrosion shall be properly cleaned to remove greases, oils, and residues before application of the corrosion resistant material.

15. Passage holes provided for wiring and hoses shall be thoroughly sealed to prevent dust and moisture intrusion and be sufficiently protected to ensure against wear from friction and the elements.
16. When completed, all body side sections and roof sections including structure shall be at a minimum 1-½" thick.
17. Where body segments are joined, they shall be properly sealed to prevent intrusion of drafts, fumes, dust, and water to the interior of the bus body.

Source Michigan Office of Passenger Transportation [2]

19.1.2 Exterior Panels

Alternative 1

1. All exterior side and roof panel material shall be fiberglass reinforced plastic (FRP) constructed of a minimum of 2.16 mm (0.080") thick material comprised of various layers of gel-coat, reinforcement and resins.
2. It shall be designed to resist impact caused by flying road debris.
3. The material must resist rot, corrosion, and mildew and cannot be affected by cleaning related chemicals, road residue, or environmental exposure.
4. Reinforcements shall be installed around all window openings to transfer stress around the opening.
5. All door openings shall have full structural framing (tube) or imbedded reinforcements, equal to the structural members of the body that will adequately support concentrations of stress around openings. All exposed doorframe structure shall be made of 304 stainless steel (including the fasteners), which does not discolor with age.
6. Where a stiffener or a backer material (substrate) is used for the exterior panels, it shall be bonded with waterproof adhesive to the exterior panel; it shall be a water resistant material that will not wick water; and it must be thoroughly sealed from the elements when installed so that the substrate will not be exposed to or absorb moisture and cause corrosion to the interior of the panel or any body structure.
7. Exterior panel substrate shall not be of wood composition, plywood, or a pressed wood product. Where body segments are joined, they shall be properly sealed to prevent intrusion of drafts, fumes, dust, and water to the interior of the bus body.
8. Exterior lower skirt panels shall be fiberglass or composite material and shall be sufficiently stiff to prevent vibration, drumming, or flexing while the bus is in service. Lower edge of skirt panels shall be re-enforced to prevent cracking/breaking due to excessive flexing.
9. Lower skirt panels may be one piece in length at manufacture but shall be repairable in sections. Lower skirt panels shall not use a wood substrate material for a panel stiffener.
10. Body front and/or rear endcaps may be molded fiberglass panels installed with required structural framing or a FRP composite structure.
11. Where exterior panels are lapped, the upper or forward panels shall act as a watershed.
12. Exterior panels that are cut shall have the cut edge sealed (paint or special sealing compound).
13. Sealing and fastening of panel joints, including front and rear cap-to-body joints, shall prevent entrance of moisture and dirt.

14. Joint sealing shall be made through use of a non-shrinking bonding sealant, and joint sealing shall not be solely dependent on an exterior trim strip or a trim cap nor shall the sealing of the panels be dependent on caulking alone. Any visible caulk shall be painted after water testing is complete.
15. All exterior panels shall be buck riveted and/or bonded to the body frame structure.
16. The exterior body panels shall have on each side one heavy-duty rubrail. Rubrails (1½" x ½" minimum) shall be extruded UV resistant plastic with a flexible, rubber-type resilient material inserts or a solid rubber-type of flexible, resilient material. Rubrails shall be located no less than 25" nor more than 43" above the ground on each side. Where the rubrails and fender opening guards are not an integral part of the body, installation of rubrails shall be made after the finish coat of paint is applied to the bus. Rubrails shall be sealed to prevent debris seepage into and from behind rubrail.
17. Gun installed huckbolt fastenings, buck rivets, bonding adhesives, or approved equivalent shall be utilized on all exterior body panels, rubrails, and all other locations where stress is concentrated.
18. All rivets, screws, bolts, nuts, washers, clamps, and other types of fasteners used in the construction process, including those that would be exposed to the elements, on the exterior and interior of the unit shall be properly plated to resist corrosion.
19. No sheet metal screws shall be permitted, except for rubrails and rubber fender splash guards (see mudflaps/splash guards) which can be secured with stainless steel or equivalent plated locking-type, self-tapping fasteners.
20. Fastener materials shall be compatible with materials being fastened. Where self-tapping fasteners are used, body panels shall be reinforced with steel backing, aluminum backing, or stainless-steel backing.
21. Window openings cut into body panels shall have a maximum frame clearance of 1/8" on each side to minimize the need for caulking. All openings cut into metal body exterior panels must have the exposed cut edges primed or properly coated to inhibit water intrusion and corrosion before further assembly or painting occurs. Window frames installed in the body openings shall be properly caulked/sealed to prevent intrusion of moisture and dust.
22. The Contractor shall submit roof, sidewall, and flooring drawings showing structure and structural specifications indicating metal size and type used. Include side sheathing and inside panels.

Source Michigan Office of Passenger Transportation [2]

19.2 Fiberglass Reinforced Plastic (FRP) Composite Unitized-type Body

19.2.1 Body Structure

Alternative 1

1. The bus body shall have a heavy-duty unitized structure and shall be of durable fiberglass reinforced plastic (FRP) composite construction.
2. The body panels shall consist of an exterior high gloss gelcoat (0.020” thickness, minimum) on a resin-hardened FRP (3/16” thickness, minimum) attached to a center layer of resin hardened Nida- -Core® or equal honeycomb (3/4” thickness, minimum) with an inner FRP panel (3/16” thickness, minimum); or may be ¾” polyurethane foam insulation gelcoated to ¼” FRP exterior

with ¼" FRP interior, reinforced with steel perimeter and transverse supports, completely fiberglassed to adjoining body parts.

3. It shall use proper adhesive materials to adequately bond and mechanically fasten all joints and points of stress with sufficient strength to comply with the FMVSS 220 rollover protection test.
4. Each Contractor shall provide certification that the bus meets the FMVSS 220 rollover protection test as bid.
5. The bus shall be designed to withstand road shocks, stop, and start operations, seasonal weather and road extremes, and other conditions found in Michigan transit bus service.
6. The body shall be securely fastened to the chassis frame structure using a method of uniform attachment consisting of strategically placed rubber isolators/cushions consistent with cab/chassis isolators/cushions with connector bolts that permit body flexing independent of chassis flexing.
7. Roof, side, front, and back panels shall be secured to the floor and lower body frame members; all of which shall result in a permanent, fully integrated structural unit adequately reinforced at all points where stress concentration may occur.
8. The body floor sub-frame assembly, including lower skirt reinforcements, shall be, at a minimum, gauge number 14 (0.075" thickness) galvanized steel, or gauge number 16 stainless steel, or gauge number 12 aluminum, or gauge number 14 steel treated a with corrosion resistant coating, insulated against electrolysis between dissimilar metals. All body floor sub-frame assembly shall meet 1,000-hour salt spray test per ASTM procedure B-117, with no structural detrimental effects to normally visible. Certification of compliance with this requirement shall be published by an independent company.
9. Wheel wells shall have minimum yield strength of gauge number 14 galvanized steel, gauge number 16 (0.060" thickness) stainless steel, or gauge number 12 (0.10" thickness) aluminum properly welded or secured with approved corrosion resistant fasteners to the floor structure.
10. Passage holes provided for wiring and hoses shall be thoroughly sealed to prevent dust and moisture intrusion.
11. The entire lower body frame shall be coated with corrosion resistant primer/paint (steel) or properly treated to resist corrosion (other materials).
12. All treated components shall be properly cleaned to remove greases, oils, and residues before application of the corrosion resistant material.

Source: Michigan Office of Passenger Transportation [2]

19.2.2 Exterior Panels

Alternative 1

1. All exterior side and roof panels when completed shall be at a minimum 1-1/8 roof, and front cap shall be interlocked by adhesives, resin saturated fiberglass matting, and mechanical fasteners, forming a unibody design without exposed fasteners or protruding moldings. Imbedded reinforcements shall be installed at all door openings to support door mounting hardware and door operating mechanisms.
2. All door openings shall have full structural framing to maintain integrity of the body structure. All exposed doorframe structure shall be made of 304 stainless steel (including the fasteners), which does not discolor with age.

3. Where a stiffener or a backer material (substrate) is used for the exterior panels, it shall be bonded with waterproof adhesive to the exterior panel; it shall be a water-resistant material that will not wick water; and it must be thoroughly sealed from the elements when installed so that the substrate will not be exposed to or absorb moisture and cause corrosion to the interior of the panel or any body structure.
4. Interior panels may be an integral part of the FRP composite panel or may be made of scuff-resistant laminate/FRP finished material. Where threaded fasteners are in the interior panel only, an imbedded reinforcing nut or a reinforcing panel shall be integrated into the FRP composite for added strength and fastener retention.
5. Exterior panels may be an integral part of the FRP composite panel.
6. Exterior panels shall be sufficiently stiff to prevent vibration, drumming, or flexing while the bus is in service.
7. Lower skirt panels shall be sufficiently fastened and braced to prevent damage from ice and snow build-up. Lower skirt panels may be one piece in length at manufacture but shall be repairable in sections.
8. Where panels are lapped, the upper and/or forward panels shall overlap the lower and/or rearward panels to prevent intrusion of water under the panels.
9. Sealing and fastening of joints, including front and rear cap-to-body joints, shall prevent entrance of moisture and dirt. Any visible caulk shall be painted after water testing is complete. In no case shall the sealing of the panels be dependent on caulking alone.
10. All exterior panels shall be bonded to the lower body frame.
11. The exterior body panels shall have on each side one heavy-duty rubrail. Rubrails (1½" x ½" minimum) shall be extruded UV resistant plastic with a flexible, rubber-type resilient material inserts or a solid rubber-type of flexible, resilient material. Rubrails shall be located no less than 25" nor more than 43" above the ground on each side. Where the rubrails and fender opening guards are not an integral part of the body, installation of rubrails shall be made after the finish coat of paint is applied to the bus. Rubrails shall be sealed to prevent debris seepage into and from behind rubrail.
12. No sheet metal screws shall be permitted, except for rubrails and rubber fender splash guards which can be secured with stainless steel or equivalent plated locking-type, self-tapping fasteners.
13. Fastener materials shall be compatible with materials being fastened and meet the 480-hour ASTM B117 Salt Spray test and the 480-hour ASTM D2247 Humidity Resistance test. Where self-tapping fasteners are used in body panels, the body panels shall have an imbedded reinforcing nut, or a reinforcing panel shall be integrated into the FRP composite for added strength and fastener retention.
14. Window openings cut into body panels shall have a maximum frame clearance of 1/8" on each side, to minimize the need for caulking. All openings cut into body exterior panels must have the exposed edges of the cutout properly coated to prevent moisture intrusion before further assembly or painting occurs. Window frames installed in the body openings shall be properly caulked/sealed to prevent intrusion of moisture and dust.
15. Contractor drawing submission requirements identical to other construction technique.

Source Michigan Office of Passenger Transportation [2]

20 Wheel Housings

Alternative 1

1. Rear wheel housing shall be constructed of 14-gauge (minimum) one-piece steel constructed and adequately reinforced to prevent deflection. Ample clearance shall be provided for tires under load and operating on both smooth and rough terrain. All steel shall be treated for corrosion resistance. If tires extend beyond side of the vehicle, splash aprons and fenders shall be provided.
2. Front wheel housings are to be provided with the chassis cab section.

21 Passenger Stepwell

Alternative 1

1. All entrance steps and stepwells shall be gauge number 14 (.075" thickness) stainless steel, minimum. Steps and stepwells shall have adequate structural bracing.
2. All metal trim hardware in the stepwell area shall be stainless steel. All fasteners in the stepwell area shall be stainless steel that will pass the 480-hour ASTM B117 Salt Spray test and the 480-hour ASTM D2247 Humidity Resistance test.
3. Ground to first step shall not exceed 12" in height, each additional vertical step shall not exceed 9½" and all tread depths shall be 9" minimum. All steps in the entrance stepwell shall be of the same width. A suspension kneeling feature may be used to achieve the required 12" step height.
4. Stepwells shall be covered with flooring material as described in section 22.
5. Step shall not retain water.
6. Any interior stainless steel except for exposed door frames shall be brushed, not painted.
7. The Contractor shall submit detailed engineering drawing(s) for the design of the entrance step configuration.

22 Flooring

Alternative 1

1. Proposals shall include a description of the material that will be used and structural drawings of the floor assembly.
2. Flooring shall be a minimum of 5/8 inch thick, engineered wood with moisture barrier and sealed edges. Proposer shall submit manufacturer of flooring provided.
3. The entire body frame under structure of the vehicle shall be primed on all surfaces, allowing the primer to cover all metal surfaces, applied at the time of manufacture. Any sub-component installed underneath the vehicle shall not be primed. Proposer shall submit details of the primer to be utilized.
4. Manufacturer shall provide an access panel for the fuel pump assembly.
5. Manufacturers shall provide a flat floor for vehicles requiring three (3) wheelchair positions or greater.
6. Floor covering shall be slip resistant rubber flooring. Steps shall have a yellow edge or nosing to pronounce the presence of the step. The floor covering shall meet the requirements of FMVSS-

302. At the step well(s), there shall be no lip or nosing overhang, the step tread flange shall be flush with the vertical riser to eliminate any tripping condition.

7. A cove molding shall be installed in the body to the floor corners to aid in floor cleaning.
8. Samples and a description of the standard and optional floor covering material, available patterns, and colors, shall be submitted with proposal.
9. There shall be a 2" wide white "Standee Limit" stripe set into the aisle covering located to the rear of the driver's section. The Standee Line shall meet the requirement of 49CFR section 393.90 and include a notice to passengers "Law Prohibits Passengers Standing Forward of the White Line While Bus in Motion", or approved equal phrase, posted in an area adjacent to white line and in clear view of passengers facing forward.

Source: Florida Department of Transportation [1]

Alternative 2

1. The floor deck may be integral with the basic structure or mounted on the structure securely to prevent chafing or horizontal movement.
2. All floor fasteners shall be corrosion resistant steel and shall remain secured and corrosion resistant for the service life of the bus.
3. The floor deck shall be ¾" C/D plywood of marine grade material or ¾" fiberglass encased material, minimum with sealed edges to prevent moisture intrusion.
4. The floor deck upper surface shall have all cracks and voids filled and the whole surface rough sanded before installing the flooring material.
5. A layer of sealer shall be installed between floor deck edges that butt against structural members and other deck sections to prevent dust and moisture intrusion.
6. Passage holes provided for wiring and hoses in the floor deck shall be thoroughly sealed to prevent dust and moisture intrusion.
7. Passenger seating floor rail/track shall not be installed in the wheelchair lift or wheelchair securement areas.
8. The floor deck, including the sealer, attachments, and coverings, shall be waterproof, non-hygroscopic, resistant to wet and dry rot, and resistant to mold growth.
9. The floor deck shall not be sandwiched between the wall structural members and the floor structural members.
10. The entire passenger area including the wheelchair securement area, entrance steps and stepwell area, shall be overlaid with smooth, slip resistant flooring material. The resilient sheet flooring system (2.2 mm thickness minimum) shall be a high-quality vinyl with aluminum oxide and color quartz grains throughout the thickness, silicon carbide grains in the surface layer and a non-woven polyester/cellulose backing with glass fiber reinforcement.
11. The flooring shall extend up the sidewall and rear wall to the seat rail line and shall be coved at the floor/wall joint to form a smooth watertight transition.
12. A cove molding radius backing block, approved by the flooring manufacturer shall be installed behind all floor covering and shall be 1.5" radius minimum.
13. Installation of flooring must be done strictly according to the flooring manufacturer's directions using the proper accessories, tools, and adhesives.
14. Suggested sources: Altro Transflor™ Meta, Altro Transflor™ Chroma.

15. Step treads shall be one-piece resilient sheet flooring system matching the passenger compartment flooring. All step edges (nosing of step tread material) shall have a band of bright yellow contrasting color running full width of the step. Step tread to stepwell joints shall be sealed to prevent intrusion of moisture and debris.
16. An aisle width standee line of bright yellow contrasting color shall be in the aisle just behind stepwell (must meet ADA contrast requirement). Suggested Sources: Altro Safety Step System.
17. Color of all flooring and step tread shall be equal to Altro Transflor genome (grey) or bison (tan) as requested by the agencies.
18. Standee decals shall be furnished and mounted at the center of the bus above the windshield.
19. Wheel wells shall be thoroughly sealed to prevent intrusion of moisture and dirt. Metal wheel wells inside the passenger compartment shall be covered with flooring material or molded fiberglass (FRP or ABS).

Source Michigan Office of Passenger Transportation [2]

23 Doors

A method shall be provided to lock all entrances to the bus when it is not in use. Except for the OEM driver's door and ignition, all secondary door locks shall be keyed the same.

23.1 Passenger Doors

Alternative 1

1. Passenger entry door shall be a dual, electric swing out type with two glass windows.
2. Clear door opening shall be a minimum of 30 inches wide by a minimum of 80 inches in height.
3. The entry door shall be fully encompassed by an integrally welded steel door surround. The entire door surround shall be fully welded to the steel substructure (cage) and floor cross members and become an integral part of the vehicle structure.
4. Entry doors shall incorporate gaskets and / or seals to provide a barrier against intrusion by wind, water, and dust around their perimeter. The seal at the center of the door shall be by means of full height overlapping rubber seals and shall include a barrier or sweep at the bottom of both doors.
5. All entry doors shall utilize long-life friction reducing materials and/or methods at upper and lower door-leaf pivot points. All door header linkages and rotation points shall incorporate similar long-life friction reducing materials/methods in their construction.

Source: Florida Department of Transportation [1]

Alternative 2

1. The manufacturer shall provide a heavy duty electrically operated passenger entrance door.
2. The door shall be located on the right side of the bus near the front wheel.
3. The entrance door shall provide a 30" clear width opening, minimum. Door opening height from the top of the first step to the door header shall be a minimum of 76". Where interior height is low at the entrance header, the header shall be padded to prevent injury to those exiting the bus.
4. The front passenger entrance door shall not extend below the step frame.
5. The passenger entrance door shall be an anodized aluminum frame, split-type double leaf swing door. The doorframe strength shall be designed to match the entrance door size.

6. The door shall have a flexible soft rubber cushion on the meeting edge 1½" in width, minimum.
7. The door glass shall be see-through, AS-2 tint (70% luminous transmittance) safety glass.
8. Under all operating conditions and bus speeds, an airtight, watertight, and dust-proof seal shall be formed between the door and the stepwell, between the door and body opening, and between the door leaf sections.
9. Any door with an exposed (metal showing) outer frame shall be made of 304 stainless steel (including the fasteners), which does not discolor with age.
10. Door fasteners shall be anchored through a metal frame, NOT through a wood frame.
11. Physical doorstops shall be used to prevent marring or damage to doors and/or surrounding parts.
12. The Contractor shall submit detailed engineering drawings(s) of the design of the entrance door and door-opening device.

Source: Michigan Office of Passenger Transportation [2]

23.2 Passenger Entry Door Operation

Alternative 1

1. The passenger entry door shall function using an electric door operator.
2. This door operator shall be modular in design for easy installation and reliable performance.
3. The door operator shall develop sufficient force to close the doors and keep closed during normal operation, while at the same time provide slam free operation.
4. The door operator shall either open or close the door in approximately 2.5 seconds.
5. For normal operations, the door operator shall not open the passenger door until the transmission lever is placed in PARK. With the door in the open position, the transmission will remain locked in the Park position until the door is totally closed.
6. The entry door shall be equipped with a sensitive edge as standard that will reopen the door when closed on a passenger or object in the doorway.

Source: Florida Department of Transportation [1]

Alternative 2

1. The passenger entry door shall function using an electric door operator.
2. The electric door operator strength shall be designed to match the entrance door size.
3. The door leading edge opening speed shall not exceed 18 inches per second and the closing speed shall not exceed 12 inches per second to provide a total door closing or opening in 2 to 4 seconds.
4. The passenger door control switch shall be in the driver's compartment within easy reach of the driver and be clearly marked for "open" and "close" (switch shall operate the same on all buses). The control switch shall be powered by a constant battery feed circuit with circuit breaker protection. The control switch shall be "hold on" for operation and of a different color than the standard switch.
5. The operator for the entrance door shall be in an overhead compartment above the passenger entrance doorway; it shall be concealed from passengers and shall be easily accessible for servicing through a hinged access door. The electronic control module shall be in a weatherproof enclosure to prevent water damage. The access door shall be hinged to open up with a holding

device or shall be a complete access cover that is secured with ¼" threaded knobs (knobs shall match access cover). The access door or cover shall be as large as will fit in the overhead compartment space.

6. Door motor operation shall be limited electrically to control door travel at full open and full closed positions and shall be adjustable to keep the door closed during bus operation.
7. Electric door operator, door linkage, and baseplate components shall be of a single manufacturer. Suggested source: A&M Systems Inc., Excell, Vapor.

Source: Michigan Office of Passenger Transportation [2]

23.3 Emergency Door Operation

Alternative 1

1. For emergency situations, a manual door release control shall be provided adjacent to the door that allows disconnection and re-engagement of the door operator so that the entrance doors can be manually opened in the event of loss of electrical power or another emergency.
2. This manual door release control shall be quickly identified for emergency exit only.
3. The door operator motor shall not run continuously when the manual release is operated.

24 Emergency Exits

24.1 Escape Windows

Alternative 1

1. Hinge-out windows shall be installed for emergency escape.
2. Lever-type latches used for emergency windows shall secure the windows tightly shut, shall be easily operated, and shall not unlatch due to vibration during bus operation. The latches shall be made of non-corrosive materials and be designed for minimal maintenance needs. Latches shall be located on the sides, NOT the bottom.
3. The emergency release handle will meet FMVSS-217 requirements and shall not return to the locked position automatically; it shall require the driver or other authorized person to manually re-lock it.
4. Emergency escape windows shall comply with FMVSS-217.

24.2 Rear-Emergency Door

Alternative 1

5. A rear emergency door with upper and lower windows shall be installed.
6. This door shall have a lock to prevent entry from outside.
7. In all seating arrangements a 12-inch-wide (minimum) unobstructed aisle shall be provided leading to the rear emergency door.
8. The vehicle transmission shall not shift out of the park position when the rear emergency door is locked or when the door is unlatched or opened.
9. An audible alert capable of 95 db(A) and a driver warning light shall be produced any time the emergency door is open, and the ignition is on.

Source: Florida Department of Transportation [1]

Alternative 2

1. Each bus shall be equipped with a rear exit door with a minimum opening of 1296 square inches (a rear exit window in place of the door is optional).
2. All exposed exit door frame/jamb structure shall be made of 304 stainless steel, a grade which does not discolor with aging.
3. The rear door exit and side window exits shall meet federal requirements of FMVSS 217.
4. The manufacturer shall provide a method to lock the rear exit door.
5. The rear exit door shall have an audible alarm at the driver's area activated when the exit door latch handle starts to open and when the exit door is locked with the ignition on.
6. A bus with a rear exit door shall have one small window on each side of the exit door in the rear endcap.
7. The rear exit door shall have two windows, an upper window, and a lower window, as a part of the door. The door glass shall be see-through, AS-2 tint (70% luminous transmittance) safety glass. The upper door window height shall match top of rear bus windows as close as practical, one on each side of rear door. Door windows shall match design of bus rear windows.
8. Heavy-duty door latch mechanism with handle guard shall provide a quick release for opening from inside and outside the bus but be designed to offer protection against accidental release. The emergency release handle will meet FMVSS-217 requirements and shall not return to the locked position automatically; it shall require the driver or other authorized person to manually re-lock it.
9. The door latch shall cause the door to compress the perimeter door seal to provide an airtight, dustproof, and watertight seal around the door under all operating conditions and speeds.
10. Door panels shall match exterior and interior body and have spray foam insulation in between panels.
11. All doors shall be fitted with screwed or bolted-on heavy-duty stainless-steel piano hinges or heavy-duty hinges of a noncorrosive material.
12. A restraint shall be installed to prevent the door from opening beyond 105° or striking the rear panel of the bus when the door is opened.
13. A passageway of 16" minimum width shall be provided to the rear exit door. No seats or other objects shall be placed in bus, which restricts passageway to rear exit door.

Source: Michigan Office of Passenger Transportation [2]

24.3 Roof Hatch

Alternative 1

All vehicles shall be equipped with a low-profile roof hatch that is equipped with both an internal and external operating handle. Hatch shall open from rear toward the front.

Source: Florida Department of Transportation [1]

Alternative 2

1. One-closing static exhaust vent, a combination roof vent-emergency exit (23" by 23" minimum), shall be installed at the mid-point on the longitudinal center line of the roof of the passenger section of the bus.

2. The roof vent-escape hatch shall provide fresh air flow inside the bus when opened and when the bus is in a forward motion.
3. The escape hatch shall have an inside and an outside release handle.
4. There is no warning buzzer requirement for the escape hatch.
5. Suggested source: DMA 1122, Specialty Manufacturing Co., Transpec Inc.

Source: Michigan Office of Passenger Transportation [2]

24.4 Emergency Exit Labeling

Alternative 1

1. Instructions for proper use of all emergency exits shall be marked near the release mechanisms.
2. All interior markings shall be durable materials affixed to the interior panels' smooth surfaces or markings shall be durable materials affixed to metal plates fastened to the interior panels of the bus.
3. Instructions may be labels, of contrasting color, affixed to a location that shall be approved by the state.
4. All emergency exits shall be marked on the exterior of the bus.

Source: Michigan Office of Passenger Transportation [2]

24.5 Emergency Exit Lighting

Alternative 1

5. Each emergency exit shall be identified with a 12-volt red LED lamp assembly, with a 10,000-hour life bulb, illuminated when vehicle ignition circuit is “ON”.
6. This system, along with window signage, shall provide passengers with a clear identification of exit routes.
7. Next to or immediately below each LED light fixture shall be a decal, one (1) inch Helvetica Medium white letters on red background, stating “Emergency Exit”.
8. Suggested Source: Series 29, Sorenson Lighting Company.

Source: Florida Department of Transportation [1]

25 Windows

25.1 Passenger Compartment Windows

Alternative 1

1. Passenger compartment windows shall be T-slider type.
2. The sash shall be equipped with latches. Sash shall not slide (open or close) upon brake application.
3. The street-side (left) rear most passenger window shall be fixed, not allowing the window to be opened. This is to keep exhaust fumes from entering the bus.
4. Side sash and rear glass may be either laminated safety glass or tempered safety glass:
    a. Side sash glass - double density
    b. Rear end glass - double density

c. Windshield glass - single density
d. Driver's window glass - single density
e. Right side glass opposite Driver -single density
f. Entrance door glass - single density

5. Tinting color shall be smoke (gray) Maximum tinting of side and rear windows shall be 31% light transmittance.
6. Glazing material shall be in accordance with the latest version of ANSI - Z26.1, Safety Code for Safety Glazing Materials for Motor Vehicles Operating on Land Highways. Glass must be AS-3 tempered. Glass grade shall be visible on each windowpane.
7. Window frames maybe anodized black or remain clear metal finish, as per the desire of the Purchaser. The Proposer shall submit if there is a pricing differential for both finishes.
8. Passenger compartment windows shall be T-type slider at top, full slider, or top tip-in type for window ventilation.
9. Windows shall have tempered safety glass and heavy-duty locking features which shall meet FMVSS 217 for emergency exits, if applicable.
10. Window glazing material shall be able to maintain its seal and glass retention for the life of the unit. Caulking around windows shall be used only as a seal, not to make up for body defects or out of tolerance window openings (maximum clearance of Â¼" around the frame, 1/8" on each side).
11. All window glass shall be tinted passenger windows AS-3 tint 31% luminous transmittance, right and left driver's side windows AS-2 tint 70% luminous transmittance, and windshield shaded-tinted AS-1 tint and meet applicable federal standards.
12. Driver's compartment right and left side windows shall be designed for maximum window area to provide unobstructed vision.
13. Driver's compartment left side window shall be adjustable vent type (moveable front section of lower portion for ventilation) or chassis Original Equipment Manufacturer (OEM) door window. Driver's right-side window shall be one piece. Suggested sources: Clear-Vision, Hehr, Kinro, Sampers.
14. Black trim shall be installed or painted to completely cover the space between all side passenger windows. The trim line shall match the bottom edge of the windows. If equipped with a side lift door, a black trim stripe shall be painted from and around the lift door windows to match the trim of the side windows. The window trim shall give the illusion of one solid window.
15. Windshield shall be OEM.

Source: Florida Department of Transportation [1]

26 Insulation

Alternative 1

Proposals shall include type of insulation to be applied in or on roof, side walls, front cap and rear cap surfaces. Documentation of R-Value for each area shall be provided.

Source: Florida Department of Transportation [1]

Alternative 2

1. Inside walls, ceiling, passenger floor area, driver floor area, and fire wall area shall be adequately insulated for sub-zero winters with spray-type foam insulation or glued in place insulation with a minimum R factor of 5.
2. The insulation shall be non-formaldehyde, fire-resistant (FMVSS 302 minimum), non-hygroscopic, and resistant to fungus.
3. Insulation shall prevent condensation and thoroughly seal bus so that drafts cannot be felt by the driver or passengers during operations with the passenger door closed.
4. Insulation shall not cover up electrical wiring harnesses, electrical switches, or other devices and shall not be sprayed in wheel wells.
5. All mechanisms (moving or stationary parts) that are affected, create a fire hazard, or are rendered useless by an application of sealant or insulation shall be cleaned free of sealant or insulation, including vent canisters and drainpipes.
6. Tectyl 121-B shall not be applied over foam insulation.
7. Engine hood cover and driver's area shall have adequate insulation to keep driver's foot area cool during summer months, warm during winter months, and reduce engine noise to an acceptable level.

Source Michigan Office of Passenger Transportation [2]

27 Bumpers

Alternative 1

1. Bumpers shall be provided at both front and rear of the vehicle.
2. The front bumper shall be OEM chrome.
3. Rear bumper shall be steel and painted black. The rear bumper shall be installed using heavy duty brackets bolted to the frame or frame extensions (not welded). The bumper shall be bolted directly to the bumper brackets with a minimum of 8 bolts (4-each side). Bolts shall be a minimum 7/16-inch grade 8 or approved and must have a flat transition panel from the body to the bumper.

Source: Florida Department of Transportation [1]

Alternative 2

1. The front bumper shall be an OEM bumper.
2. The rear bumper shall be a high energy absorbing bumper. The rear bumper shall be installed per bumper manufacturer's specifications. Bumper attachment shall use a minimum of SAE grade 8 fasteners with thread locking feature or other shake-proof (Nord-Lock) mounting in all attachment brackets. Rear anti-ride bumper installation shall allow space between the bumper and the body for energy absorption movement without body damage.
3. Rear bumper Suggested source: Romeo R.I.M. Inc. H.E.L.P. bumper, SMI.
4. Lifting pads shall be provided as part of the bus so that the bus may be lifted (at curb weight) at the front and/or the rear without any deformation or damage to the bus or bumpers and mounting hardware.

Source: Michigan Office of Passenger Transportation [2]

28 Mud Flaps and Splash Guards

Alternative 1

1. The bus shall have commercial grade anti-sail mud flaps/splash aprons behind front and rear wheels which contain no visible imprinted logo or advertising. Front mud flaps shall be rubber and rear shall be rigid type mud flaps.
2. The flaps/aprons shall be securely fastened with full width metal strips and appropriate fasteners. The flaps/aprons shall be compressed between a gauge number 11 (.125" thickness, minimum) support bracket and a gauge number 14 (.075" thickness, minimum) metal strip. The support bracket shall be fastened securely to the body substructure or chassis frame.
3. The flaps shall extend to within 6" of the road surface at curb weight. The mud flaps/aprons shall be at least 1" wider than the tire widths (single front, dual rear) to control splash at the rear of wheel openings.
4. Other mud flaps/splash aprons/shields shall be installed to protect bus equipment (AC components, batteries, front wheel inner shield, auxiliary heater box, and the like) from road splash.
5. Rubber fender splash guards secured with stainless fasteners shall be installed on the rear wheel well opening.
6. Where the mud flaps and splash guards are not an integral part of the body, installation shall be made after the finish coat of paint is applied to the bus using appropriate fasteners and adhesive.

Source Michigan Office of Passenger Transportation [2]

29 Towing

Alternative 1

1. Tow hooks shall be provided with two in the rear and two in the front of the bus, which shall be of sufficient strength to tow 1½ times the GVWR of the bus.
2. Tow hooks shall be equipped with a spring safety clips (rear only), easily accessed, and free of interference with the bumper system when in use. Access to tow hooks may be made through holes in the bumper assembly.
3. The intended use for tow hooks is only to safely move the bus to a point of tow truck hook-up.
4. Tow hooks shall be installed to prevent them from dragging when the bus is driven over an incline.
5. The tow hooks, equal to Original Equipment Manufacturer (OEM) units, shall be mounted and adequately secured to the chassis frame as recommended by the tow hook manufacturer or may be supplied by the OEM as standard equipment on the chassis.
6. The bus shall be designed to be towed from the front or from the rear with either a frame contact or a wheel lift.
7. A fuel tank protection frame shall not interfere with a frame contact lift. The Contractor shall provide the towing and lifting procedure at delivery.

Source: Michigan Office of Passenger Transportation [2]

30 Exterior Paint and Finish

Alternative 1

1. All welds shall be chipped to remove slag.
2. All metal parts shall be de-greased and properly cleaned and sanded in preparation for painting.
3. All metal surfaces shall be sprayed with primer. Parts and surfaces that will be covered in the finished vehicle shall be given a second coat of primer to prevent corrosion as much as possible.
4. If any parts are pre-primed prior to assembly and should any welding be done during assembly then the weld shall be chipped. The weld and the surrounding area shall be primed again.
5. All surfaces that will be exposed on the finished vehicle shall be properly sanded prior to finish color paint application.
6. Vehicles shall come standard with a quality painted white finish.
7. Finished color paint brand and description shall be proposed. The proposals shall also include a description of the manufacturer's painting procedure. Proposals shall include samples of the manufacturer's most popular paint schemes with pricing.

Source: Florida Department of Transportation [1]

Alternative 2

1. All exterior surfaces shall be smooth and free of visible fasteners (excluding round head structural rivets), dents, and wrinkles.
2. As appropriate for the paint used and prior to application of paint, the exterior surfaces to be painted shall be properly cleaned and primed to assure a proper bond between the substrate and successive coats of original paint.
3. All FRP body paint must match OEM chassis paint codes.
4. Paint shall be applied smoothly and evenly, with the finished surface free of dirt, runs, orange peel, and other imperfections.
5. All exterior finished surfaces shall be impervious to diesel fuel, gasoline, and commercial cleaning agents. Finished surfaces shall not be damaged by controlled applications of commonly used graffiti-removing chemicals.
6. All exterior paint shall be a two-part acrylic-urethane-type or polyurethane-type with low volatile organic compound (VOC) emission.
7. The finish coat of paint shall be applied before rubrail covers or inserts, fender flares, exterior lights, and other body mounted accessories are installed.
8. Paint shall be applied in the following method:
    a. If on bare aluminum, use proper cleaner. Suggested sources: DuPont 2253, PPG followed by aluminum conversion.
    b. If on bare steel, use proper cleaner. Suggested sources: DuPont 5717S, PPG followed with steel conversion.
    c. For all bare metal, use primer. Suggested sources: DuPont Prime 615/616 (two coats), PPG.
    d. Appropriate prep to stainless steel surfaces shall be used to ensure proper paint adhesion.

e. Appropriate primer as required shall be used on fiberglass surfaces.

f. Coat entire prepared surface to be painted with minimum of two coats of paint properly activated and reduced and have a minimum thickness of three millimeters. Suggested sources: DuPont, PPG Concept System, Sikkens Corporation U-Tech brand.

g. Standard paint color for all buses shall be the manufacturers pre-finished white exterior panels (to match OEM chassis white).

h. Color scheme on all buses shall be provided at the time of ordering. Special design paint application pricing will be negotiated at the time of ordering by the transit agency.

Source: Michigan Office of Passenger Transportation [2]

31 Exterior Mirrors

Alternative 1

1. Two (2) exterior rear-view mirrors shall be provided; one (1) at the driver's left side mounted in the OEM location, one (1) on the right/curb side.
2. The mirrors shall have a minimum of 60 square inch reflective area.
3. The mirrors shall be mounted out of the driver's normal driving line of vision to prevent blind spots.
4. Mirror must be adjustable to meet FAC 14-90.
5. All mirror mountings will be sufficiently rigid to prevent viewing distortion due to vibration. Exterior mirror mountings shall permit moving out of position to prevent mirror damage from automatic bus washers.
6. Provision shall be made for a minimum 5-inch convex mirror on each side of the vehicle attached permanently to the exterior view mirrors.

Source: Florida Department of Transportation [1]

Alternative 2

1. Each bus shall be equipped with exterior, powered-remote, heated, left-hand and right-hand rear-view mirrors of flat glass with convex mirrors (3" in diameter, minimum) attached or a combination flat/convex glass in a single mirror head. Suggested source: B&R Manufacturing, OEM, Mirror Lite Co, Inc., ROSCO, Velvac.
2. The mirror shall contain at least 70 square inches of flat glass viewing area.
3. Both flat and convex glass shall be power remote adjustable.
4. The mirror brackets shall be brushed stainless steel or die-cast, anodized aluminum.
5. All mirror mounting shall not cause premature body damage. No use of self-tapping screws to mount mirrors.
6. To prevent obstructed front and right-hand view, a convex, asymmetric, exterior cross view mirror (8" minimum diameter) shall be provided on the left front corner of the bus. Suggested sources: ROSCO Eye-max LP Hawk, Mirror Lite Co, Inc., Bus Boy.
7. All exterior mirrors shall be constructed with high impact plastic or stainless-steel housings.
8. Mirrors shall be remote adjusting and shall move independently of the mirror housing.

9. The mirrors shall be modular in design so that the glass can be replaced using the twist lock mechanism for service without removing the entire mirror assembly from the bus.
10. Mirror mountings shall be reinforced when not in a structural frame member to prevent mirror vibration, with approval by the State at the time of Pilot Model Inspection.
11. The mirror placement shall not obstruct driver vision nor have window divider bars between the driver and mirror face.

Source: Michigan Office of Passenger Transportation [2]

32 Reflectors

Alternative 1

Reflectors shall be size, type color and location required to comply with the requirements of both FMVSS – 108.

33 Rust Proofing

Alternative 1

1. The entire underbody, including wheel housings shall be rust proofed with Primer.
2. Provide the product manufacturer and the process of application.
3. Proper care shall be taken to prevent any coating from being deposited on grease fittings, moving parts, brake hoses, and drive shaft.

Source: Florida Department of Transportation [1]

Alternative 2

1. When the unit is completed, the sections of the underside of the bus exposed to the elements shall be treated with an undercoating material except those areas of the OEM chassis where undercoating is not recommended.
2. Undercoating shall be warranted for the same period covered by the body/structure warranty.
3. Suggested source: Tectyl 121-B.
4. All box type steel tubing (except stainless steel) used in the floor structure and sidewall structure from the top of the window down, shall have the interior of the tube coated with corrosion resistant material conforming to MIL-C-62218 as outlined in Federal Standard 297E. Rustproofing shall be warranted for the same period covered by the body/structure warranty. Sections that are treated shall be properly cleaned to remove greases, oils, and residues before application of the corrosion-proofing material. Suggested source: Waxoyl, Ziebart Type-A.
5. All mechanisms (moving or stationary parts) that are affected by or rendered useless by an application of sealant or insulation shall be cleaned free of sealant or insulation including vent canisters and drainpipes.

Source: Michigan Office of Passenger Transportation [2]

34 Interior

Alternative 1

1. The interior walls and ceiling surface finish shall be reinforced plastic of sufficient thickness adequately supported to prevent buckling and provide a washable surface.
2. No Luan plywood shall be utilized in the vehicle construction.
3. A detailed description of the products or materials, including available patterns and colors, will be submitted.
4. During the negotiation process, the RFP Review Committee may request samples as needed for evaluation.
5. All interior materials must comply with FMVSS-302.

Source: Florida Department of Transportation [1]

Alternative 2

1. The interior height of the passenger compartment at center aisle shall be 76" minimum. At 6" from the sidewall there shall be 67" of interior height, minimum, with a gradual contour to the center aisle (no bulkheads). Interior headroom at the back of bus (rear air conditioning evaporator area) may be reduced to a minimum of 60", but it shall increase to the normal ceiling height at the front of the rear seat cushion. The interior width at seat line shall be 90", minimum.
2. The interior of the bus shall provide a pleasant, aesthetically pleasing atmosphere.
3. All interior panels shall be made of laminate/FRP finished material scuff-resistant materials.
4. All interior finished surfaces shall be impervious to diesel fuel, gasoline, and commercial cleaning agents.
5. All materials and treatments shall be easily cleaned. Finished surfaces shall not be damaged by controlled applications of graffiti-removing chemicals.
6. The door and driver instrument panel are to be painted or otherwise finished with a non-reflective, anti-glare finish that matches the overall interior tones of interior panels.
7. A white or light gray color shall be installed in the interior area above the seat rail lines, in the ceiling area, and on the rear end wall.
8. The interior design and colors shall be approved by the State.
9. Panel fastening devices shall match color of panels.
10. All interior hinged access doors shall use quarter-turn, non-corrosive metal, thumb latches with positive stop mechanism to hold the door positively closed.
11. All interior markings shall be durable materials affixed to the interior panels' smooth surfaces or markings shall be durable materials affixed to metal plates fastened to the interior panels of the bus.
12. All surfaces, items, or hardware in the passenger compartment having sharp edges, corners, or angles that could cause injury, shall be padded with a heavy-duty, vinyl-covered, energy absorbing material to match interior colors. Areas inside the passenger compartment of low headroom where a person is prone to strike his head shall be marked and padded. All handrails shall have rounded edges where exposed.

13. A storage area with a hinged, lockable, access door shall be provided in the interior area either above the windshield (without destination sign) or on the side above the driver as space permits. This area above the windshield shall also be constructed to adequately support 60 pounds of two-way radio communication equipment. Storage area door shall open upward, be hinged at the top and have a clip/spring to retain the door in the open position.

Source: Michigan Office of Passenger Transportation [2]

35 Controls and Switches

Alternative 1

1. All controls and switches shall be mounted within easy reach of the driver.
2. They shall be permanently labeled for quick and unmistakable identification. Glued identification decals are not acceptable.
3. All controls and switches shall be lighted for nighttime operation in such a way as to prevent glare in the windshield or driver's side windows.

Source: Florida Department of Transportation [1]

36 Gauges

Alternative 1

The following gauges and alarms required:

1. Voltmeter gauge and low voltage warning light and audible warning.
2. Engine water temperature gauge and warning light and audible warning.
3. Low engine oil pressure light and audible warning.
4. Fuel gauge and low fuel warning light and audible warning.
5. Generator/alternator not charging gauge, warning light and audible warning.
6. Rear emergency door open/unlatched warning light and audible warning.
7. Directional/hazard flasher indicator lights and audible indicator.
8. Headlight high beam indicatory light.
9. Parking brake applied indicator light.
10. Speedometer with odometer.

Source: Florida Department of Transportation [1]

Alternative 2

Chassis OEM gauges shall be used in the driver’s instrument cluster, but if they are not available, VDO brand gauges or Stewart Warner gauges shall be used. Each bus shall have an instrument cluster with the following non-glare needle-type gauges which are easily monitored by sight from the driver’s position (lights in lieu of gauges are not acceptable).

1. Voltmeter and its wiring shall be compatible with generating capacities.
2. Engine oil pressure gauge.
3. Engine coolant temperature gauge.
4. Fuel gauge.

5. Air system pressure gauge with low air warning alarm and light for busses with an air system.

Source: Michigan Office of Passenger Transportation [2]

37 Sun Visor

Alternative 1

Sun visor shall be padded type, fully adjustable, to provide sun glare protection at the windshield or the driver's side window. A friction device shall hold it securely in any position during travel over rough road surfaces.

Source: Florida Department of Transportation [1]

Alternative 2

Windshield sun visor system shall be standard Original Equipment Manufacturer (OEM) chassis visor(s). If the OEM chassis is not equipped with a windshield sun visor, two large transit-type, fully adjustable, double-knuckle, arm-type Plexiglas sun visors shall be provided for the driver at the windshield, and at the side window. Suggested source: OEM or Manufacturer's standard.

Source: Michigan Office of Passenger Transportation [2]

38 Interior Mirrors

38.1 Interior Rear-View

Alternative 1

Interior rearview mirror shall be OEM.

Source Michigan Office of Passenger Transportation [2]

Alternative 2

1. One interior dead angle view mirror shall be located above the windshield.
2. One OEM rear view mirror shall be windshield mounted.
3. All mirror mountings will be sufficiently rigid to prevent viewing distortion due to vibration.

Source: Florida Department of Transportation [1]

39 Driver's Seat

Alternative 1

OEM driver seat with right arm rest shall be standard. Seat shall be fully adjustable type and shall include shoulder and lap restraining belt with retractor and right armrest. The seat shall be vinyl and shall be color keyed to the passenger seats.

Source: Florida Department of Transportation [1]

Alternative 2

1. The driver's seat shall comfortably hold and support the human body in the ergonomically correct position for driving and meet the flammability requirements of FVMSS 302.

2. The driver's seat with arm rests (right side seat arm rest, left side door arm rest) shall have adjustments for fore and aft slide, 4" minimum travel, back recline, 20° minimum, and weight range capacity up to 350 pounds.
3. Design criteria of bus purchased shall be for all females from the 5th percentile, to males of the 95th percentile, to be equally as comfortable in using all controls required to safely drive and maneuver the bus. All driver controls shall comply with FMVSS 101, with hand and foot controls required to operate the bus safely, including the placement of exterior adjustable mirrors, positioned to meet this safety requirement.
4. While seated, the driver shall be able to make all these adjustments by hand without complexity, excessive effort, or being pinched. Manual operated adjustment mechanisms shall hold the adjustments and shall not be subject to inadvertent changes.
5. The seat shall be high-backed and shall be properly aligned (centered) behind steering wheel to allow for maximum seat adjustments and operator comfort.
6. The seat belt with shoulder harness, automatic retractor, and supplemental restraint (SRS) system shall be chassis Original Equipment Manufacturer (OEM) equipment.
7. All seats and seat mountings shall meet applicable federal standards.
8. An option for an electric 6-way power adjustable seat shall be available.
9. Suggested sources: OEM, USSC G2E, Recaro Ergo Metro with headrest and armrests.
10. The driver's seat cushion shall be molded high resilient (HR) polyurethane foam padding with indentation load deflection (ILD) 35 pounds minimum, and the back cushion shall be molded or fabricated high resilient (HR) polyurethane foam padding (ILD) 25 pounds minimum. There shall be no web or bead across the front of the seat cushion under the driver's legs. Compressions to 10 percent maximum and tensile strength, 15 lbs. per square inch minimum. Seat and back cushion foam shall meet the typical physical properties of ASTM D-3574 and the flammability requirements of FVMSS 302.
11. The driver's seat covering shall be gray cloth-type woven fabric (with flame retardant qualities) or material and color matching bus seats if possible, meeting the requirements listed below in Section 40.4.

Source: Michigan Office of Passenger Transportation [2]

40 Passenger Seats (Standard)

40.1 General Requirements

Alternative 1

1. Standard seating must meet or exceed all applicable Federal Motor Vehicle Safety Standard including FMVSS 210 seat belt certification test.
2. All aisle seat positions are to have top grab rails. Grab rails must be molded and bolted to the seat frame structure. The grab rails must meet White Book test requirements.
3. The bidder shall provide a description of the seats they propose along with a copy of their seat pull test for the model bus.

Source: Florida Department of Transportation [1]

Alternative 2

1. All passenger seats shall be mid-back and are required to meet all applicable FMVSS testing including FMVSS 210.
2. Two-passenger, forward facing seats shall be 35" minimum width with a non-foam, black energy-absorbent, vandal-proof grab handle mounted to the top of each seat back (two per double seat). Grab handles are not required on seats that have a back against a wall.
3. Single passenger seats shall be 17-½" minimum width with a black, energy-absorbent, vandal-proof grab handle mounted to the top of the seat back.
4. Forward facing seats shall have 27" minimum knee to hip room.
5. Aisle facing seats shall have arm rests on both ends if the seat is not against a modesty panel.
6. Aisles shall not be less than 16" wide except as noted in Part 18 of this section.
7. The first double seat, aisle side, on the passenger side of the bus shall have an integrated child restraint seat capable of safely carrying children of 20 to 50 pounds.
8. The seating arrangements and configuration shall be furnished by the Program Manager or Designee and/or Ordering Entity.
9. Suggested sources: American Seating Horizon 8535 Mid-Back Series; C.E. White LE Series; Freedman Feather Weight.

Source: Michigan Office of Passenger Transportation [2]

40.2 Frames and Mounts

Alternative 1

All seat frames will be attached to the vehicle using mounted tracks that are welded to the floor and walls.

Source: Florida Department of Transportation [1]

Alternative 2

1. All seats shall be supported on the floor with high carbon steel support brackets. Floor anchorage shall be neat and not interfere with entering and exiting the seat. Passenger seating floor rail/track shall not be installed in the wheelchair lift or wheelchair securement areas.
2. Seat frame shall be cold-roll steel tubing.
3. All seat mounting bolts shall be corrosion resistant coated/plated fasteners.
4. The Contractor shall provide certification test data that the installation of the seats, seat mountings including floor anchorage and floor fasteners shall meet all applicable FMVSS including FMVSS 207, 208, 209, and 210 for the bus model being offered in this contract.
5. All metal components of the seat assembly shall be coated with a powder coat epoxy paint finish that shall meet the following:
    a. Salt spray - 480 hours, ASTM B117
    b. Humidity resistance - 480 hours, ASTM D2247
    c. Impact resistance – to 80 inch-pounds, ASTM D2794
6. All testing is to be performed on standard metal seating materials that have coating thickness of 1.3 to 1.8 mils. Certified test documents are required.

Source: Michigan Office of Passenger Transportation [2]

40.3 Fold-Away Seats

Alternative 1

1. Forward facing seating shall meet or exceed all applicable Federal Motor Vehicle Safety Standards including FMVSS 210 seat belt certification test.
2. The bidder shall provide a description of the seats they propose along with a copy of their seat pull test for the model bus.

Source: Florida Department of Transportation [1]

Alternative 2

1. Forward facing (double) fold-away or flip (double) seats with seat belts shall be provided in the wheelchair securement area. All aisle facing seats provided shall be flip seats.
2. Fold-away or flip seats shall include all dimensional, structural, and testing requirements of the standard seat specification (Section 40.2).
3. Seat locking/latching devices shall be of high quality and be easy to latch and unlatch. Seats must positively latch in the seated and folded position to prevent inadvertent folding or unfolding of the seat.
4. Any support legs resting on flooring shall be non-marring or rest on metal plates flush mounted with flooring.
5. All fold-away seats shall be able to pass FMVSS 210 without having to fasten additional latches or cables.
6. All fold-away seats shall fold against the wall when wheelchair space is required (no further than 12" from wall in the vertical folded position).
7. Seat may not extend into bus more than 37½" (two passenger) and 18½" (1 passenger) when folded down for passenger seating. Aisle space may be reduced to 14 inches where fold-up seating is placed on each side of the aisle or 15½" where placed opposite a stationary seat.
8. The seat bottom cushion shall be a 5° tilt up from level, minimum, and back cushion shall be at 95°, minimum.
9. The seats shall be of the same design as the other passenger seats.
10. All seat backs of the fold-away/fold-up seats shall be covered with material matching seat cushion color and fabric.
11. Suggested source: American Seating Horizon 8800 Cantilevered Folding Seat or 8700 Flip-up; C.E. White LE Series; Freedman Feather Weight Foldaway or Mid-Hi Flip; Braun #125.

Source: Michigan Office of Passenger Transportation [2]

40.4 Seat Materials

Alternative 1

Upholstery material will be vinyl thirty-two ounce per linear yard.

Source: Florida Department of Transportation [1]

Alternative 2

1. Seats shall be individually contoured to each passenger for occupant comfort and retention. Seats shall be covered with loth-type woven fabric or vinyl fabric at the transit agency's option. Cloth-type fabric or vinyl shall completely enclose the seat cushion and the seat back.
2. Seat background colors shall be gray, red, blue, and other in-stock colors (Contractor to provide available choices). All background colors shall be approved by the Program Manager or Designee.
3. Cloth-type Woven Fabric Requirements (with flame resistance)
    a. Minimum weight 23 ounces per linear yard.
    b. 50,000 minimum double rubs (ASTM - 3597-77 Wyzewbeek Method).
    c. Color fastness to light 300 hours minimum (AATCC-16-1977 Carbon Arc.)
    d. Comply with California BLT-117.
    e. All cloth-type woven fabrics except Holdsworth Wool shall be treated with a flame proofing solution following the manufacturer's specifications, No-Flame by Amalgamated Chemical Inc., or equal.
    f. The fabric shall be a plush material.
    g. Suggested source: Flame Resistant Fabrics by, CMI, Holdsworth Wool, or LaFrance Mills. Contractor shall provide technical data sheet including flammability and smoke emissions for the seat covering material supplied.
4. Vinyl Fabric
    a. Shall be transportation grade expanded vinyl, 35 ounces per linear yard minimum.
    b. Suggested source: Flame Resistant vinyl by CMI or Omnova.
    c. Contractor shall provide technical data sheet including flammability and smoke emissions for the seat covering material supplied.
5. Cushions
    a. Seat cushion and back cushion shall be molded high resilient (HR) polyurethane foam padding.
    b. Seat cushion indentation load deflection (ILD) shall be 35 pounds minimum, with compression to 15% maximum, and tensile strength of 15 minimum.
    c. Seat and back cushion shall meet the physical properties of ASTM D-3574 and the flammability requirements of FMVSS 302, minimum.
    d. The technical data sheet for the foam supplied shall be included with the seat information.
    e. Suggested source: Manufacturer’s standard.
    f. Seat and back cushions shall be supported with a spring-type support system. Seat and back cushions shall be completely covered with seat cushion covering material. Seat back depth shall not exceed 3Â½" overall.

Source: Michigan Office of Passenger Transportation [2]

40.5 Seat Belts

Alternative 1

1. All seat belts shall meet or exceed FMVSS 209 (seat belt assemblies, performance, and strength) and FMVSS 210 (seat belt mounting certification).
2. The passenger seats, frames and seat belts should operate as a complete system. All two-point seat belts must be permanently mounted on the seat frame. Seat belts attached to the floor track or wall track are not acceptable.
3. All seat belt retractors must be permanently located under or behind the seating position.
4. All seat belts must be user friendly, easy to operate, lightweight, and durable with metal buckles.

Source: Florida Department of Transportation [1]

Alternative 2

1. The Contractor shall provide certification test data that the seat belts, and the installation follow FMVSS-207, 208, 209, and 210 where applicable for the bus model being offered.
2. Two universal "Buckle Up" decals approximately 6" by 6" shall be furnished loose with each bus. Decals shall indicate that seat belt use is recommended.
3. All seats shall be equipped with seat belts for each designated seating position.
4. The latch end of the belt will have a locking retractor. The retractor will be mounted underneath the seat to the seat frame and there shall be no lap retractors except on the rear center bench seats (if equipped).
5. Belts shall have a push button latch release mechanism with push button on aisle side of seat.

Source: Michigan Office of Passenger Transportation [2]

41 Grab Rails and Stanchions

Alternative 1

1. Handrails and stanchions shall be provided in the entrance of the vehicle and elsewhere in a configuration as specified in 49 Code of Federal Regulation, Part 38, Subpart B, and Section 38.29.
2. There shall be a continuous ceiling-mounted grab rail on both sides of the aisle (except over doorways), vertical stanchions from floor to ceiling or seat back grab handles to provide a passenger with secure holding areas from front of the vehicle to the rear.
3. Grab rails/handles shall be mounted on both sides of the passenger door entry.
4. In the positioning of stanchions and grab handles, there shall be no more than 38 inches between one holding device and the next, from one end of the aisle way to the other. The 38-inch dimension can be figured longitudinally of the body, across the body or diagonally from one to the other.
5. Ceiling grab rails shall terminate into vertical stanchions or turn up into the ceiling. No exposed ends will be accepted.
6. Ceiling grab rail support brackets shall be stainless steel or anodized cast aluminum.
7. A modesty panel shall be positioned at the rear side of the entry door. Panel shall be mounted with 1½ - 2 inch spacing between the bottom of the panel and the floor to facilitate cleaning the

floor. Fastening of the panel shall be by bolts or rivets, screws will not be acceptable. The forward side of this panel shall include a handle for boarding and alighting passengers in line with the door grab handles described above.

8. Grab rails and stanchions shall be made of 1¼ inch diameter stainless clad tubing, stainless clad shall be 0.02 inches thick. Fitting ells, tees, flanges, and bolts shall be stainless steel. Propose other available material options for stanchions and handrails.

Source: Florida Department of Transportation [1]

Alternative 2

1. All handrails shall meet ADA regulation in 49 CFR Part 38, Subpart B--Buses, Vans, and Systems, §38.29 requirements for position and size.
2. All handrails and stanchions shall be positioned so as not to interfere with wheelchair movement and shall meet ADA requirements for position and size.
3. Floor-to-ceiling stanchions (yellow) shall be provided near aisle on each side of front entrance.
4. Left and right-side entrance handrails (yellow) shall be installed from low stepwell to floor-to-ceiling stanchions near aisle. Entrance handrails shall be positioned so passengers entering or exiting the bus will have handrail support throughout the entering/exiting process and so that articles of clothing may not become entangled in the handrail-stanchion-guardrail assemblies.
5. A guardrail (yellow) shall be provided in front of and at the rear of the front entrance steps, extending from the vertical stanchions to the right side of the bus 30" plus or minus 2" above the floor.
6. Two full length transit-type ceiling handrails shall be provided and securely attached to roof structure. The handrail ends shall curve toward and terminate at the ceiling.
7. A floor-to-ceiling vertical stanchion shall be provided near the rear of the driver's area. A guardrail shall be provided behind the driver's area extending from the vertical stanchion to the left side of the bus 30" plus or minus 2" above the floor. A padded modesty panel shall be provided from the guardrail to within 8" of the floor. Stanchion and guardrail shall not restrict any driver's seat adjustments.
8. A smoked Plexiglas panel, 3/8" thick, shall be provided behind driver from top of the driver's seat to within 12" of bus ceiling. The panel shall not impair driver's seat adjustments. The panel shall be fastened with bolt and nuts or double screw heads. Self-tapping/threading screws shall NOT be used. The panel shall be located to allow the driver's seat back to recline to ½ its maximum reclined adjustment with the driver's seat in the position furthest from the steering wheel. Panel may be incorporated into the stanchion and guardrail behind the driver and shall have cutouts to give hand access to the vertical stanchion.
9. A modesty panel (padded both sides, vinyl clad) shall be provided to the left (rear side) of the entrance from guardrail to floor (in case of lift bus, provide floor-to-ceiling stanchion with guardrail and modesty panel to rear of platform lift).
10. The handrails and stanchions shall be a minimum of 1¼" outside diameter. All handrails and stanchions in the passenger entrance area shall be highly visible yellow in color. All other handrails and stanchions shall be brushed stainless steel. Mounting brackets and fittings shall be composed of the same kind of material used for the stanchion or handrail. Stanchion mounting rubber grommets shall be able to handle roof to floor flex without excessive damage or ejection.

11. All handrail and stanchion mountings shall have reinforcement plates welded to or imbedded in the structure behind surface panels of sufficient size and strength to withstand passenger force. Self-tapping/threading screws shall NOT be used.
12. Final locations shall be determined at pilot model inspection.

Source: Michigan Office of Passenger Transportation [2]

42 Interior Lighting

42.1 Ceiling Mounted Lights

Alternative 1

1. Vehicles shall incorporate side and/or center ceiling mounted interior lighting and shall be LED fixtures.
2. The number of lights and their light output shall be determined by providing a minimum average of 15 foot-candles illumination on a 1 square foot plane at an angle of 45 degrees from horizontal, centered 33 inches above the floor and 24 inches in front of the seat back at each seat position. Floor surface in the aisles shall be a minimum of 10 foot-candles.
3. There shall be two (2) shielded front passenger door floor/step well lights, wired to illuminate when the passenger door opens and shall be mounted to provide light on the entry floor platform and steps. The floor light shall meet with ADA requirements and shall activate only when the doors open and will turn off when doors close. The lights shall be LED type.
4. A separate light shall be installed to illuminate the outside area on the ground surface to a level of no less than 1 foot-candle for three (3) feet beyond the doorway. The outside door light shall be located to prevent casting a shadow on the step tread and shall illuminate the ramp when deployed. Lamps at the front passenger door shall comply with ADA requirements and shall activate only when the doors open. The light fixtures shall be LED type.
5. Vestibule (area between passenger door and driver seat) shall be illuminated to a minimum of 4 foot-candles with the front doors open and a minimum of 2 foot-candles with the front doors closed.
6. The driver's seat and instrument panel area shall have a LED flush-mounted ceiling light to provide general illumination and it shall be capable of illuminating the area between the lower half of the steering wheel nearest the operator and the operators seat, to a level of 10 to 15 foot-candles. This light shall be controlled by the operator through a switch on the front console or with the integral design of the light fixture. This light shall illuminate without ignition activation.
7. For interior floor, seat, and aisles the light fixture must maintain constant light output over a 12-volt range.
8. Each light fixture must have an integral power driver to maintain proper current and voltage to the fixtures.
9. Instrument panel and switch panel shall be indirectly lighted in a way as to prevent casting a glare on the windshield. All light sources shall be located to minimize windshield glare when the bus is in motion, with distribution of the light focused primarily on the passengers' reading plane.
10. Light fixtures shall utilize an integral harness and weatherproof connector to inhibit water and dirt intrusion yet allow for easy removal and service. Lens material shall be polycarbonate. All light fixtures, excluding instrument panel and switch panel, in this section shall be LED.

11. Proposer shall provide technical information, life expectancy, warranty and identification of the manufacturer providing the above LED light.

Source: Florida Department of Transportation [1]

Alternative 2

1. Interior lighting shall be LED and provide a minimum of two foot-candles of illumination at a reading level.
2. Interior lighting fixtures shall be reasonably flush with the interior walls and ceiling, so no hazard exists for the passengers.
3. All lights shall have lead wire long enough to remove light at least 6" from bus and easy access to the connectors for service.
4. All interior lights shall be grounded by an in-harness ground attached in the fuse panel to a common grounding point.
5. All lights shall have access holes large enough to easily remove electrical connector.
6. Overhead entrance and stepwell lights shall be LED and provide no less than two foot-candles of illumination on the entrance step tread or lift or ramp with the door open. Outside light(s) shall provide at least 1 foot-candle of illumination on the street surface within 3 feet of step tread outer edge.
7. Overhead entrance and stepwell lights shall be wired to and be automatically activated by a door-controlled switch. Lights shall operate any time the ignition key is on and the door is opened.
8. Stepwell light shall be on the side away from wheel splash.
9. Light installation shall be designed to illuminate the lift platform when deployed at floor level at no less than two foot-candles of illumination. Outside light(s) shall provide at least 1 foot-candle of illumination on the street surface within 3 feet of step tread outer edge. This system shall provide illumination automatically when the lift door is open and meet ADA requirements. On-off light switch shall be lift door-actuated.

Source: Michigan Office of Passenger Transportation [2]

43 Exterior Lights

Alternative 1

1. Tail brake lights, rear turn signals, back-up lights shall be 7-inch round LED fixtures.
2. Brake lights shall have a minimum output of 350 lumens measured at 3 feet.
3. A center-top 7-inch round third brake light shall be provided, and it shall be an LED fixture.
4. The mid-bus and front and rear marker lights along with the state license tag light shall all be LED fixtures.
5. Proposer shall provide technical information, life expectancy, warranty and identification of the manufacturer providing the above LED lighting.

Source Florida Department of Transportation [1]

Alternative 2

1. All exterior body lights shall be from the same manufacturer throughout the body.

2. Exterior lighting shall be in accordance with Federal Motor Carrier Safety Regulations (393.11) and ADA regulations.
3. All lights shall have the lead wires long enough to remove the light at least 6" from bus for service.
4. All lights shall have access holes large enough to easily remove electrical connector.
5. All lights shall have the mounting to body sealed to prevent moisture intrusion and grounded to the frame.
6. All exterior lights shall be grounded by an in-harness ground attached in the fuse panel to a common grounding point.
7. Unless specified, all exterior lights of the bus shall be light emitting diodes (LED) sealed lamps retained in a rubber grommet mounting except for front headlamp/turn signal assemblies.
8. Exterior marker lights shall be light emitting diodes (LED) (2" in diameter sealed lamp) retained in a rubber grommet mounting and conform to Federal Motor Carrier Safety Regulations Part 393.
9. All marker lights shall have a weatherproof two prong (one positive and one ground) plug-style connector with the ground wire connected to an in-harness ground attached to a common grounding point.
10. Marker and taillights shall be operated through a relay controlled by the headlight switch. Suggested Sources: Dialight,Grote, Optronics, Peterson, SoundOff Signal, Trucklite.
11. Hazard flashers shall use the OEM switch and control system with an electronic flasher.
12. Headlights shall be Halogen lamps and the standard front park/turn lights may be a part of the OEM headlight assembly.
13. An amber, LED, mid-ship light (sealed) shall be installed on both sides of the bus and shall operate with the hazard flashers, marker, and turn signals.
14. License plate LED shall be Peterson Model M153C-MV with Peterson Model 150-40 bracket or Optronics LPL-55 series for those not mounted in the preformed recess in the rear panel.
15. Brake/taillights shall be red 4" round sealed voltage regulated LED lamps and shall not override hazard flashers or turn signals.
16. Directional rear turn signal lamps shall be amber 4" round sealed voltage regulated LED lamps.
17. LED high mount stop lamp shall be mounted centrally in the rear panel of the bus and work in conjunction with the brake lights. The high mount stop lamp shall be mounted either above the rear emergency exit door or above the rear emergency exit window. Final location of high mount stop lamps shall be determined at pilot model production. Suggested Sources: Command Electronics model 003-82, Dialight, Grote, Optronics, Peterson, SoundOff Signal, Truck-Lite.
18. Back-up lamps shall be clear, 4” round, sealed, voltage regulated LED lamps. Back-up lights shall be 500 lumens minimum.

Source Michigan Office of Passenger Transportation [2]

44 Electrical

44.1 General Requirements

Alternative 1

The vehicle shall be equipped with a heavy-duty (12 volt) electrical system. The entire electrical system shall comply with CFR 49 sections 393.29, 393.30, 393.31, 393.32, and 393.33 respectively.

44.2 Alternator

Alternative 1

The vehicle charging system shall have a minimum of one OEM 12-volt alternator with the highest output available from the chassis OEM with larger than OEM cables installed.

Source: California Joint Procurement [5]

Alternative 2

1. The alternator equipment shall be furnished by the chassis manufacturer where high output will match system needs.
2. This system shall be a 12-volt serpentine belt drive with internal or external voltage regulator.
3. It shall be capable of maintaining the battery at a state of full charge under all operating conditions and equipment loads, 200 amp minimum.
4. The alternator(s) shall be supplied with frame and the engine block to reduce two-way radio interference.
5. Any bracket modifications shall not reduce the strength of the mounting bracket.
6. Chassis alternator equipment available that is unable to meet electrical needs may be replaced by Delco/Remy, Mitsubishi, Leece-Neville, or PennTex that will meet system needs.
7. Any non-Original Equipment Manufacturer (OEM) alternator equipment installed on a bus by the body manufacturer shall be covered by a minimum warranty period equal to the chassis OEM alternator warranty.
8. It is the responsibility of the manufacturer (bus supplier) to match the alternator performance to the bus's electrical system needs.

Source: Michigan Office of Passenger Transportation [2]

Alternative 3

1. OEM alternator is preferred where total amperage draw does not exceed total output (excluding wheelchair ramp).
2. If an aftermarket alternator is used, a belt analysis must be performed and approved by the alternator manufacturer.
3. Bus manufacturer may be asked to furnish a sample of any aftermarket alternator for testing prior to award of contract.
4. The alternator(s) must meet or exceed the alternator manufacturer performance standards. Alternator must be capable of producing this level of output with alternator surface temperatures up to 220 degrees Fahrenheit. Manufacturer shall perform testing of total amperage draw on all vehicles to ensure compliance.

5. The upgrade (non-OEM) alternator manufacturer shall provide a permanent label under the hood stating brand, model number, serial number, and alternator output.
6. The OEM alternator output cable to the OEM power supply box must be retained and a separate second stage cable shall be installed ensuring even voltage distribution between the two sets of circuits.
7. If an alternator or alternators is/are equipped with a separate rectifier bridge or an external regulator, the rectifier and or regulator shall be mounted inside cab of the vehicle.
8. The alternator(s) proposed must meet or exceed the alternator manufacturer performance standards.
9. **{Include any additional performance test requirements here and attach test procedures as require}**.

Source: Florida Department of Transportation [1]

44.3 Batteries

Alternative 1

1. The vehicle shall have dual 700 cold cranking amps batteries.
2. Batteries shall be in a readily accessible area on a pullout stainless steel tray under the body. The access door shall be non-locking latch type.
3. The vehicle shall be equipped with a storage battery electrical power main disconnect switch. The disconnect switch shall be labeled in red lettering “Battery Disconnect, Emergency Use ONLY”.
4. All battery cable connections shall be coated to prevent corrosion.
5. Batteries must be date stamped and be no older than 1 year from delivery date.

Source: Florida Department of Transportation [1]

Alternative 2

1. The vehicle shall include dual, maintenance free batteries with reserve capacity of 400 minutes at 80°F, 950 cold cranking amps minimum, 12-volt minimum.
2. The battery equipment shall be furnished by the chassis manufacturer where available.
3. The batteries must be a matching pair of units.
4. Both batteries shall have a protective cover over the positive charge.
5. One battery shall be mounted under the hood and the second battery shall be mounted on a slide-out tray with nonmetal battery hold down secured with bolts.
6. The tray, covers, slides and rollers shall be stainless steel. The slide-out tray shall be mounted on properly supported mechanism, all of which shall have adequate capacity to support the battery equipment. The battery slide-out tray shall allow movement to permit full service of batteries outside of the bus body.
7. The battery compartment must be located below the floor line with adequate reinforcement brackets mounted to floor supports. The inside of the battery compartment shall be covered with a durable insulating material to prevent electrical shorts. The totally enclosed battery compartment shall be vented, and the tray shall be coated with an acid resistant coating. The battery compartment shall be fitted with an insulated standard exterior access door to prevent accidental grounding with hinge and quarter-turn, non-corrosive metal, thumb latches with

positive stop mechanism or flush pull-style latch(es) (SouthCo Model #M1-61-1), which match latches on other compartment access doors. The batter compartment shall be marked “auxiliary battery inside”.

8. The battery compartment may utilize the passenger stepwell. The stepwell shall remain gage 14 (0.075” thickness) stainless steel with a stainless-steel battery tray that is easily accessible with a removable step cover. The battery compartment shall be vented in a manner that prevents debris from entering and the tray shall be coated with an acid resistant coating. The stepwell shall have adequate capacity to support the battery equipment. The battery tray shall allow movement to permit full service of batteries outside of the bus body. The stepwell compartment must be marked “auxiliary battery inside”.

Source: Michigan Office of Passenger Transportation [2]

44.4 Battery Cables and Grounds

Alternative 1

1. Three added ground shall be installed: 1) between the engine and frame, 2) between the cutaway body frame and chassis frame, and 3) between the lift pump housing and the side battery.
2. All ground shall consist of #0 gage cable and must be continuous and without splices.
3. Paint must be removed from all ground connections and a coating of dielectric material applied to the cleaned surface where each ground attaches.

Source: California Joint Procurement [5]

Alternative 2

1. A main 12-volt disconnect, preferably mounted on engine cover with Weatherpack connectors shall be used to disconnect all 12-volt power.
2. Battery positive and ground cables shall be AWG size 2/0 minimum, fine stranded, flexible copper wire with permanently affixed cable connector ends with heat shrink tubing applied.
3. All cable ends shall be fastened in a manner equal to the method used by the chassis Original Equipment Manufacturer (OEM).
4. Positive cable ends at the battery shall use a protective cover or cap as an added insulator. Cable assemblies installed in place of chassis manufacturer's battery cables and operation of all systems.
5. Engine, body, and equipment grounds (properly sized) shall be installed to handle subsystem electrical capacity.
6. For all ground wire connections: 1) paint shall be removed at the grounding point to provide a cleaned surface; 2) grounding wires and cables fastened to the frame or body structure shall use a bolt with nut installed in a proper sized hole; and 3) a coating of dielectric material shall be applied to the cleaned surfaces, cable ends, bolts, and nuts where each positive or grounding cable or wire is attached.
7. The following is a list of grounding locations:
    a. A ground of the battery cable size shall be installed between the engine and chassis frame.
    b. Between the transmission case and the chassis frame.

c. The bus body shall be properly grounded with cables to the chassis frame in at least two places.

d. Lift pump motor shall be grounded directly to chassis frame using a cable of the same size as the pump motor feed wire.

e. All exterior lights and accessories, added by the body manufacturer, shall be grounded by an in-harness ground attached at a common grounding point. There may be a common grounding point in the rear of the bus along with a required grounding point at the fuse panel.

8. All buses shall be supplied with proper radio frequency (RF) suppression equipment to reduce radio interference and improve radio transmission and reception performance.

    a. High corrosion resistance and high conductivity braided ground straps shall be added: between the engine and the chassis frame of 1" width, minimum; between the engine and the firewall of ½ " width, minimum; two between the frame and the body sections of ½ " width, minimum; and between the separate body sections of ½ " width, minimum.

    b. All braided high corrosion resistance and high conductivity ground straps shall be as short as possible and shall use the negative battery cable attachment point (except those between separate body sections) as the termination point of the RF grounding.

    c. For all braided ground wire connections, paint shall be removed, and a coating of dielectric material applied to the cleaned surfaces where each braided cable attaches as is required in other ground wire applications.

    d. All removable covers in the engine area including fiberglass hoods need to be shielded and RF grounded.

Source: Michigan Office of Passenger Transportation [2]

44.5 Wiring Harnesses

Alternative 1

1. The wiring harness must be built by a reputable wiring harness manufacturer and must be built to length of bus. Proposer must supply the name of this manufacturer and provide a list of recent customers.
2. Each harness shall be as built except for optional items. Harness may incorporate wiring for options not selected by the end user.
3. Proposer must submit a proposed wiring schematic. Each wiring schematic must identify each optional circuit. Schematics shall include each connecter pin number and location. It shall also include symbols identifying electrical components along with location of each component. Each set of schematics shall have a legend that identifies each symbol used, including grounds.
4. All wiring shall be vinyl insulated to 200 degrees Fahrenheit, shall meet SAE standards, and shall be color coded and number coded at least every eighteen (18) inches and permanently labeled to identify their function.
5. Battery cables shall be 1/0 gauge with minimum of 0.075" wall plastic insulation.
6. All wiring shall be of sufficient size to carry the required currents without excessive voltage drop.

7. Entire harness system and mating electrical components shall be plug-connected with lock tab connectors; all terminals are machine crimped; all harnesses shall be covered in high temp conduit and all exterior under body/under hood connectors are Weather-Pak connectors.
8. All multi-pin connectors with 12 or more conductors shall be environmentally sealed electrical connectors with a tab connector.
9. All connectors with 3 to 12 circuits that are under the hood and/or under the vehicle shall be environmentally sealed high impact plastic connectors with pull apart locking tabs.
10. All connections containing one to two circuits shall be made with Posi-Lock connectors. Any solder joints must be pre-approved.
11. No butt connectors will be allowed.
12. All body wiring shall be run inside the body in a protected area.
13. All wiring shall be in a loom and secured for maximum protection.
14. Clamps shall be rubber or plastic coated to prevent them from cutting the wiring insulation.
15. When routing wiring under vehicle all wiring shall be encased in a loom and attached to the frame and sub-floor structure with rubber or plastic-coated P-clamps every 12 inches and shall not be bundled with hoses.
16. The harness shall run in straight lines as close to the chassis frame rails as possible.
17. Any harness that goes over the rear suspension shall be encased in a conduit fixture securely fastened to the sub-floor rails or routed inside the frame rails.

Source: Florida Department of Transportation [1]

Alternative 2

1. All non-OEM connections shall be WeatherPack.
2. The manufacturer shall furnish complete as built wiring diagrams with integrated body and chassis wiring marked to show the codes used. Mating harnesses and harness connectors shall use matching wiring and coding unless chassis OEM wiring and coding is different from the body's manufacturer.
3. Install a 12-volt power point for handheld equipment in the driver's area.
4. All accessories and accessory electrical equipment shall be wired through a constant solenoid energized when the bus's ignition switch is in "ignition on" or "run" mode.
5. A master switch with constant solenoid shall be provided and act as a quiet switch overriding individual switches for accessories. This master switch is wired in series with the ignition switch to control the constant solenoid.
6. The constant solenoid shall not control headlights, taillights, emergency lights, charging system voltage regulator energizer lead, a fused power lead for the passenger door, and a fused constant power lead for all electronic control units' long-term memory.
7. All control switches, relays, and circuit breakers used for the various electrical circuits shall have a current carrying capacity adequate for the circuit that they control and shall be properly marked for their function. The illuminated switch markings shall be permanent and not wear off with switch use.
8. Control switches shall be positioned for easy access from the driver's seat.

9. All cable and wires added by the body manufacturer shall be continuous color coded and numbered or function coded. All wiring supplied by body builder shall have each wire permanently labeled with its function at least every eighteen inches.
10. The wiring shall be designed to be a plug and play system where the harnesses and components are fastened through common standard terminal ends and connectors.
11. All wiring added to chassis fuse block shall be securely fastened to prevent wires from being knocked loose or loosening from vibration.
12. All added wiring shall be installed in a properly sized and supported split open-type loom or a properly supported raceway for protection.
13. The manufacturer shall use wire raceways where needed. Wiring, harnesses, and raceways shall be supported at regular intervals by "P" clamps, or by other supporting hangers where necessary, and routed in separate hangers from heater hoses or air conditioning hoses.
14. All wiring passage holes through engine cowl, floor area, and other partitions shall be thoroughly sealed to prevent dust and moisture intrusion.
15. Any excess harnesses shall be properly secured.
16. All wiring shall be heavy-duty; be properly grounded to body frame structure and the chassis; use a common grounding point; and be adequate for electrical system capacity.
17. All wiring harnesses shall have adequate length to allow for harness flexing from supporting brackets and where harnesses connect to electrical equipment.
18. Any wiring added by splicing into an existing chassis Original Equipment Manufacturer (OEM) harness or wire shall match modification standards set forth by the chassis manufacturer, such as circuits shall not interfere with nor back-feed into other electrical circuits.
19. Wiring added from OEM chassis wiring to rear lights, fuel tank, and/or other accessories shall be supported and protected from the ice and snow build-up. Wiring shall be inside bus where possible.
20. Wiring to taillights and other exterior lights shall be long enough to remove assembly by 6" for service.
21. Exterior connections shall be weatherproof positive lock connectors coated with dielectric grease.
22. Scotch lock wire connectors are not acceptable and shall not be used for wiring installation.
23. Terminals shall be installed as follows:
    a. Machine crimped on wire ends shall be used on all harnesses and cable assemblies used in the production of buses.
    b. Harness assemblies shall have connectors matching a mating connector where harnesses attach to other harnesses, switches, or other electrical units. Connections made in any harness assembly shall use Sta-Kon® disconnects and splice connectors where machine applied connectors cannot be used. Connectors shall be properly crimped with Sta-Kon® tools and covered with heat shrink tubing.
    c. In-line fuse assemblies shall use spade type fuses in a Weather-Pak holder and shall be located for ease of service.

d. All exterior wiring connectors (plug-ins) including harnesses shall be weatherproof positive lock with the connector pins applied with the proper crimping tool (Weather-Pak, Metri-Pak).

e. All exterior ground connections, except factory supplied braided ground straps, shall have properly applied terminal ends with heat shrink insulation applied.

f. All connections exposed to the weather shall have dielectric grease applied to prevent corrosion.

Source: Michigan Office of Passenger Transportation [2]

44.6 Circuit Protection

Alternative 1

1. All fuses and relays (other than chassis OEM) shall be placed in an electrical panel. The panel shall be accessible through a non-locking door.
2. Connection to OEM electrical system shall be accomplished through connectors supplied by the chassis manufacturer using locking mating connectors. A legend shall be provided on the circuit box door that displays circuit fusing and identification information.
3. All electrical circuits shall be properly sized and protected as described by the applicable SAE standards. If multiple components are powered from a single power source, additional circuit protection shall be provided.

Source: Florida Department of Transportation [1]

Alternative 2

1. Electrical panels installed by the body builders shall be located for easy access.
2. Circuit breaker circuit protection shall be standard, but blade type fuses may be used when expressly required by the component manufacturer.
3. The master electrical panel shall use a separate plug and play connector and terminal system.
4. Highest quality components available shall be used.
5. Two spare electrical fuses that match fuses used on the bus body and chassis shall be supplied with the bus and stored in a box or spare circuit area at fuse box.
6. All components shall be placed on the front of the electrical panel for ease of service.
7. Body fuse/electrical panel shall be sufficiently sealed to prevent intrusion of dirt and moisture.
8. Lift equipped buses shall have a circuit breaker with a manual reset in the lift feed circuit. The circuit breaker shall be installed vertically (on the side wall) in the battery box, in the positive power cable leading to the lift power pack.

Source: Michigan Office of Passenger Transportation [2]

44.7 Back-Up Alarm

Alternative 1

A reverse direction alarm (BUA) in compliance with SAE J994b with respect to acoustical performance for a Type B device but emitting at least 7dbb (A) plus or minus 4db with a supply of 14 volts shall be installed. Conformity to the environmental test stipulated by the SAE shall not be required.

44.8 Wipers and Horn

Alternative 1

1. EM equipment preferred). Wiper motors shall be mounted for easy access and not interfere with other equipment mounted in the front bulkhead/cowl of the bus. Where individual wiper motors are used (one for each side), each shall be supplied by its own fused feed wire.
2. The bus shall have two electric horns.

45 Heater/Defroster

Alternative 1

1. The OEM and passenger heater unit(s) must achieve a 65-degree interior temperature with an empty coach when the ambient temperature is “30” degrees Fahrenheit within 30 minutes (measured at front mid-vehicle and rear in the vehicle).
2. Additional passenger compartment heater(s) shall be mounted to the floor under seats at the manufacturer’s standard location to produce an even interior temperature.
3. The blower motors for the passenger compartment heater system(s) shall be easily accessible for servicing and controlled by a three-position switches having HIGH, LOW, and OFF positions.
4. All passenger compartment heaters shall be shielded to prevent blowing hot air onto the passenger’s legs.
5. Interior heating must meet performance standards described above. Manufacturer must submit testing results following the procedures described in **{insert reference to appendix containing test procedures}** with the proposal.
6. There shall be vacuum/electric shut-off valves in the heater piping.
7. A booster pump may be required to meet the above performance standard with gasoline engines and shall be standard with diesel engines.
8. Heater hoses shall be of top-quality silicon material. Hose clamps shall be stainless steel constant torque type. Hoses will be insulated with wrap-around foam pipe insulation.
9. Hoses shall be protected and supported by approved clamps in all locations where they are close to or pass-through metal frame members to prevent chafing. Hoses shall be shielded against heat at any location where they pass over or near any part of the exhaust system. All heater hose shall be routed below floor level to ensure passenger safety.
10. **{Attach heating system test procedures/performance standards as an appendix}**

Source: Florida Department of Transportation [1]

Alternative 2

1. During normal passenger service, front and rear heavy-duty heating system shall be capable of raising the interior temperature of a bus from 0°F to 60°F at knee level (22" above the floor) throughout the interior of bus within 30 minutes from engine startup.
2. After initial warm-up, while the bus is in passenger service, the front and rear heavy-duty heating system shall be sufficient to maintain a minimum of 64°F at knee level throughout interior of bus and at the driver's foot space when the outside temperature is 0°F.
3. Heating system operation will be verified by the required system testing as defined in **{insert referenced to addendum containing test procedures}**.

4. In addition to the front heater and windshield defrosters, for increased air circulation, one 6" two-speed fan with non-glare blades and body shall be mounted away from passenger and driver traffic in the driver's area near the windshield. The fan shall be mounted securely with nuts, bolts, and washers.
5. Grounding for all heater fan motors shall be supplied by an in-harness ground wire attached in the fuse panel to a common grounding point. All HVAC fan motors shall be supplied with proper radio frequency (RF) suppression equipment to remove two-way radio interference.
6. Front heating unit shall be automotive in-dash type, chassis Original Equipment Manufacturer (OEM), and shall be capable of delivering heat, fresh air ventilation, and air conditioning (optional) to the driver's area. The front heater shall have a temperature control valve which can be regulated from the driver's area. The driver's area shall have air circulation in each mode of defrost, heat, fresh air ventilation, and air conditioning (optional) of 125 cfm at the foot area, with a total driver's area circulation of 400 cfm minimum.
7. Rear heating unit(s) shall distribute heat in at least a 180° direction and ensure air distribution to all passenger areas of the bus interior. Heating unit(s) shall have a minimum ¾" I.D. heater inlet and outlet ports with a BTU/hr output rating to match the specified HVAC performance requirements. Coolant flow through the heating units shall not be restricted by excessive bends or kinks in hoses or excessive lengths of hoses. Heating units shall have rubber or nylon insulator(s) between their mounting base and floor of the bus. Suggested sources: ACC Climate Control, A. R. Lintern, Bergstrom, Pro-Air, MCC Mobile Climate Control.
8. The premium heater hose (¾" ID minimum) shall be high temperature resistant Ethylene Propylene Diene Monomer (EPDM) material. Hose shall be a reinforced type with Aramid knitted fiber reinforcement between the EPDM tube and EPDM cover. Heater hose material shall be compatible with all types of coolant including long life coolant. Rated temperature limits of the hose shall be -40°F to +300°F minimum, with a burst pressure of 130 PSI minimum.
9. Manual shut off valves for the rear heater shall be placed as close to the engine as practical. The ¾" ID heavy-duty brass gate shut off valves shall be in the heater outlet line (from engine to heater) and in the heater inlet line (to engine from heater). Shut off valves shall be accessible by personnel without going under the bus with access panels. Location to be determined at pilot model inspection.
10. Front heater shall have coolant temperature control valve or other controls which can regulate heater temperature from the driver's area.
11. All heat lines and hoses shall:
    a. have exterior routing along the bus frame rail where possible.
    b. be sufficiently protected to ensure against wear from friction and the elements.
    c. be insulated to reduce heat loss.
    d. use routing that eliminates excessive bends and hose lengths.
    e. and have heater hose passage holes through engine cowl and floor area thoroughly sealed to prevent air, dust, and moisture intrusion.
12. **{Attach heating system test procedures/performance standards as an appendix}**

Source: Michigan Office of Passenger Transportation [2]

46 Air Conditioning

Alternative 1

1. Air conditioning equipment manufacturer must be approved by the **{enter state name}** Department of Transportation.
2. The air conditioning equipment must be capable of cooling buses to meet or surpass the minimum requirements of **{insert reference to air conditioning performance test procedures}**.
3. Vehicles shall have a totally split system. No "Add-On Systems" shall tie into OEM System in any way.
4. Air circulation shall be high volume with low velocity to provide draft-free passenger comfort.
5. All hoses shall be routed and secured in such a way that they will not rub or chafe. Routing of these hoses shall not interfere with the access of routine maintenance items such as dipsticks, air filters, or access doors. When routing hoses under the coach the hoses shall be run in a straight line and shall be secured with rubber or plastic-coated p-clamps every 12 inches.
6. Refrigerant hoses shall be a refrigerant type double braided barrier construction. Refrigerant fittings shall be "Quick Click" or equivalent.
7. Hoses and fittings must be qualified to SAE specification J2064. AC System shall be equipped with a digital control panel with diagnostic capabilities.
8. All brackets, pulleys, and belts required for the operation of A/C compressors shall be part of the second stage A/C system and must be specifically engineered for each chassis provided. Proposal shall identify the bracket manufacturer.
9. **{Attach air conditioning system test procedures/performance standards as an appendix}**

Source: Florida Department of Transportation [1]

Alternative 1

1. Air Conditioning - Split System
    a. The air conditioning system (AC) shall have a separate compressor, condenser, and evaporator for the front system and or the rear system (two separate systems). The systems shall be 12-volt and use refrigerant type R-134A. The systems shall be of sufficient capacity to maintain interior temperature requirements stated in the test procedure for air conditioning systems during summer operation **{insert reference to appendix containing test/certification procedures}**.
    b. The front AC system shall be integrated as part of the front heating/ventilating unit including the driver's area evaporator unit (complete front system may be Chassis OEM with OEM controls and sensors). The front system shall provide temperature control with sufficient cooling ventilators for driver comfort with no reliance on the rear system for front temperature control. Front and rear air flow and temperature shall be controlled by separate switches on the driver's control panel or dash panel. Front and rear systems shall have separate fan, evaporator, and compressor controls.
    c. The rear system shall have an electronic control system capable of providing automatic temperature control, freeze protection, compressor protection, and diagnostic functions. The driver's automatic temperature and system control panel shall be mounted in the driver's station. The control system shall be an integral part of the

system temperature controls. The system shall be able to monitor system voltage, high refrigerant pressure, low refrigerant charge, and clutch cycling intervals and shall protect the system by controlling compressor clutch engagement. The system shall be able to interpret associated problems and provide codes for technician diagnosis. Suggested sources: ACC Climate Control Model MDS, MCC ECO Temp Lite, Thermo King Clima Aire.

d. Compressors: There shall be two engine mounted, serpentine belt driven air conditioning compressors of nominal 13cu. in. displacement each, minimum, one for the front system (may be chassis OEM) and one for the rear system. Hose end metal fittings connecting hoses to the compressor shall be electro-coated steel that pass the ASTM B117 480-hour Salt Spray test. The compressor clutch circuit shall be interrupted when abnormal pressures are detected by the pressure monitoring switches. Low pressure switch shall be located between the expansion valve and the compressor in the low-pressure side of the system. The high-pressure switch shall be located between compressor and condenser (for TXV systems) or between the condenser and the orifice tube (for orifice tube systems) in the high-pressure side of the system. Suggested sources: ACC Climate Control, American Cooling Technology, Inc., Thermo King, Trans/Air; MCC Mobile Climate Control.

e. Condensers: The rear system's condenser shall be roof mounted (10" or less in height) and the front system may use the Chassis OEM radiator mounted condenser. The protective external grille work for the roof mounted condenser coil fins shall not be mounted directly against the condenser fins. The condenser fans and motors shall be enclosed within the condenser housing. The housing shall be galvannealed or aluminum with heat-fused powdered epoxy coating. The condenser coil shall be copper, or aluminum tube expanded into aluminum fins or MCHX condenser. Hose end metal fittings connecting hoses to the condenser shall be electro-coated steel that pass the ASTM B117 480-hour Salt Spray test. High pressure cut out switches shall be wired into the clutch circuit. The condensers shall be equipped with axial fans dynamically balanced with permanent magnet totally enclosed motors. The condensers shall blow air upward and toward the rear of the bus assisted by the forward motion of the bus. A refrigerant dryer and a sight glass where necessary shall be included in the system. A branch guard the same height as the condenser shall be mounted just forward of the condenser assembly on the roof of the bus which shall not restrict air flow into the condenser assembly. Suggested sources for roof mounted condenser: ACC Climate Control, American Cooling Technology, Inc., Thermo King, Trans/Air.; MCC Mobile Climate Control.

f. The front evaporator (may be chassis OEM equipment) and rear evaporator(s) shall have three-speed continuous duty permanently lubricated blower motors with sufficient CFM capacity to maintain interior temperature requirements stated in test procedure. The rear evaporator cores shall be a copper coil with aluminum fins (three rows deep, minimum), galvanized heavy-duty frame and coil end sheets with a galvanized or plastic drain pan. The rear evaporator expansion valve or orifice tube shall have "O" ring refrigerant connections. Suggested sources: ACC Climate Control, American Cooling Technology, Inc., Thermo King, Trans/Air; MCC Mobile Climate Control.

g. The driver's evaporator (may be chassis OEM equipment) shall be controlled separately from the rear passenger area evaporator. The controls shall include an on/off switch and a three-speed blower switch. The in-dash unit shall not interfere with removal or replacement of the engine cover or be blocked by the entrance door control mechanism.

h. The passenger area evaporator system shall be separately controlled from a control station at the driver's position. The controls shall include an on/off switch and a three-speed blower switch. The evaporator shall be ceiling mounted at the rear of the passenger compartment.

i. The components of the air conditioning system shall be readily accessible for maintenance. Service/charging ports shall be accessible under-hood without removing any other component or item. The refrigerant hose construction shall comply/exceed SAE specification J2064 Type D or E. Refrigerant fitting construction shall comply/exceed SAE specification J2064 Type D or E. All refrigerant hose end fittings shall be electro-coated steel that will pass the ASTM B117 480-hour Salt Spray test. The hose coupling end of all fittings shall include two hose barbs and two areas of elastomeric or HNBR seals. Refrigerant hose clamp construction shall: comply/exceed SAE specification J2064 Type D or E; be made of stainless steel to ensure coupling integrity; properly align hose end fitting; and clamp the hose directly over the elastomeric or HNBR seals. Refrigerant hose fittings shall be Aeroquip E-Z Clip system, ATCO Air-O-Crimp, MCC FlexCLIK.

j. The wiring shall meet all applicable specifications 44.5. The evaporator and condenser wiring (power and ground circuits) shall be properly sized to provide maximum voltage drop of 1.5v to farthest system component.

k. Air conditioning electrical circuits shall be protected with manual resettable circuit breakers or fuses.

l. The rear air conditioning system shall be supplied from the equipment manufacturer as a complete unit including controls, wiring and hoses. The whole system shall be warranted from in-service date, by the manufacturer, for a period of two years with unlimited mileage.

m. All fault codes shall be cleared upon delivery.

n. **{Attach air conditioning system test procedures/performance standards as an appendix}.**

2. Air Conditioning - Tie-in System

a. The air conditioning system (AC) shall use the OEM compressor, condenser, and evaporator for the front system and a separate condenser and evaporator for the rear system (two tied systems). The systems shall be 12-volt and use refrigerant type R-134A. The systems shall be of sufficient capacity to maintain interior temperature requirements stated in the test procedure for air conditioning systems during summer **{insert reference to appendix containing test/certification procedures}**.

b. Evaporator: One (1) free blow evaporator rated up to 45,000 BTU/hr. The evaporator shall have one (1) dual shaft blower assembly. The motor is minimum three (3) speed continuous duty permanent magnet and utilizes a resistor to limit amperage requirements. Drain pan shall not be part of evaporator cover but shall be part of the

evaporator module with drain valleys to insure proper drains of the condensation. The return air filter is located at the coil and is easily accessible for maintenance without removal of the evaporator cover. The evaporator coil is copper tube design with aluminum fins. Evaporator assembly shall be a galvanized design. The evaporator shall utilize and orifice tube in lieu of a thermal expansion valve for a more trouble-free operation. The evaporator cover has no sharp edges and must meet FMVSS 302 specification standards. High Pressure and Low Pressure (switch) protection shall be part of the evaporator assembly to maximize compressor and entire system protection. Evaporator air outlet louvers shall be adjustable to provide maximum directional airflow throughout the vehicle.

c. Driver's area in-dash evaporator: The OE Chassis supplied drivers in-dash evaporator shall be utilized and is tied into to passenger area air conditioning system.

d. Condenser: One (1) skirt mounted condenser rated at 67,000 BTU/hr. The condenser shall have two (2) 11" high performance fan/motor assemblies with extended brush life motors. The coil shall be a parallel flow design for lighter weight and maximum heat rejection efficiency. The condenser assembly shall be designed to distribute air away from the vehicle floor. The condenser is installed in such a manner to assure the entire coil face area is exposed to fresh air from the outside of the vehicle skirt (the skirt of the vehicle will not in any way interfere with direct airflow through the coil). The system design shall use an accumulator with filter desiccant in lieu of a filter drier. The accumulator shall be mounted at the lowest point of the system (on the chassis frame rail) for maximum system protection. In addition, the accumulator shall include an oil pickup tube to insure proper compressor lubrication upon startup of the a/c system. The electrical connections shall be corrosion resistant.

e. A three (3) speed fan switch and a rotary thermostat control shall be included and located in an area easily accessible to the driver. All wiring shall be color coded. The entire electrical system shall utilize a relay board with ground leg switching. The relay board shall

f. individual fuses for greater protection of the relay board components. The system shall be protected with manual reset circuit breakers.

g. **{Attach air conditioning system test procedures/performance standards as an appendix}.**

3. Air Conditioning/Heat - Rooftop System

a. The rooftop AC system shall meet all of the requirements of the AC split system except that the rear evaporator and heating unit shall be an integral part of the rooftop AC unit so that the condenser unit, evaporator unit, and heating unit are part of a single roof mounted unit. A coolant circulating pump shall be installed in the coolant lines for the rooftop heating unit. The auxiliary coolant heating unit and coolant pump for the rooftop heating unit shall be connected electrically to run whenever the bus's rooftop unit calls for heat. The rooftop unit shall be a free blow system installed in the central area of the passenger compartment of the bus with stainless steel fasteners and cover bolted down. No ¼ turn fasteners on cover. The air conditioning/heating system shall be supplied from the equipment manufacturer as a complete unit including controls, wiring, electrical protection devices, and hoses. A branch guard shall be installed to protect the roof-mounted air conditioner. The whole system shall be warranted from

in-service date, by the manufacturer, for a period of two years with unlimited mileage. Suggested Sources: ACC Climate Control, American Cooling Technology, Inc., Thermo King, Trans/Air.; MCC Mobile Climate Control.

Source: Michigan Office of Passenger Transportation [2]

47 Wheelchair Lift

47.1 General Requirements

Alternative 1

1. Vehicle shall be equipped with a fully automatic wheelchair lift mounted on the curbside of the vehicle, accessible via access doors. The lift components, including the platform, shall be easily disassembled to facilitate repairs and replacement of parts.
2. The wheelchair lift, design, installation, and operation shall comply with the Americans with Disabilities Act (ADA), Regulations and Requirements, as amended (Title 49 Code of Federal Regulations, Part 38, Subpart B, Section 38.23) and 49 CFR Part 571.

47.2 State and Local Requirements

{This section is reserved for relevant state regulations}

47.3 Lift Capacity and Dimensions

1. Minimum capacity of {600, 800, or 1000} pounds.
2. Minimum entryway height of 68 inches.
3. Minimum platform width of {32, 34, or 44} inches.
4. Minimum platform width of {50 or 54} inches.

47.4 Lift Door/Gate

Alternative 1

1. The lift gate shall be of heavy-duty frame design.
2. The wheelchair entrance door shall be open swinging type with window. The outer edges of the wheelchair access doors shall be weather-stripped with a continuous strip to provide a watertight seal.
3. A cylinder type gas shock mechanism for opening and closing the door shall be installed. This mechanism shall be capable of holding the door in the fully open position when the lift is in use.
4. Manufacturer shall provide a detailed description of the method of attachment of door surround to the body cage.

Source: Florida Department of Transportation [1]

Alternative 2

1. The Type I platform lift (passive lift) shall be installed in a separate door opening for use by persons with disabilities.
2. All door openings shall have full structural framing around the opening equal to the structural members of the body. Wall and floor mounting points shall be reinforced and shall be attached with fasteners having a thread locking feature.

3. Any exposed lift door frame structure shall be constructed of 304 stainless steel, a grade which does not discolor with aging.
4. The lift doors shall be manually operated, double door with an outside key locking handle. The lift door(s) shall have an upper window like the side windows of the bus.
5. Spring loaded struts; gas struts shall be provided on the lift doors to positively hold the doors in the open position.
6. The entire lift assembly shall have adequate protection installed on all sharp corners or items that protrude into the passenger area to prevent accidental injury to passengers.
7. Lift installation shall insure that no lift rattling exists when the bus is operated while the lift is stowed.
8. Lift door operated interrupt switch shall prevent use of lift with lift door(s) closed. Heavy-duty long-life switches shall be used in this application.
9. The bus manufacturer must provide documentation that the lift complies with the lift manufacturer's lift installation requirements.

Source: Michigan Office of Passenger Transportation [2]

47.5 Lift Mechanism

Alternative 1

1. The lift mechanism shall be designed to also provide a minimum 68" vertical clearance.
2. The lift shall be mounted so as not to detract from structural integrity of the vehicle. A minimum of four (4) support bars installed underneath the floor are required.
3. The wheelchair lift shall be installed using the instructions and hardware provided by the lift manufacturer.
4. The lift shall have provision for manual operation in the event of a power failure so that the platform can be operated.

Source: Florida Department of Transportation [1]

Alternative 2

1. The lift shall be an electro-hydraulic type.
2. The platform lift equipment shall be a double "C" channel parallel arm construction, hydraulically operated by two single-acting cylinders with gravity unfold, gravity down, power up, and power fold (stow) operation.
3. If the lift has a crossbar, it shall be above the door opening and well padded.
4. No part of the lift platform shall exceed 6 inches/second during the lowering and lifting of an occupant and shall not exceed 12 inches/second during deploying or stowing.
5. The lift shall have a mechanical outboard safety wheel stop to prevent wheelchair from rolling off the platform during the lifting cycle.
6. The Contractor shall deliver the lift equipped bus with the type of lift equipment requested by the State. Suggested sources: Braun, Ricon.
7. A manual safety override shall be provided that will remain operable. Lift shall have manual override instructions visible from inside and outside the bus with door open.

Source: Michigan Office of Passenger Transportation [2]

47.6 Lift Platform/Gate

Alternative 1

1. The lift shall have a self-cleaning, see through; non-skid platform which shall fold and unfold.
2. The useable platform space must be fully maintained in operation from ground surface to provide a minimum 5-inch barrier to prevent the wheelchair from rolling off the lift during operation.
3. If the hinged barrier is automatically activated, it must be designed to allow for manual operation.
4. A barrier at least 4 inches high shall also be provided on each side of the platform to prevent wheelchairs from rolling over the side edges.

Source: Florida Department of Transportation [1]

Alternative 2

1. Platform, bridge plate, and area between bridge plate and aisle shall be skid resistant.
2. Bridge plate and platform shall be coated to resist rust.
3. Platform shall include automatic locking inboard safety wheel stop (minimum 6" height) and outboard safety wheel stops to prevent wheelchair from rolling off.
4. Platform shall have horizontal handrails (one each side) on platform to assist passenger during lift operations. Handrails (yellow) shall fold automatically to prevent any obstructions into the bus passenger area.
5. Platform shall automatically stop at floor level.
6. Platform shall automatically stop when lowered to ground level.
7. Handheld controls shall be conveniently located on a flexible or coiled, cut-resistant cable and shall be mounted with access from inside or outside the bus. The cable shall be routed to eliminate being pinched in any moving parts.

Source: Michigan Office of Passenger Transportation [2]

47.6.1 Interlock System

Alternative 1

An interlock system, such as Intermotive Gateway ILIS, or approved equal, shall be provided which renders the lift inoperative unless the transmission shift lever is in the “Park” position and the emergency brake is applied.

Source: West Virginia Department of Administration [3]

Alternative 2

1. A lift control interlock system shall be installed that shall ensure that the bus cannot be moved when the lift is not stowed and that the lift cannot be deployed unless the interlock is engaged [to meet ADA regulation in 49 CFR Part 38, Subpart B-Buses, Vans and Systems, §38.23, (b)(2)(I)].
2. The interlock system shall engage when the lift operation sequence is followed.
3. Interlock operating instructions shall be included with the bus at delivery.
4. An indicator light (red, labeled) shall be provided at the driver's station that is activated when the lift door is open and when the lift is in operation.

5. An audible warning signal shall be activated in the vehicle if the lift doors are opened, and the interlock is not engaged.
6. An interlock override system shall be installed that allows service personnel to move the bus to a safe area for repairs.
7. Suggested Source: Intelligent Lift Interlock System (ILIS) by Intermotive Products.

Source: Michigan Office of Passenger Transportation [2]

47.7 Signage, Reflectors, Warning Lights

Alternative 1

1. A strip of 3-inch reflective tape shall be added to the outer edge of the lift platform side barrier and shall run the full length of the side barriers [1].
2. The outside edges of the platform shall either be painted yellow of use 3M™ vinyl safety stripe tape to enhance visibility when extended on the ground [2].
3. All lift equipped buses shall display the international symbol of accessibility, one each on left and right side of the bus [2].
4. A caution sign shall be prominently displayed in full view of persons standing at curbside of the vehicle as a warning to stand clear for lift operations [3].
5. Activating the lift circuitry switch will cause the rear hazard lights to flash [3].

47.8 Labeling

Alternative 1

All lift manufacturers or installers shall legibly and permanently mark each wheelchair lift assembly with the following minimum information in a location easily visible without deploying the ramp:

1. The manufacturers name and address.
2. The month and year of manufacture.
3. A certification that the wheelchair lift, and installation conform to State of {insert state name} requirements applicable to accessible vehicles.

48 Securement Devices

48.1 Regulatory Compliance

Alternative 1

Securement devices, their design, installation and operation shall comply with the Americans with Disabilities Act (ADA), Regulations and Requirements, as amended (Title 49 Code of Federal Regulations, Part 38, Subpart B, Section 38.23) and 30 mph/20G impact Test Criteria per SAE J2249.

48.2 Restraint System

Alternative 1

1. Each vehicle shall be equipped with forward facing mobility aid securement and occupant restraint system.

2. The occupant restraint system shall be equipped with a height adjuster for the shoulder belt, having a vertical adjustment of approximately 12 inches.
3. The tie-down system shall be able to secure a standard wheelchair or mobility aid in less than 10 seconds.
4. A set of four (4) "webbing loops" is to be provided at each station.
5. The occupant restraint system shall meet the following requirements when used in conjunction with the retractor system:
    a. Federal Motor Vehicle Safety Standards (FMVSS209 & MVSS302).
    b. 49 CFR Part 38 Americans with disabilities Act (ADA).
    c. 30MPH/20G impact test criteria SAE J2249.
    d. Floor attachments shall be installed according to appendix F in SAE J 2249.
6. Manufacturer shall install all restraint hardware provided (including under floor backer plates) by the sub-component supplier and by the instructions provided by the sub-component supplier. All securement stations must be ADA compliant.

Source: Florida Department of Transportation [1]

Alternative 2

1. Forward facing wheelchair tie down and occupant restraint shall consist of four floor attachment points for the chair and a retractable combination lap belt/shoulder restraint with manual height adjuster for the occupant.
2. The integrated securement system shall restrain the occupant and the wheelchair separately and securely.
3. Fold-away seating shall be provided for use when wheelchairs are not being carried.
4. All components shall be installed to the securement manufacturer's recommended specifications.
5. Suggested sources: Q'Straint Model Q-8100-A1L, Sure-Loks's Retraktor™ Systems for L trak AL-712S-4C.

Source: Michigan Office of Passenger Transportation [2]

48.3 Anchorage Points

Alternative 1

1. Floor anchorage points shall be anodized aluminum, stainless steel or other non-corrosive metal construction and consist of aircraft type insert pockets that can be flush mounted with the flooring (Flanges L style trak, QStraint, Sure-Lok – Omni aluminum 6061-T6 or equivalent with matching end caps).
2. Anchorages and securements must be tested together and be compatible.
3. Floor anchorage points for the first securement space shall be spaced at a minimum of 54 inches from center of the front track to center of the rear track.
4. Floor anchorages shall be located no closer than 8 inches from a stationary wall or obstruction (forward or rearward) that would hinder an operator from attaching the securement system.

5. The center run of anchorage track between two securement locations can be shared with the rear anchorage if the front securement system and the front anchorage of the rear securement system.
6. The width of the anchorage track shall be no less than 30 inches wide allowing for the widest of mobility devices.
7. Shoulder belt wall anchorage shall be permanently fastened to the body structure in the wall according to the securement manufacturer's instructions.
8. Shoulder belts manual height adjustment shall allow approximately 12 inches of vertical height adjustment allowing for differences in height of secured mobility aid passenger.

Source: Michigan Office of Passenger Transportation [2]

48.4 Retractors

Alternative 1

1. The wheelchair or mobility aid retractors shall be equipped with "S" or "J" hooks to simplify operation.
2. Retractors shall be heavy duty with heat treated components and a metal or impact resistant plastic housing.
3. The retractor shall be complete with combination retractor straps with height and vertical adjustment for securing the wheelchair or mobility aid and two retractors for the occupant restraint system.
4. The wheelchair mobility aid retractors shall be equipped with self-adjusting tension controllers for tightening and have the ability for quick release.
5. The wheelchair or mobility aid retractors shall be capable of being mounted directly to the vehicle structure using a retractor mounting kit. Retractors with a slide and click type system, are preferred.

Source: Florida Department of Transportation [1]

Alternative 2

1. The four belts that attach to the wheelchair from the floor anchorage points shall use a simple J or S style speed hook end for attachment.
2. The belts shall have self-tensioning heavy-duty retractors with a hard metal cover.
3. The retractors shall have an available tightening knob for aiding in additional securement control.
4. All floor attachment belts shall be the same and work in any of the floor attachment points. Attachment belts shall be equipped with pin connector brackets for the lap belt assembly.
5. Automatic self-tensioning and self-locking retractors with metal covers shall be part of the floor belt assemblies for automatic belt tensioning.
6. Belt ends with floor attachments shall be easily identified for placement in the floor track.

Source: Michigan Office of Passenger Transportation [2]

48.5 Restraint Storage System

Alternative 1

Storage containers for restraint system belts and instructions for use of restraint system shall be included and mounted in safe and convenient location.

Source: Florida Department of Transportation [1]

Alternative 2

A wheelchair restrain storage system shall be positioned under the foldaway seats at each wheelchair space. The storage system shall:

1. Keep restraints clean.
2. Be free of any sharp edges.
3. Provide easy accessibility to restraints.
4. Restraints shall be stored securely to prevent noise while the vehicle is in motion.
5. Restrain storage system shall be compatible with the installed securement system (L-Track or 360-degree single point securement system)
6. Suggested source: Freedman Tie-Down Storage System.
7. A storage pouch, from the securement manufacturer, shall be provided for the lap belt restrains.

Source: Michigan Office of Passenger Transportation [2]

49 Safety Equipment

Alternative 1

Each vehicle shall be provided with the following equipment as standard:

1. Fire Extinguisher: Provide a Fire Extinguisher, 5-pound rechargeable ABC type, with charge status gauge and decal noting most recent charge date. This unit shall be mounted in an easily accessible interior location near the driver's position and/or vestibule areas.
2. Warning Triangles: Provide Warning Triangles, reflective type, three (3) unit kit, secured in a location readily accessible to the driver.
3. Deluxe Medical Truck Kit: Provide a Deluxe Medical Truck Kit, (see Part 2, Exhibit 3: Medical Kit Supplies), mounted in an accessible location.
4. Seat Belt Cutters: Provide two (2) Seat Belt Cutters, mounted in an accessible location, one near the wheelchair ramp and the other accessible to the driver.
5. Blood Pathogen/Bodily Fluid Spill Kit: Provide a Blood Pathogen/Bodily Fluid Spill Kit, secured in a location readily accessible to the driver, and manufactured by the First Aid Only Company, or approved equal. The Kit must meet federal OSHA regulation 29CFR1910.1030(d)(3)(i).
6. Oxygen Tank Holder: Provide an Oxygen Tank Holder, shipped loose inside each bus at delivery. Dealer to install at a location selected by Purchaser.
7. 3- Axis G-force Accelerometer/Recorder: Provide a G-force accelerometer monitor and recorder as standard, configured with 2 Accelerometer devices allowing it to detect and record G-forces in 3 axes, front/rear – left/right – up/down. System should also provide the following inputs: reverse, brake and left and right turn signals. Data shall be recorded and retained for a maximum of 60 seconds before and 15 seconds after an event.

8. Engine Compartment Fire Suppression System: Provide a fire suppression system as standard equipment. System to be equipped with 4 nozzles at minimum, located in the engine compartment connected to a piston accumulator that contains a water-based liquid fire suppressant agent. The size of the piston/accumulator and number of nozzles shall be determined by the manufacturer based on vehicle size and configuration.

Source: Florida Department of Transportation [1]

Alternative 2

The following safety items shall be provided on each bus

1. One UL listed 5 pound, 2A-10BC dry chemical fire extinguisher. Fire extinguisher shall have a metal head, a gauge to indicate state of charge, and a bracket with strap for securement. Fire extinguisher shall be serviceable and rechargeable for the life of the bus with metal mounting brackets. Fire extinguisher shall be shipped loose. Source: Manufacturer's Standard.
2. One container of bi-directional emergency reflective triangles that meets FMVSS 125 and shall be in a location easily accessible to the driver.
3. A 12-volt 97-db sealed solid state electronic warning alarm that is readily audible from outside the bus when transmission is in reverse. The alarm shall: be steam cleanable; have passed a 1 million cycle test; and meet SAE J994, OSHA, Bureau of Mines and all State Regulations. The alarm shall be mounted with bolts and properly grounded and mounted on the rear of the bus. Suggested source: OEM standard.
4. The rear door shall have an audible alarm at driver area that is energized when the rear door latch handle starts to open and when the rear door is locked with the ignition in the on or accessory position.
5. An automatic daytime headlight control system shall be provided. The system shall illuminate the headlights when the ignition switch is on and the headlight switch is off. The system shall activate automatically after engine start up with the headlamp switch off and shall deactivate automatically when the headlamp switch is on or the ignition switch is turned off. Suggested source: Chassis OEM.
6. A low-profile electronic strobe light (white) with a clear lens and branch guard shall be provided. The light shall meet SAE J1318 requirements and be mounted centrally on the roof of the bus approximately 6 feet forward of the rear of the bus. Strobe light mounting shall have free access to connector with enough room to remove connector without removing any produce 80 (±10) double flashes per minute and have a light intensity of 1 million candlepower with a current draw of approximately 1 ampere. Suggested Sources: Meteorlite, Peterson, Target Tech Pulsator® 451, Truck-Lite.

Source: Michigan Office of Passenger Transportation [2]

50 Optional Equipment

50.1 Limited Slip Differential

Alternative 1

The limited slip differential powers both wheels yet freely permit wheel speed differentiation when required during turning using standard OEM equipment.

50.2 Spare Tires

Alternative 1

Optional spare tires shall be offered for both the steer and drive axle tires if they are of different tread design. Spare tire shall match brand and specifications on delivered vehicle.

50.3 Running Boards/Steps and Grab Handle

Alternative 1

The bus shall be equipped with either OEM driver's side steps or a 12" wide running board. The steps or running board shall be securely attached to the chassis and have the capacity to support 300 pounds. When available from OEM, a grab-handle shall be supplied on the outside driver's side.

50.4 Back-up Sensor System

Alternative 1

1. A rear back-up sensor system shall be installed with a minimum of four water-resistant and corrosion resistant sensors flush-mounted to the rear bumper (painted to match the bumper).
2. The system shall automatically engage when the vehicle is in reverse and warn of objects and/or people up to seven feet (minimum).
3. The system shall utilize an LED monitor, mounted within view of the driver, which displays the distance (in feet) from the object(s). The system shall also emit a pulsating alarm or beep that is audible to the driver as the vehicle approaches the object(s) and then the system shall emit a steady alarm within at a minimum of 1.5 feet from the object(s).
4. Suggested Sources: Ackton Transportation Technologies, American Road Products, Intermotive Hawkeye.

Source: Michigan Office of Passenger Transportation [2]

50.5 Manual Entrance Door (in lieu of electrically powered door)

Alternative 1

1. The manufacturer shall provide a heavy duty manually operated passenger entrance door with control handle located in the driver's compartment within easy reach of the driver.
2. The passenger entrance door shall not extend below the step frame.
3. The door shall be located on the right side of the bus behind the right front wheel. The entrance door shall provide a 30" clear width opening, minimum, with all handrails installed.
4. Door opening height from the top of the first step to the door header shall be a minimum of 76".
5. Passenger entrance door shall be a double-folding, split-type double leaf swing door. This door shall have a flexible soft rubber cushion on the meeting edge 1 1/2" in width, minimum.
6. The door glass shall be see-through, tinted (AS-2) safety glass.
7. Under all operating conditions and bus speeds, an airtight and dust-proof seal shall be formed between the door and the stepwell, between the door and body opening, and between the door leaf sections.
8. All exposed door frame structure shall be made of 304 stainless steel acid-etched, coated with zinc-based primer and powder coated OEM white (including the fasteners).

9. A method shall be provided to lock the bus when the bus is parked.

Source: Michigan Office of Passenger Transportation [2]

50.6 Powered Driver's Seat Base

Alternative 1

Provide an OEM six-way power seat base that allows for fore and aft, up and down, front tilt and rear tilt.

50.7 Destination Sign

Alternative 1

1. Option 1 - Roller/Curtain: A 12-volt destination sign with a motor driven movable sign curtain mechanism shall be provided which meets ADA requirements (one front sign and one side sign). The sign curtain shall be approximately 36" wide and illuminated. The sign box shall have a door to open for the operator to view the sign curtain position. The door shall be positioned for ease of driver operation. A restraint shall be installed to prevent the storage door from opening beyond 105" when the installation allows the door to swing open. Suggested source Transign LLC.
2. Option 2 - LED: A solid state, LED destination sign shall be provided which meets ADA requirements (one front and one side sign). Signs shall be programmable using latest version of Microsoft Windows® based software. All hardware and/or software shall be provided with the first bus purchased by each transit agency. Suggested sources: Transign LLC Destinator, TwinVision MobiLite.

Source Michigan Office of Passenger Transportation [2]

50.8 Farebox/Donation Box

50.8.1 Farebox

Alternative 1

1. The farebox shall be mounted with the trip handle toward the driver and within easy reach of the driver. The farebox shall be mounted on an adequately braced stanchion; shall be located over a flat floor surface near the driver; and shall be accessible to passengers entering the bus (meet ADA requirements). An indirect farebox light shall be connected through an entrance door jamb switch to the running light circuit operational only when door is opened.
2. The farebox shall be lockable and supplied with two vaults that are interchangeable and lockable (2 keys for each lock). The vaults shall be keyed alike. The vault and farebox exteriors shall be marked with key reference. (Location shall be approved by the State at pilot model inspection.) Suggested source: Diamond Model NV.

Source: Michigan Office of Passenger Transportation [2]

50.8.2 Farebox Electrical Prep

Alternative 1

Electrical connections and wiring only (no farebox) along with support stanchion shall be supplied to the area where the standard farebox would be mounted (location shall be approved by the State at pilot model inspection).

Source: Michigan Office of Passenger Transportation [2]

50.8.3 Donation Box

Alternative 1

A donation box (in lieu of the farebox) shall be mounted on an adequately braced stanchion; shall be located over a flat floor surface near the driver; and shall be accessible to passengers entering the bus (meet ADA requirements). The lockable donation box shall be supplied with two keys (location shall be approved by the State at pilot model inspection). Suggested source: Diamond.

Source: Michigan Office of Passenger Transportation [2]

50.9 Stop Request System

Alternative 1

1. An interior Stop Requested sign, chime and driver signal activation system shall be installed and activated by ¼" diameter yellow cord mounted on the side wall even with the bottom of the tip-in-transom portion of the windows.
2. Signal touch buttons mounted in an ADA mandated wheelchair accessible area shall be no higher than 4' above the floor, with no exposed wiring.
3. A single "stop request" chime shall sound when the system is first activated and a tell-tale light indicator on the driver console will stay light continuously until the passenger door is opened.
4. A double chime shall sound when the system is first activated from wheelchair passenger areas.
5. A "Stop Requested" message in Helvetica medium yellow letters on a green background shall be illuminated when the passenger system is activated.
6. The "Stop Requested" message shall remain visible until doors are opened.
7. The sign unit shall be flush mounted on the front destination compartment door and the message shall be visible to the seated operator and all seated passengers.
8. The operator shall be able to deactivate the signal system from the operator's area as well as automatic deactivation each time the passenger door is opened.

Source: Michigan Office of Passenger Transportation [2]

50.10 PA & Entertainment System

Alternative 1

1. Option 1: An AM/FM stereo radio system shall be installed in the dashboard area within reach of the driver. At a minimum, the stereo system shall have an illuminated or LCD display along with controls for power, tuning, volume, and the ability to turn off sound to the rear speakers. A total of four (4) speakers shall be installed in the bus with two (2) speakers mounted in the front (audible to the driver and front passengers) and two (2) speakers mounted in the top rear wall of the bus. Suggested sources: OEM.

2. Option 2: A public address (PA) system shall be installed in the dashboard area within reach of the driver and utilize a handheld microphone. At a minimum, the PA system shall be equipped with controls for power and volume. A total of two (2) speakers shall be mounted with one in the front and one in the top rear wall of the bus. Suggested sources: Custom Radio Corporation model PA6, Jensen, Mobile Page Model 470, REI.
3. Option 3: A combined AM/FM stereo radio and a public address system shall be installed with four (4) speakers. The combined system shall meet or exceed the specifications outlined in option 1 and option 2. The speakers shall be mounted per locations specified in option 1. Suggested Sources: Jensen, Panasonic, REI.
4. Option 4: Additional speakers shall be offered at locations requested by the ordering agency.
5. System shall fade from front to rear and left to right for all systems.

Source: Michigan Office of Passenger Transportation [2]

50.11 Two-Way Radio

{Add specifications for optional two-way radio}

50.12 Video Surveillance System

50.12.1 Video Surveillance Preparation Package

Alternative 1

A video surveillance preparation package shall be offered (less cameras and digital video recorder system) allowing for one to four camera locations. The preparation package shall include the installation of camera wiring or conduit, DVR electrical connections, location for the DVR, and access covers for camera mounting/locations. Ordering agency shall specify the camera system to use and have the flexibility to position cameras.

Source: Michigan Office of Passenger Transportation [2]

50.12.2 Video Surveillance System

{Add specifications for optional video surveillance system}

50.13 Auxiliary Coolant Heater

{Add specifications for optional auxiliary coolant heater}

50.14 Auxiliary Air Heater

{Add specifications for optional auxiliary air heater}

50.15 Entrance Stepwell Heater

{Add specifications for optional entrance stepwell heater}

51 References

[1] Universtiy of South Florida, "Standard Cutaway Chassis Type Transit Vehicles Request for Proposal TRIPS-15-CA-RFP," Center for Urban Transportation Research, Tampa FL, 2015.

[2] State of Michigan, "Specifications for Small Class of Buses, Class I - 5 Years/150,000 Miles (minimum); Class II - 7 Years/200,000 Miles I (minimum) of Non-lift and Lift Transit Buses with Alternate Seating," State of Michigan, Lansing MI, 2016.

[3] "Electronic Code of Federal Regulations Title 49 - Transportation, Chapter VI, Part 665 - Bus Testing," US Government Printing Office, 28 June 2021. [Online]. Available: https://www.ecfr.gov/. [Accessed 30 June 2021].

[4] "Vehicle Specifications New Hampshire Department of Transportation Medium/Heavy Duty Low Floor Transit/Paratransit Cutaway Buses Class 4/5," New Hampshire Department of Transportation, Concord NH, 2017.

[5] "Request for Proposal for Joint Procurement of Cutaways, Minivans, Large Cutaways and Low Floor Cutaways," Paratransit Inc., Sacramento CA, 2013.

[6] State of West Virginia, "Solicitation Passenger Cutaway Bus," State of West Virginia, Charleston WV, 2013.

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