Transit Vehicles for National Parks: Selection Factors and Technologies

Prepared for the National Park Service
U.S. Department of the Interior
Vehicle Design Conference
Estes Park, Colorado
March 25, 2002
Updated March 2003

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Introduction

Increasingly, national parks are purchasing and operating buses and other alternative transportation vehicles to transport visitors to and from or within park boundaries. Selecting alternative transportation vehicles is a complex, multi-faceted process that involves the careful analysis of numerous factors. This material in this report originally was developed as a primer to orient park superintendents and transportation managers who participated in an Alternative Transportation Vehicle Workshop held March, 2002 in Estes Park, CO. It provides useful information and supplements Volume 1 (Candidate Vehicle Technologies) of the Federal Lands Alternative Transportation Systems Study.[1] This updated version contains the essentially the same material provided to the workshop participants.

This primer addresses fundamental considerations for evaluating and choosing buses, including: vehicle technologies, vehicle types, fuels, infrastructure and associated costs. These should not be viewed as independent topics, but as parts of a system in which each part may be affected by, and may affect, the other parts. Alternative transportation systems will be unique based on the differences and the particular needs of individual parks. Therefore, rather than provide extensive details about specific parks, the sections herein outline basic system considerations that should be investigated further in relation to the specific conditions at a given park.

The primer presents NPS staff with a multitude of ways to meet the goals of enhancing visitor experience while minimizing environmental impacts. The first section, "Vehicle Considerations" covers general vehicle characteristics that can be modified to fit park specific requirements. Statutory provisions and implications for visitor experience, environmental impact, cost, and maintenance are also discussed. The next section describes the range of passenger buses on the market today along with the trade-offs between these – one of the most salient differences being the fuel and propulsion system used. The final section outlines the availability, cost, infrastructure requirements, and environmental benefits of the fuel options, as a means of further aiding park staff in evaluating and choosing transit vehicles.

[1] See: http://www.nps.gov/transportation/alt/ats_study.htm

Vehicle Considerations

Overview

Within the United States, there are several types of passenger bus operations that range from urban and rural public transit providers, to the military, schools, businesses that need to move groups of people, recreational facilities, and the national and state parks. Each has a different need for a vehicle or vehicle type. These needs include varying capacity, operating conditions, range, and fuel. Vehicles purchased for public transit need to meet significantly different requirements than those that are used by schools, national parks, the military, or the private sector. In the United States, the bus industry segment that sells to public transit agencies produces approximately 5,000 vehicles ranging in size from 22 feet to 60 feet, with about 80 percent being 40-foot transit buses. This section details the qualities and functionality of each vehicle type, as well as other factors relevant to determine the suitability of given vehicle types for use in a specific national park transit application.

Factors that should be addressed in determining the type of vehicle(s) being considered are: passenger load, boardings and alightings at each stop, route structure (speed, turning radius, distance, etc.), type of passengers, other passenger factors (e.g., packages and baggage, recreational equipment, age distribution, and strollers and wheelchairs), the purpose of the trip (e.g., sightseeing, visitor shuttle service, employee shuttle), and other related factors. Some configurations and propulsion systems have numerous quality manufacturers, while others may have a limited number of qualified manufacturers. These factors may affect the ability to obtain cost-competitive bids on certain vehicle types or configurations. Some manufacturers prefer to use certain component or sub-component suppliers. It may be desirable, for maintenance purposes, to specify that a specific manufacturer with a service facility in the area be used for primary components such as the engine.

Vehicles typically are classified by minimum design lifetime: 12 years/500,000 miles, 10 years/350,000 miles, 7 years/250,000 miles, 5 years, and 4 years. It is not uncommon for many heavy-duty vehicles to last beyond 12 years or 500,000 miles. A comparison of the vehicle types and configurations is contained in Appendix A.

Altoona Bus Testing

The Federal Transit Administration (FTA) requires that all bus models to be purchased with FTA funds complete Altoona Bus Testing. Organizations not using FTA funds, including other governmental agencies and private operators, are not required to purchase Altoona-tested vehicles. However, the Altoona testing provides valuable performance and costs estimates for the expected lifetime of the vehicle. It is important to note that Altoona is not a pass/fail test, and no grade is given. The test simply reports on the performance of the vehicle during the testing protocol, and is not an endorsement of any vehicle that completes testing. Some transit operators have incorporated Altoona performance metrics into their specifications for new vehicles.

Americans with Disabilities Act

The Americans with Disabilities act (ADA) requires that vehicles used for public transportation meet minimum standards and requirements for mobility, accessibility, and information conveyance to people with mobility and auditory or visual impairment. There are several technologies that address these needs, including wheelchair lifts and ramps, in-vehicle signs, and in-vehicle annunciators.

Technologies and Options

There are numerous technologies that are common to any bus. Several key technologies are covered in this section. These directly affect the functionality of a vehicle and its suitability for a given application.

Floor height

A transit vehicle can either be configured as a high-floor vehicle, which requires steps from the curb to the floor, or as a low-floor vehicle, in which no steps are present and the maximum step-up height is 15 inches. Low-floor vehicles are quickly becoming the industry standard. They were developed to better meet ADA requirements. Unlike high-floor vehicles, which require a wheelchair lift, low-floor vehicles use a rapid deployment ramp. Passengers with other mobility restrictions also benefit, and the average loading and off-loading times for other passengers are reduced by half a second or more per passenger. Low-floor buses typically offer less seating than a comparable high-floor bus due to the need to accommodate the wheel wells within the passenger compartment. The low-floor technology increases the cost of a 40’ bus by about 10%. Ground clearance (including break-over angle and approach / exit angles which affect ground clearance in going up and over inclines) also may be less with a low-floor than with a high-floor vehicle.

Doors

The width and number of doors will affect the loading and off-loading time, but will also impact the seating and standing capacity of the vehicle, and can affect ADA compliance. The greater the number of doors and the greater the width, the less seating capacity. Doors can either be configured as single-wide or double-wide. The manner in which they open (swing out or fold) also can impact the available passenger capacity.

Suspension

The suspension technology used on a vehicle will affect the ride and control of a vehicle. Suspensions may be configured with variable height capability and/or kneeling technology. Variable height allows a vehicle to raise or lower its height depending on road and speed conditions. Kneeling technology allows the vehicle to lower several inches near the boarding area to facilitate loading and off-loading.

Wheelbase

The wheelbase, measured as the distance between the tires, affects the ride comfort and performance, turning radius, axle load, and the approach, exit, and break-over angle of a vehicle. Wheelbase choices to optimize one characteristic may negatively affect another.

Seating

Several factors influence seating. Vehicle seating capacity differs based on seat design, configuration and ADA compliance. Seating capacity can also be affected by the space required for luggage and recreational equipment. The interior configuration, and the ability to possibility to locate seats with in a vehicle are affected by the floor height and other vehicle technology choices, such as the size and location of the engine. The durability, appearance, cost, and comfort of the vehicle can be affected by the choice of seating materials and seat design.

Materials

The materials used in a vehicle's frame and body affect its cost, performance, and durability. Material choices include stainless steel, plain carbon steel, high-strength steels, aluminum, and carbon-fiber composites. These materials vary in cost, weight, environmental durability, and maintainability. The benefit and value of a given material must be evaluated relative to its specific application. Moreover, some materials may not be offered for some vehicle types.

Windows and Visibility

The design, number, and location of windows will affect passenger views from the vehicle. Some vehicles are designed to be fully or partially open to the outside, thereby allowing for greater visibility and clarity, as well as for greater sensory interaction with the environment (smell, sound, etc.). However, such vehicles also expose visitors to the elements. Not all window configurations may be possible on all vehicle types, and some manufacturers use custom designs unique to their vehicles. Window design will also affect maintenance and replacement costs.

Environment

The natural environment in which the vehicle is being operated must be considered and factored into the vehicle designbecause it may affect vehicle operation, maintenance, and suitability for use. Several technologies require additional power, and may affect the environmental impact of the vehicle, visitor and rider experience, and performance. For example, the capacity of a vehicle's Heating, Ventilation, and Air Conditioning (HVAC) system is important to insure passenger comfort in both extreme cold and heat, but requires additional on-board power. In addition, the ability to incorporate technologies appropriate for a specific environment, such as snow chains for winter operations, should be considered. Electrical components operating in or near marine environments or where salt is used should have components that are rated for a high salt environment. Other factors such as altitude, precipitation, climate, protection from insects and nature, etc., also need to be considered.

Interior Comfort

Interior comfort is determined by several factors. These include seat design and orientation, legroom, climate, internal noise, aesthetics, and amenities. Interior noise is a function of vehicle design, window design, the propulsion system, and the sound insulation or noise mitigation technology used. In general, interior comfort depends upon overall vehicle design and should be approached from a comprehensive integrated systems perspective.

Audio–Visual Equipment

Audio-visual (AV) equipment may be incorporated into many vehicle designs. The quality and effectiveness of this technology is in part a function of the vehicle design, internal and external noise, and glare. The equipment's impact on the external environment should also be considered, particularly in open-air vehicles.

External Appearance

External appearance is important for both aesthetics and visual impact on the park setting. Ridership may increase by the desire to use a vehicle with a specific appearance or design. Special body panels or other unique design options exist for some vehicle types. In addition, decals and temporary or permanent paint schemes may also be used to create the desired vehicle's external appearance.

Roadway/Guideway

The type of roadway or guideway, and its condition, affects the type and functionality of a vehicle that is operating on it. Certain vehicles require the use of a dedicated or fixed guideway. Guideways or dedicated rights-of-way may offer improved service. Road conditions will affect the comfort of the ride, operation of the vehicle, and durability and maintenance costs. And, heavier vehicles accelerate road wear and deterioration due to increased axle loads.

Fuel and Propulsion Technology

The fuel and propulsion system technology is discussed in Section 2.

Vehicle Types

The following sections delineate various vehicle sizes and types. Each section provides information on vehicle descriptions, configurations, and costs, as well as a discussion on how the technologies described above may be incorporated.

40-foot Transit

<u>Description</u>

The 40-foot transit bus is the workhorse of the public and mass transit industries. The heavy-duty, class 8 vehicles are built to last a minimum of 12 years or 500,000 miles. Seating capacity for a 40-foot transit bus ranges from 39 to 47 passengers with additional room for standees, depending on the seat configuration. The turning radius ranges from 40 to 45 feet.

<u>Configuration</u>

Depending on the manufacturer, the bus can be designed as a high floor, partial low floor, or full low floor. Fuel and propulsion systems currently in full or limited production are diesel, Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), and diesel-electric hybrid. Liquid Petroleum Gas (LPG – a.k.a. Propane) may be an option. Prototype fuel cell buses are being tested. Vehicle width is either 96 or 102 inches. The 40-foot bus is typically equipped with two doors, but can be configured with additional doors.

<u>Cost</u>

A typical 40-foot transit bus ranges in cost from $250,000 to $500,000 depending on the configuration and fuel or propulsion type. Fuel costs vary depending on the fuel and route structure. A typical bus has a 2.5-4 mpg diesel or dge (diesel gallon equivalent), but may be as high as 4.5 in some duty-cycles. Maintenance costs also vary. The Bureau of Transportation Statistics (BTS) reports a typical yearly operating cost, including maintenance, of about $35,000 per vehicle (not including driver and related costs).

35-Foot Transit

Description

The 35-foot transit bus is similar in design and concept to the 40-foot transit bus. Typically a five-foot section from the center of the bus is removed. The bus is appropriate where decreased passenger loads are present, or where a shorter turning radius is dictated.

Configuration

The 35-foot transit bus may be configured in the same way as a 40-foot bus. However, not all configurations are currently offered. Seating capacity is between 30-35 passengers. The turning radius is approximately 35 feet.

Cost

The purchase cost of a 35-foot transit bus is slightly less than that of a 40-foot bus. The operating costs are almost identical to those of a 40-foot bus.

30-Foot Transit

Description

The 30-foot transit bus is similar to that of a 35- or 40-foot transit bus. Some manufacturers use the same basic platform as in their 40-foot bus, and others have designed unique platforms. The vehicles are used where capacity demands do not dictate the use of a larger vehicle, or where operational restrictions such as turning radius do not permit a larger vehicle. The vehicles are manufactured as 10-year/350,000 mile or as 12-year/500,000 mile vehicles.

Configuration

Depending on the manufacturer, the bus can be designed as a high floor or partial low floor. Fuel and propulsion systems currently in full or limited production are diesel, CNG, LNG, propane, and diesel or NG hybrid. Prototype fuel cell buses are being developed. Vehicle width is either 96 or 102 inches. The 30-foot bus is typically equipped with two doors. Seating configuration, in conjunction with the floor type, provides a seating capacity of 27-30 passengers, with room for additional standees. The turning radius ranges from 29 feet, 5 inches to 34 feet.

Cost

The purchase cost of a 30-foot bus is approximately $175,000-$250,000, varying based on its design and configuration . Driver and maintenance costs are slightly less than those of a 35- or 40-foot transit bus.

22-Foot Bus

Description

The 22-foot bus is commonly used as a shuttle. Most 22-foot buses do not require a commercial driver's license for the driver. The vehicles are manufactured as 7–year / 250,000 mile vehicles, but can be manufactured and tested for longer use.

Configuration

The 22-foot bus is typically offered as a low-floor vehicle with one door and seating for approximately 22 people. Fuel options include diesel, CNG, battery electric, and hybrid. The vehicles have a turning radius of 22-36 feet. The 22-foot bus is a common platform for electric and hybrid electric propulsion.

Cost

The purchase cost of this vehicle varies significantly depending on configuration and fuel type, and can range from $125,000-$200,000.

Articulated Bus

Description

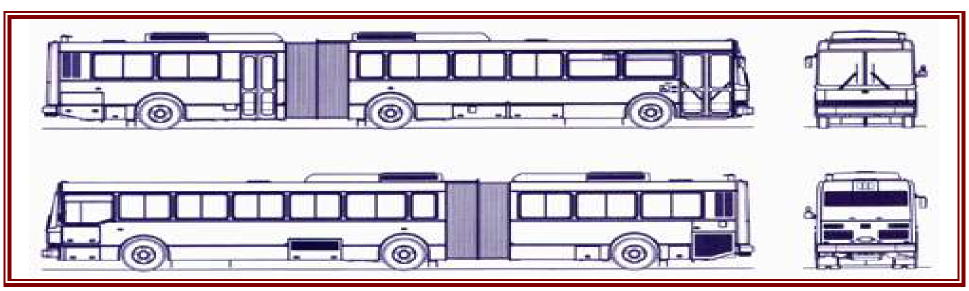
The articulated bus is typically a 55- or 60-foot long bus comprised of front and rear sections connected by an articulated joint that makes the bus more maneuverable. Some European manufacturers also produce a dual-articulated bus with lengths up to 80 feet. The bus can be built as either a pusher (engine in the rear articulated section) or a puller (engine in the front section). These vehicles can be used either as a conventional transit bus with added capacity, or as part of a Bus Rapid Transit (BRT) system. An articulated transit bus is designed as a 12-year/500,000 mile vehicle, while some BRT vehicles are designed to last significantly longer, up to 25 years or 750,000 miles.

Configuration

If the vehicle is used in regular transit service, the interior of the vehicle is similar to that of a 40-foot transit bus. In bus rapid transit applications, articulated buses may be configured to operate on dedicated roads or guideways, and may incorporate technologies such as very low floors that can operate in the environment. The vehicles typically are offered as pure diesel, diesel electric, or electric. The vehicles may also be configured with natural gas.

Cost

The cost for these vehicles ranges from $400,000 up to $1,000,000 plus. The maintenance and operating cost will vary significantly depending on the specific application and use.



Trolley Replica Bus

Description

Trolley replica buses are vehicles with an exterior, and usually an interior, designed to look like a streetcar from the early 1900s. These vary in length, but are typically around 30 feet long. These vehicles offer open air seating, and are often used for tours. Fuel options include diesel, CNG, battery electric, and hybrid electric.

Configuration

Manufacturers produce these vehicles either from a standard medium-duty platform, or as unique platforms. Except for electric propulsion models, these vehicles are only offered in high-floor design. The engine can be located in the front or the rear of the vehicle. These vehicles are not typically designed for standees.

Cost

The cost of a trolley replica varies depending on its size, fuel or propulsion system, and configuration. A trolley replica that is manufactured on a standard medium-duty platform may be cheaper, but is also typically less durable.

Tram

Description
Trams can be used to move high and low volumes of people with ease over relatively short distances. These are modular and usually configured with a tug or tow vehicle and one or more trailers. Trams are commonly found in use at zoos, amusement parks, and airports. Trams typically operate on closed loops or private roadways, but may operate on lower-speed public roads. Trams are typically constructed to reduce weight, and this may affect their durability in harsh operating conditions.

Configuration
Trams can be in the form either of a towing tug pulling passenger trailers, or of a power car with passenger seating, with either closed or open sides. Open-sided trams allow quick and easy boarding, and the most interaction with the environment, but are limited to approximately 20 mph, and also may be weather-limited. Fuel options include electric, gas, diesel, or LPG. Passenger capacity typically ranges from 28 up to 78. Trams are modular and seating capacity can be added or removed depending on demand.

Cost
The cost of a tram is dependent on the design, fuel type, and number of modules. These typically offer a cost-effective means of moving people at lower speeds over shorter distances.

Specialty/Cutaway

Description

Cutaway vehicles are built on standard platforms, such as a 1-ton truck or a medium-duty chassis, and are customized for a specific use. These vehicles do not typically require that operators have a CDL (commercial driver's license). The operation and servicing of these vehicles is simpler than for larger transit buses. They are often used for extended travelor as shuttles.

Configuration

Cutaways can be designed with accessible seating options or luggage racks. Larger cutaway vehicles can hold over two-dozen passengers. Seats are often high-backed, and vehicles are not designed to allow standees. Fuel options are the same as those available on the base platform and include gasoline, diesel, and CNG. Some manufacturers are now offering low-floor options. These vehicles may be equipped with amenities similar to those on an intercity bus, particularly on larger vehicles. Some specialty vehicles are designed as large limousines.

Cost

The cost of the vehicle depends on the size, customization, and fuel type, and can range from $50,000 to $200,000 or more.

School Bus

Description

A school bus is a medium- or heavy-duty bus. These buses are designed used to transport students; however school buses are used by the military and other organizations to move groups of people. The vehicles typically are spartan and simplified, in design compared to an equivalent length transit bus.

Configuration

Many school buses have a front engine and are built on a standard 1-ton, medium, or heavy-duty chassis. Models are available with either a front engine or rear engine. School buses do not have a middle door, but they do have a rear emergency exit. Forward facing benches replace seats. School buses used to transport pupils are not required to be ADA compatible and, thus, usually do not contain a lift or a designated wheelchair seating area. School buses do have to meet specific Federal Motor Vehicle Safety Standards (FMVSS) safety standards. Lengths vary from 18 to 40 feet, with passenger capacity varying from 14 up to 72. School buses are not designed to allow standees.

Cost

The cost of a school bus depends on its size and configuration. A typical full-size school bus costs between $50,000 and $100,000. The simplified systems on a school bus allow for reduced maintenance compared to a transit bus.

Airport

Description
An airport bus is similar to a 30- to 40-foot transit bus. These buses are typically operated at lower speeds and are intended to move passengers from one boarding location to a single exit location.

Configuration
An airport bus is designed for easy on- and off-loading. They will typically be very low floor, and have several double-wide doors. Limited seating is available to maximize capacity and help manage luggage.

Cost
The cost for an airport bus is comparable to that of a 40-foot transit bus ($250,000 to $500,000).

45- foot Intercity

Description

An intercity bus is a bus having a single front door, luggage and storage compartments, high-backed seats for long distances, and normally a restroom. These buses are designed for high-speed long distance trips. Windows on intercity buses are designed to maximize the external view. Current fuel options are diesel and natural gas.

Configuration

Seating is typically in rows, with 2 seats on each side of a center aisle. The number of rows depends on the size of the seats and the spacing between rows. Overhead storage or bins are typically present. Overhead, individually controlled vents and reading lights, similar to those in airplanes, are often present. Tray tables and video monitors are also available options. The buses have a turning radius between 40-47 feet.

Purpose-Built Specialty Vehicles

Description
A wide range of purpose-built specialty vehicles exists. These vehicles may be similar to conventional vehicles, or have unique platforms. These vehicles are designed to be used in a specific application, and may have increased functionality in one area but be limited in other areas.

Configuration
The configuration of purpose-built vehicles varies significantly. They may use any of the technologies or configurations described in this section, and vary in length from 22 to 45 feet or more.

Cost
The cost of the vehicle depends on size, configuration, and technologies used. Because the total production may be limited, and the vehicle will have to be designed and tested as a unique platform, there may be a price premium.

Passenger Van

<u>Description</u>
A passenger van is a 12- to15-passenger vehicle built on a standard ½-1 ton light-duty truck platform. Several auto manufacturers offer these vehicles. They offer significant parts compatibility with other cars and light-duty trucks, and are easy to operate.

<u>Configuration</u>
These vehicles are available with many stock configurations, and can also be modified or built with special options. Seating can also be removed to accommodate cargo or work equipment. Current fuel options are gasoline and CNG. The passenger van requires a lift to meet ADA requirements.

<u>Cost</u>
These vehicles offer a cost-effective means of transporting small groups. The average cost of a van is about $25,000-$35,000, but may vary depending on the level of options used. Regular oil changes every 3000-5000 miles and scheduled maintenance must be performed. These vehicles typically get about 12-15 mpg. For fleets operating a small number of these vehicles, service can be contracted out easily to a dealership or garage.

Low Speed Vehicles

Description

Low speed vehicles are a class of small vehicles that are speed limited to 25 mph. This category encompasses a variety of passenger and specialty work vehicles. These vehicles are not permitted to operate on high-speed roads and are not required to meet the FMVSS and other safety standards and regulations.

Configuration

The vehicles typically hold one or two occupants but may hold 4 or more. Common platforms may be configured differently to hold various numbers of passengers and types of cargo, and perform many work functions. Low speed vehicles often have open sides, but could be equipped with light doors. These vehicles have proven to be a strong niche market for battery electric propulsion but are also available with gasoline engines. Hybrid configurations may also be available.

Cost

The cost of the vehicle will vary depending on its actual model and configuration. These typically provide a more economical vehicle for many local transportation and utility work functions. Cost varies from $2,000 to $10,000 dollars andabove.

Personal Mobility Vehicles

Description

Personal mobility vehicles encompass a wide range of vehicles that are user operated. They include bicycles, scooters, and other similar vehicles. These vehicles offer the flexibility to users to travel at their own pace. Park visitors may be able to bring these vehicles in on their own, or rent or borrow them on-site.

Configuration

The vehicles typically hold one or two passengers. Propulsion can be human powered, electric, or small gasoline engine. These vehicles usually have two wheels and are exposed to the elements.

Cost

Depending on they exact type of vehicle, the cost can vary from one hundred to a few thousand dollars. Maintenance, as well as fuel or electricity charges are usually minimal.

Fuel and Propulsion Systems

Within the U.S., several fuel and propulsion technologies exist. The number of vehicles and manufacturers for each type of fuel or propulsion technology varies significantly, as does the level of maturity of each fuel or propulsion technology. Alternative fuel and propulsion systems, primarily compressed natural gas, currently account for about 30% of the transit vehicles being built.

When evaluating candidate fuel and propulsion technologies, one must understand the vehicle requirements, which include the necessary power, range, configuration, performance and reliability, as well as the cost, and desired environmental impact. These factors must be weighed and compared to the individual qualities of each technology, and the relative importance of each goal. The suitability of each fuel must also be evaluated in relation to the existing conditions within each national park. Moreover, the federal government, along with certain states, offers financial subsidies for certain fuel or propulsion technologies as well as money for public awareness and advertising. General properties and factors of fuel and propulsion systems that should be evaluated are outlined in this section.

Conventional Fuels

Diesel

Background

Diesel is the dominant transportation fuel for medium- and heavy-duty vehicles and is used in some light-duty applications. Diesel is a liquid fuel that is used in compression ignition engines (CI) and may also be used in turbines. The common form is #2 diesel, which may be blended with #1 diesel (kerosene) for cold weather operation. Diesel engine technology is very mature.

New U.S. Environmental Protection Agency (EPA) regulations limiting the sulfur content in diesel fuel to a maximum of 15-ppm (parts per million), will go into effect in 2006 (or earlier in states, such as California, due to state requirements) and will have an overall effect on diesel fuel properties. The new 15-ppm sulfur diesel will have a dramatically reduced lubricity, and will require the addition of an additive to insure proper operation.

Availability

Diesel fuel is widely available throughout America. Diesel fueling infrastructure is available at most fleet maintenance facilities, some local service stations, and many service stations and truck stops located throughout the Interstate highway system. Low (30 ppm) and ultra-low (15 ppm) sulfur diesel is not universally available yet, but production is increasing. The long-term availability (beyond 15 years) of the fuel is somewhat uncertain as a result of dependence on imports to guarantee supply, and an increasing worldwide demand.

Cost

The cost of diesel depends on the manner in which it is purchased. Negotiated long-term, bulk fuel procurements for fleets may be as low as $0.70/ gallon (conventional diesel). Local availability and pricing fluctuates but is currently about $1.25/gallon (conventional diesel). The price for ultra-low sulfur diesel is expected to add an additional 5-15 cents per gallon over conventional diesel costs as a result of additional refining. Lubricity additives may also increase costs.

Environmental impact

The environmental and health impacts of using diesel is a concern for the EPA and other regulatory agencies, as well as the public. However, recent studies have raised questions over the actual severity and health impact of diesel emissions. New "clean diesel" technologies that involve catalytic and/or particulate filters, exhaust gas recirculation, and other advances do help to reduce particulate matter (PM), oxides of Nitrogen (NOx), and other emissions -- lowering diesel emissions to levels comparable to some alternative fuels, but these technologies do not eliminate emissions. Known environmental impacts of diesel fuel include that it will contaminate soil and ground water if spilled, and the California Air Resources Board (CARB) classifies some diesel emissions as carcinogens. The current best available diesel-based engine technology meets the 2004 EPA mandates, and further advances to reduce NOx are anticipated to allow diesel engines to meet the EPA 2007 requirements.

Gasoline

Description

Gasoline has been the dominant fuel for use in light-duty applications for almost a century. The fuel is a high-octane liquid fuel that is used in spark ignition (SI) engines or turbines. It is available in multiple grades determined by its octane rating.

Availability

Gasoline is widely available in the United States, and extensive fueling infrastructure exists throughout the country. Formulation of the fuel may vary depending on region to meet local air quality demands. The long-term availability(greater than 15 years) of the fuel is somewhat uncertain as a result of dependence on imports to guarantee supply, and an increasing worldwide demand.

Cost

The cost of gasoline varies from region to region, and also fluctuates over time. Current prices range from $1.25-$2.00 for a gallon of mid-grade gasoline. Long-term, bulk fuel purchase options are available. The fueling infrastructure and maintenance facilities are the benchmark for light-duty vehicles.

Environmental Impact

Gasoline emissions include Carbon Monoxide (CO) and Carbon Dioxide (CO_2), unburned hydrocarbons, NOx, and other regulated and unregulated emissions. Today, vehicles must meet increasingly strict EPA regulations, and are significantly "cleaner" than the vehicles of 10 years ago. However, gasoline-powered internal combustion engines are still a major contributor to urban air-quality non-attainment. The fuel will contaminate soil and groundwater if spilled.

Alternative Fuels and Propulsion Systems

Biodiesel[2]

Background

Biodiesel is the name of a cleaner burning alternative fuel produced from domestic, renewable resources like soybean oil or recycled restaurant grease. It can be used in compression-ignition (diesel) engines with few or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. More than 100 major fleets currently use some form of the fuel, including Cincinnati Metro city buses, the U.S. Postal Service in Manhattan, the City of Philadelphia, the Missouri Department of Transportation, Yellowstone National Park, and several school districts.

Although biodiesel contains no petroleum, it can be blended in any proportion with petroleum diesel. B20 (20 percent biodiesel/80 percent petroleum diesel) is the most common blend, and has demonstrated significant environmental benefits with a minimum increase in cost for fleet operations and other consumers. When reviewing the high costs associated with other alternative fuel systems, many fleet managers have determined biodiesel is their least-cost strategy to comply with state and federal regulations.

Biodiesel is registered as a fuel and fuel additive with the EPA, and meets clean diesel standards established by the CARB. The Department of Energy (DOE) and the U.S. Department of Transportation (DOT) have designated biodiesel as an alternative fuel. The national fuel specification number issued by the American Society for Testing and Materials (ASTM) is D-6751. Consumers should purchase only biodiesel that meets this standard.

Availability

Biodiesel can be made available anywhere in the United States. There are biodiesel suppliers registered with the EPA throughout the nation. The fuel is delivered in the same manner as conventional diesel.

Infrastructure

In general, the standard storage and handling procedures used for petroleum diesel can be used for biodiesel. The fuel should be stored in a clean, dry, dark environment and used within 12 months. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, and Teflon. Copper, brass, lead, tin, and zinc should be avoided.

[2] Input from the National Biodiesel Board

There may be some minor increases in maintenance costs upon initial use of biodiesel. Biodiesel has a solvent effect that may release deposits accumulated on tank walls and pipes from previous diesel fuel. The release of deposits may clog filters initially, and therefore, precautions should be taken. In addition, the fuel is not compatible with natural rubber hoses and gaskets found in pre-1993 vehicles. Biodiesel will congeal in very cold temperatures, just as the common No. 2 diesel. Blends of 20% biodiesel are managed with the same cold weather fuel management techniques as No. 2 diesel. Some of these options are:

- Blending with kerosene
- Using an additive that enhances cold flow properties
- Using fuel tank, fuel filter, or fuel line heaters
- Storing the vehicles in or near a building when not in use

Biodiesel's superior lubricity provides a solution to a widely held concern about low-sulfur diesel's lack of lubricity. Tests show blending just one percent biodiesel into petroleum diesel can counteract this effect by increasing lubricity by up to 65 percent. Biodiesel is a fuel and can be blended with petroleum diesel at any level, so unlike other lubricity additives, an accidental increase of biodiesel would not be a cause for concern.

Cost

The current selling price for B100 is between $1.25-$1.75 per gallon. B20 blends vary from $0.05-$0.15 more per gallon compared to conventional diesel fuel. The National Biodiesel Board (NBB) maintains a list of registered fuel marketers.

Environmental Impact

Biodiesel is the only alternative fuel to have completed fully the health-effects testing requirements of the Clean Air Act. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to petroleum diesel. A 1998 biodiesel lifecycle study, jointly sponsored by the U.S. DOE and the U.S. Department of Agriculture, concluded biodiesel reduces net carbon dioxide emissions by 78 percent compared to petroleum diesel. The use biodiesel in diesel engines raises the exhaust temperature. This may increase engine NOx emissions, but also may be beneficial to some of the new catalytic / regenerative emissions technologies that require a high exhaust temperature.

Battery Electric[3]

Description

Electricity is not a fuel but rather stored energy. Electricity must be stored or generated on-board. Most electric vehicles (EVs) currently have a smaller driving range than comparable conventional fueled vehicles, resulting from the limited energy-storage capacity on-board. Small vehicles have proven most suited to using this energy source. Some amenities, such as air conditioning, are either non-existent or function differently or in a very limited capacity in most battery electric vehicles.

Availability

Electricity is almost universally available throughout the United States. The availability of electricity in a given locale depends on the power distribution infrastructure on-site. This can usually be matched to the needs of the fleet. Depending on the type of charging (slow vs. rapid, number and type of vehicles or energy storage devices, etc.), the current and voltage required for a charging facility will vary, as will the availability of a given type of charger. Only a limited number of electric vehicle manufacturers exist, but the vehicles are available.

Infrastructure

There is limited electric vehicle (EV) charging and maintenance infrastructure in the United States. For most light-duty vehicles, a relatively small off-board charger that plugs into a standard 110-volt outlet is all that is required. Heavy-duty vehicles require larger chargers. Some bus fleets will utilize multiple battery packs for a single vehicle in order to extend the daily range of the bus, and to prolong the battery life. The maintenance facility will require additional battery charging and storage space. Several different charging schemes exist. These include slow charging, rapid charging, charge equalization, and opportunity charging. Most batteries can accommodate a rapid charge between 20-80% state of charge (SOC). Rapid charging outside this SOC can damage or shorten the life of the battery. Slow charging at any SOC is considered safe for the battery. Charge equalization is conducted when the battery is at or near 100 percent SOC, and is conducted to maintain battery performance and prolong the life of the battery pack. Equalization charging is done with a slow trickle charge over several hours. Opportunity charging is conducted during short breaks in the use of the vehicle, and can be done with either an on-board or an off-board charger. It does not typically return the battery to a full SOC. Maintenance infrastructure should have the proper diagnostic equipment and tools required for EV.

Safety considerations focus on high voltage safety. Depending on the type of battery used, hydrogen can be generated during recharging – resulting in a fire / explosion risk if not ventilated. Batteries with a liquid electrolyte also require the use of appropriate safety precautions.

[3] Input from the Electric Transit Vehicle Institute

Cost

Electric charging and maintenance facilities vary in cost depending on the type of charging conducted, number of vehicles and batteries charged, and the cost of electricity. Off-peak/overnight charging can take advantage of low rates. The cost of a single-port slow charger is $5,000 to $15,000. The cost of a high-voltage rapid charger is $30,000 to $60,000. In most cases, the greatest cost of converting an existing infrastructure is the change in service equipment, but few facility modifications are needed for safety. The cost of a vehicle also varies depending on the type of on-board energy storage that is used. Battery packs can cost anywhere from $1,000 for a small lead-acid pack to upwards of $100,000 for a large lithium solid-polymer electrolyte pack or supercapacitor. The electric propulsion and control system also varies depending on the complexity of the system. The incremental cost for a light-duty vehicle is typically $5,000-$10,000. The incremental costs for a medium- to heavy-duty bus or vehicle are typically $150,000 to $175,000. Maintenance personnel and drivers will require proper training for safety and optimal vehicle operation.

Environmental Impact

Electric vehicles are designated as zero-emission vehicles. In colder climate regions, a fuel-fired heating source is sometimes added to the vehicle. The zero tailpipe emissions may have significant benefits for local air quality. The total environmental impact of an EV requires a well-to-wheels and life-cycle analysis. Emissions are displaced to the power plant, and the overall well-to-wheels vehicle efficiency may be less than that of other vehicles. Proper battery disposal is important to insure that lead or other contaminants do not enter the environment.

Ethanol[4]

Description

Ethanol is a renewable, domestically produced resource derived primarily from corn (although ethanol can be produced from any resource containing starch, sugar or cellulosic material). The fuel can be blended with gasoline, diesel or used as pure fuel. Ethanol has a lower energy density that gasoline or diesel, but can achieve comparable range with a larger fuel tank. The common form of the fuel is E85, an 85% blend with 15% gasoline. E95, a 95% ethanol 5% diesel blend can be used as a diesel replacement. Ethanol is also used as an additive to gasoline (approx 10%) and is being tested as an additive to diesel.

Availability

E85 refueling stations are located primarily in the Midwest where a majority of the fuel production is located. Nearly 150 stations are now operating in more than 20 states in the Midwest and Rocky Mountains. Many other stations use ethanol as an additive. New stations continue to open. The fuel is delivered in the same manner as gasoline or diesel.

Infrastructure

Infrastructure for ethanol is similar to that for gasoline or diesel. Safety is also similar, except that an ethanol flame is nearly invisible.

Cost

E85 is sold in the Midwest at prices equivalent to those for mid-grade unleaded gasoline. This is achieved with extensive government subsidies (tax breaks and tax incentives) that may disappear. With mass production of some E85 compatible vehicles, OEMs can offer these vehicles at the same prices as comparable gasoline vehicles. In heavy vehicle applications, E95 has a difficult time competing with low diesel prices. The lower energy content of ethanol versus gasoline or diesel means that additional quantities of fuel must be purchased to travel an equivalent range. The cost of establishing an E85 refueling pump is similar to the cost of installing a gasoline pump. The cost of maintaining and servicing an E85 station would be similar to maintaining a gasoline station, and no additional equipment or modifications are required. Most transit agencies and fleet operators have experienced increased maintenance costs when using an ethanol fuel.

Environmental Impact

Vehicles running on E85 have significantly lower tailpipe emissions than identical vehicles running on gasoline. E85 has high oxygen content, making it burn cleaner than gasoline. E85 also reduces greenhouse gas emissions such as carbon dioxide as much as 39 to 46 percent compared to gasoline. The impact on soil and water if E85 spilled would be negligible, though care would still have to be taken due to the flammability of the product. Since E85's main ingredient is ethanol, which is non-toxic, water soluble and

[4] Input from the American Ethanol Coalition

biodegradable, the only negative environmental impact would come from the portion of the E85 that is gasoline.

Hybrid-Electric[5]

Description

Hybrid-electric is a growing propulsion system that combines on-board electric storage with an on-board power unit that may be fueled from any of the conventional or alternative fuels. When compared to a conventional vehicle, hybrid vehicles offer improved vehicle and emissions performance and reduced fuel use, while still offering extended vehicle range. Hybrids can exist in several configurations that can be tailored or optimized for a given use. On-board power is typically generated from an internal combustion engine (reciprocating or microturbine); fuel cells are another on-board power option. Depending on the configuration, hybrids can offer equivalent range with only a slight degradation in vehicle performance compared to equivalent conventional vehicles.

Availability

Hybrid propulsion can be available anywhere the on-board fuel infrastructure is available. By 2004, major auto manufacturers are expected to offer hybrid vehicles, and the number of medium- and heavy-duty bus and vehicle models, though currently limited, appears to be increasing steadily.

Infrastructure

The infrastructure for a hybrid electric is a combination of that of a battery electric vehicle and of the on-board fuel used for the non-electric portion of the hybrid vehicle. Depending on the configuration, a fleet of hybrid electric vehicles may require less battery charging infrastructure to maintain performance than pure battery electric vehicles. Charge equalization on a regular basis is still required to maintain battery pack performance and life. This can be accomplished via an on-board battery management system or via connection to the electrical grid depending on the system requirements.

Cost

Hybrid maintenance and fueling infrastructure facilities vary in cost depending on the configuration and type of fuel used. The incremental cost of a light-duty vehicle is about \$2,000 to \$5,000. Medium- and heavy-duty bus and vehicle incremental costs vary from \$2,000 to \$200,000. Costs may be recovered through fuel savings. Long-term maintenance costs have yet to be determined. Early models have required additional maintenance compared to equivalent conventional vehicles. Engine maintenance cost is lower, but battery replacement costs may offset these savings. Proper training is required for maintenance personnel.

Environmental impact

Hybrid electric vehicles offer significant savings in fuel use and upwards of 90 percent reduction in certain emissions, depending on the configuration and fuel used. These

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[5] Input from the Electric Transit Vehicle Institute

environmental benefits are derived from the reduction in engine load and transients. The environmental concerns for the given fuel used are still relevant although the impact is likely reduced.

Hydrogen[6]

Description

Hydrogen is one of the most common elements found on earth and in the atmosphere. Because hydrogen is chemically bound, it must be freed in order to be used as a fuel. Hydrogen is used extensively and safely by the food and chemical industry, but a high level of purity (99.999 percent) is necessary for use as a fuel in many fuel cell (FC) applications, and this level requires additional or different processing. Some manufacturers are also promoting the use of hydrogen for use in an internal combustion engine. Hydrogen is a domestic fuel/energy source, and can be produced using renewable energy, or derived from hydrogen-rich feedstocks, including fossil fuels. The energy density (hence the size of associated fuel storage and vehicle fuel tanks) varies depending on the form in which it is stored. Hydrogen has a lower energy density than natural gas and conventional liquid fuels. Range is achieved in most cases through the use of large fuel storage capacities. However, this adds weight, and/or reduces cargo or passenger capacity.

Availability

Hydrogen can be produced or delivered anywhere. Hydrogen is produced by several methods. These include electrolysis of water, reforming of a hydrocarbon (most commonly natural gas or methanol), or catalysis from a hydrate. Currently, no national hydrogen infrastructure exists. Hydrogen can be delivered on-site as either a cryogenic liquid (LH_2) or a compressed gas (CH_2) form. LH_2 may be used as a feedstock for CH_2. Hydrogen may also be produced on-site by either reformation or electrolysis, and subsequently stored. The suitability and/or availability of each production and delivery method vary from location to location, but the fuel quality should remain constant. Hydrogen thus provides the flexibility to take advantage of regional infrastructure and feedstock resources. Vehicles that use hydrogen are currently available only as prototypes. Some bus and automobile manufacturers plan to produce hydrogen-fueled vehicles in limited quantities within the next few years.

Infrastructure

Currently, limited refueling infrastructure exists nationally. Fleets operate almost all fueling stations that do exist. By design, hydrogen clusters, through fleet use, can expand to hydrogen corridors between fleets to remain on pace with demand. Those considering hydrogen vehicles need to review the fueling options, which range from individual low-cost at-home “vehicle fueling appliances” to the construction of large new fast-fill facilities. If a fleet does not want to pay the capital costs of a new station, it may be able to share facilities with another neighboring fleet, or work with a fueling station provider who will assume the capital costs in exchange for an agreement to buy a specified

[6] Input from the National Hydrogen Association

amount of fuel at an agreed-upon cost. The U.S. Government is debating tax incentives for infrastructure development. The type of infrastructure that is needed depends on the manner in which the fuel is delivered, stored, and produced. Fast fill times for hydrogen vehicles are comparable to those of natural gas and conventional liquid fuels. To assure safe design and operation, CH_2 and LH_2 vehicle fueling and repair facilities must take into account the differences in the characteristics of gaseous and conventional liquid fuels. Several codes and standards currently exist or are in development that cover hydrogen infrastructure and vehicles. When the codes, standards, and best practices are followed, hydrogen is as safe as a conventional fuel. If the fuel is reformed on-site, then the appropriate infrastructure for the hydrocarbon feedstock must also be present. If the hydrogen is stored in a stable liquid such as sodium borohydrate solution, then the maintenance infrastructure is greatly simplified. Spent-fuel storage or a means to recondition the fuel will be necessary.

Cost

As with any emerging technology, hydrogen fueling stations can vary significantly in cost. These costs depend on the means in which the fuel is delivered or produced, and the volume and rate of fill. Electrolysis is highly dependent on electricity rates. Other production means depend on the cost of the hydrocarbon feedstock. A "vehicle refueling appliance" to refill a CH_2 car or light truck at a home or business overnight will likely cost around $7,000. Slow-fill facilities for fleets (such as school bus fleets, which can fill overnight) are also relatively inexpensive. Full-blown compressor stations for fast-fill fleet use can cost from $400,000 up, as can LH_2 fueling stations. Bus depots can cost several million to convert existing infrastructure or build from the ground up. Current hydrogen vehicles are limited production prototypes. Fuel cell buses, expected to be in production within the next couple of years, are estimated to cost upwards of $1,500,000 to $3,000,000. Automobiles are not expected to be commercially available, except in limited quantities as development and test models, until the end of this decade. Federal and other incentives can help defray some of the increase in vehicle acquisition costs. Technicians must also be trained to maintain and repair hydrogen/ fuel cell vehicles properly. No data exists on long-term maintenance costs for these vehicles. Since fuel cells have no moving parts and do not require oil, maintenance costs are likely to be less than current costs, once the technology is proven and has become mainstream.

Environmental Impact.

The environmental impact from hydrogen-fueled vehicles varies. If hydrogen is stored on board, then the only measurable emission is water vapor (assuming a FUEL CELL). If hydrogen is burned in an ICE, then small amounts of NO_x and other combustion reaction products may be emitted. If on-board reforming is performed, then CO_2 and trace other emissions will exist. If off-board reforming is performed, then CO_2 and trace other emissions will exist at the reformation site from the fossil fuel being reformed. For hydrogen that is produced by electricity, the emissions are those belonging to the power plant. However, the ability for the vehicle to have zero or minimal tailpipe emissions is important, and may help meet local air quality mandates or goals and act as a driver to build the hydrogen infrastructure necessary to make the transition to renewable energy-produced hydrogen. Unless a liquid hydrocarbon is used for reformation, hydrogen and its feedstock will not contaminate soil or groundwater if spilled or released.

Liquefied Petroleum Gas (Propane)[7]

Description

Liquefied Petroleum Gas (LPG), consisting primarily of propane and butane, is a plentiful domestic and North American energy source, and has been used as a vehicular fuel since the 1920s. LPG for use as an alternative transportation fuel is typically a mixture of at least 90 percent propane, 2.5 percent butane and higher hydrocarbons, and a balance of ethane and propylene. The terms "LPG" and "propane" are used interchangeably. A special blend of propane called HD-5 has been developed for vehicular use. ("HD" stands for heavy duty and the "5" represents the maximum allowable percentage of propylene content.) HD-5 propane is distinguished from the "commercial" propane blend used for residential, commercial, and industrial heating purposes; in reality, however, most commercial propane in the U.S. meets the HD-5 specification and has been found to be a satisfactory vehicular fuel.

Propane has a higher octane rating than gasoline but less energy content, getting about 12-15 percent fewer miles per gallon. Compared with other alternative fuels, however, propane has high energy content in terms of BTU (British Thermal Unit) per gallon. This makes it preferable to other fuels as an alternative to diesel. It is stored as a liquid at pressures in the range of 125-175 psi. When released from pressure, it expands and enters the engine compartment as a vapor. This characteristic greatly improves its energy density.

Availability

Propane has an extensive and widespread infrastructure located throughout the United States. Out of a total of 5,540 alternative - refueling stations listed by the U.S. Dept. of Energy's Alternative Fuels Data Center (as of March 4, 2002), there are 3,417 LPG sites, the most for any of the alternative fuels. However, there are still relatively few propane dispensers at highway service stations. Most of the propane refueling sites are retail propane facilities that provide propane for a variety of purposes. These are typically located away from interstate highways and are open to the public only during normal business hours. Thus, most fleet users have installed their own storage tanks, meters, and dispensers on site. Propane is delivered to the site by bulk delivery truck, just like gasoline and diesel.

Cost

Propane offers the potential for significant cost savings and price stability. A typical refueling facility, including storage tanks, pumps, meters, and dispensers, will cost about $30,000 per site. Most propane-powered vehicles are produced through a conversion kit. Although conversions are still being done, the implementation by the U.S. Environmental Protection Agency of a more stringent addendum to its Memorandum 1A regarding the

[7] Input from the National Petroleum Gas Association

certification of conversion kits has limited the number of propane conversion kits certified for use, and decreased the number of propane conversions being done. This may cause a slight cost increase. The gge for propane is approximately $0.40-cent less. A light-duty vehicle driven 10,000-15,000 miles per year will realize annual savings of about $300-$500. A typical medium- or heavy-duty vehicle will realize a reduced diesel gallon equivalent (dge) cost savings, but potentially greater cost savings based on the fuel cost. Because propane enters the engine as a vapor, it leaves no sludge or carbon buildup, and there is little oil contamination. These factors greatly ease the demand for maintenance and extend the engine's tune-up and oil change intervals.

Environmental impact

The emissions of hydrocarbons, carbon monoxide, and nitrogen oxide from a properly tuned propane engine are well within EPA standards, and may offer some improvements over conventional fuels in that the fuel does not require venting from the cylinder. In the event of spillage or leakage, propane will not contaminate soil or ground or surface waters. The fire and explosion risk associated with propane is higher than for other fuels, and extra care must be taken to prevent or manage leaks.

Methanol[8]

Description

Methanol is a domestically produced fuel and is readily available in the Western hemisphere. The fuel was used as a feedstock for MTBE, as an oxygenate for gasoline, and as M85, an 85 percent blend with gasoline that has been used as a fuel for internal combustion engines. Currently methanol is used as M100 (pure methanol) as a fuel for on-board reforming for fuel cells. Methanol is primarily produced from methane (although it can be made from coal and renewable feedstocks including wood, sewage, and agricultural products). Methanol offers significantly higher fuel energy density than pure hydrogen stored on-board. Since storage volume of the fuel is reasonable, methanol fuel cell vehicles can meet the range requirements of most identified drive cycles.

Availability

The fuel can be made widely available and is stored at atmospheric pressure and temperature. Distribution is the same as gasoline and diesel. Currently, only a limited fueling infrastructure exists at a few fleet facilities, although construction costs of a methanol fueling station are relatively modest (under $100,000 per station). The long-term availability of methanol is limited only by the supply of NG, coal, or renewable feedstocks.

Infrastructure

Infrastructure for methanol is similar to that for gasoline or diesel. The materials, hoses, and gaskets must be checked for materials compatibility. Special fire precautions must be taken because a methanol flame is virtually invisible.

Cost

Methanol powered fuel cell vehicles are still considered prototypes, and the technology is undergoing rapid development to reduce cost. Current fuel cell power plants may cost $10,000 to $200,000 and upwards. Cost targets are to produce a fuel cell that is competitive with an ICE. Long-term maintenance cost for a methanol fuel cell vehicle may be less than those of a comparable ICE vehicle once the technology reaches maturity (10-20+ years). At this time, reliable long-term maintenance costs are not known. Infrastructure costs for methanol are similar to those of gasoline or diesel. On-board storage of methanol is relatively cheap compared to most forms of on-board hydrogen storage, but this may be offset by the additional cost of the methanol fuel processor.

Environmental impact

Methanol is slightly more toxic than gasoline to humans and animals. Methanol is soluble in water, and spills can temporarily contaminate the groundwater. Methanol is rapidly degraded by the environment and its impact to water and soil is limited to the initial exposure area, where concentrations may be high. When used as a fuel in fuel cells, the emissions are primarily limited to CO_2 and water, with trace amounts of CO and non-

[8] Input from the Methanol Institute

methane hydrocarbons. The CO_2 emissions from methanol fuel cells are about half those of gasoline internal combustion engines.

Natural Gas[9]

Description

Natural gas is a plentiful domestic and North American energy source consisting primarily of methane (CH_4). When used as a transportation fuel, natural gas must be at least 88 percent methane, with the balance being higher weight hydrocarbons. Natural gas has a lower energy density than conventional fuels, but achieves comparable range in most vehicles with large fuel storage devices. However, these add weight and reduce cargo or passenger capacity. Some transportation and energy experts consider natural gas to be a renewable resource because of its domestic abundance. About 25 percent of all transit buses currently produced in the United States use natural gas.

Availability

Natural gas is distributed throughout the United States in extensive pipeline systems that extend from the wellhead to the end user. Every continental state has access to natural gas through pipelines. The pipeline system consists of long-distance transmission systems, followed by local distribution systems. Some underground storage is also used to help supply seasonal peak needs. Natural gas fueling stations are located primarily where fleets exist. Compressed Natural Gas (CNG) is the dominant form of the fuel used. Most manufacturers now use 3600 psi storage. Liquefied Natural Gas (LNG) is less common. Public LNG stations are limited. LNG is used directly in some applications, and is sometimes used as a feedstock for CNG. In some regions the purity of the pipeline fuel may drop below 88 percent methane, and a transit operator should check to insure its quality.

Infrastructure

There are almost 1,300 CNG fueling stations in the U.S., but many were built for and are used only by individual fleets. Those considering CNG vehicles need to review the fueling options, which range from the use of individual low-cost at-home “vehicle fueling appliances” to the construction of large new fast-fill facilities. If a fleet does not want to pay the capital costs of a new station, it may be able to share facilities with another neighboring fleet or work with a fueling station provider who will assume the capital costs in exchange for an agreement to buy a specified amount of fuel at an agreed-upon cost. CNG stations normally work with gas delivered by the local utility and compressed and stored at the station.

The few LNG stations that exist are generally for fleet use. LNG is normally trucked to the fueling station from a major LNG plant, but small-scale liquefaction facilities may soon become more available. CNG and LNG vehicles can be fueled as quickly as gasoline and diesel (except for “slow fill” CNG systems). To assure safe design and operation, CNG and LNG vehicle fueling and repair facilities must take into account the

[9] Input from the Natural Gas Vehicle Coalition

differences between gaseous and conventional liquid fuels. Several codes and standards govern natural gas infrastructure and vehicles. When these codes, standards, and "best practices" are followed, natural gas is as safe as a conventional fuel.

Cost

CNG fueling stations vary in cost. A "vehicle refueling appliance" to refill a CNG car or light truck at home overnight costs around $4,000, with less expensive models soon to be available. Slow-fill facilities for fleets such as school bus fleets that can fill overnight are also relatively inexpensive. Full-blown compressor stations for fast-fill fleets use can cost $300,000 and greater, as can LNG fueling stations. Bus depots can cost several million to convert existing infrastructure or build from the ground up. Costs vary significantly depending on the existing facility and other infrastructure requirements, but can cost several million dollars. However, some CNG or LNG fueling station suppliers are also willing to install stations for zero capital cost, if the fleet agrees to use a specified amount of fuel at an agreed-upon price. Drivers or maintenance personal can easily be trained to refuel CNG vehicles; LNG refueling requires somewhat more training. Fuel cost is generally substantially less than that of gasoline or diesel per gallon equivalent, although local utility rates vary. Fixed-rate long-term negotiated procurements are available. The incremental cost premium for CNG or LNG heavy-duty trucks and transit buses is in the range of $30,000 to $40,000; the cost premium for a car or light truck is around $2,000. Federal and other incentives can help defray some of the increase in vehicle acquisition costs.

Fleets should be aware that changes may need to be made to maintenance and fueling facilities to take into account the safety requirements of gaseous versus liquid fuels. Technicians must also be trained to maintain and repair natural gas vehicles properly. Maintenance costs for CNG vehicles vary depending on the operator, but those properties that have a strong commitment to the fuel have experienced maintenance costs that are equal to or less than those of a conventional diesel vehicle.

Environmental Impact.

Natural gas vehicles emit fewer overall regulated emissions than equivalent pre-EPA 2004 certified diesel or gasoline counterparts, particularly with respect to particulate matter. There is ongoing debate as to the environmental and health effects of natural gas emissions from internal combustion engines, particularly with respect to ultra-fine particulate matter. New emissions-control technology may need to be developed to insure that the natural gas fuel meets the ever-increasing restrictions on vehicle emissions. Methane is an unregulated greenhouse gas, but is about 20 times as potent as CO_2 in its Ozone depleting effect. This is a concern for users of LNG, which experiences constant volatilization of the fuel that must subsequently be vented if it is not used. And natural gas, a leading candidate for off-board reforming of hydrogen for fuel cells, has potential for generating emissions from the reforming process but these generally are limited to CO_2. Unlike liquid fuels, natural gas will not contaminate soil or groundwater if spilled or released.

Other Fuel Alternatives

Bi-Fuel

Bi-fuel engines are available that use diesel and natural gas. These engines are available for medium- and heavy-duty applications. There are two competing approaches. One uses a constant amount of diesel to ignite the fuel in the cylinder, and injects additional natural into the cylinder to increase power. The other approach uses a constant ratio of diesel to natural gas. Both attempt to capture the robustness and power of diesel while improving on diesel's emissions by using a domestic fuel (natural gas). The technology requires that both fuels be stored on-board, and that the proper infrastructure (fueling, safety, maintenance, etc.) for both fuels is available.

Dual-fuel

Some vehicles are equipped with both a conventional fuel tank and an alternate fuel storage system (usually natural gas). In operations where the alternative fuel is not readily available, the vehicle is run on conventional fuel. The motor is tuned to operate satisfactorily on both fuels. The U.S. Postal Service operates several thousand dual fuel (gasoline/CNG) mail delivery trucks.

CNG-Hydrogen blend (Hythane)

Hythane, a blend of CNG and hydrogen, has been shown to improve tailpipe emissions by reducing the combustion temperature. The vehicle maintenance and fuel dispensing infrastructure required are virtually the same as for CNG, except that hydrogen may also need to be produced on-site. It is also possible to have pre-mixed hythane fuel delivered on-site or alternatively have natural gas and hydrogen delivered separately on-site, and then subsequently mixed. The fuel is not widely available yet. Some transit properties also view hythane as the first step towards transitioning to a 100 percent hydrogen fleet.

Supplied Electric

Vehicles that use supplied electric are commonly classified as electric trolley buses. The vehicles typically have no on-board electric storage and run off electricity supplied by an overhead catenary system.

Other Factors

In addition to the basic vehicles types and technologies, there are several other factors that should be considered for vehicle procurement.

Buy America

There are sections of federal law (49 CFR 661) that form the basis of the regulations known as the "Buy America" requirements. These regulations are different than the "Buy American" regulations. This section will deal only with the "Buy America" requirements. The purpose of these regulations is to insure that "...no funds may be obligated by the Federal Transit Administration (FTA) for a grantee unless all iron, steel, and manufactured products used on the project are produced in the United States."[10] The regulations (49 CFR Part 661) specifically apply to funds used for capital transit procurements that are funded with money appropriated under 49 U.S.C. Chapter 53. "The Buy America requirements do not apply to the procurement of buses and other rolling stock if the cost of components produced in the United States is more than 60 percent of the cost of all components and final assembly take places in the United States (49 CFR 661.11). Labor costs involved in final assembly shall not be included in calculating component costs. 49 U.S.C. 5323(j)."[11] There are a series of regulations and FTA Administrator "Dear Colleague" letters that provide guidance to agencies using FTA Capital Grant funds.

While these regulations address the situation in which funds are provided through FTA Capital Grants, the law and regulations do not apply if FTA Capital Grant funds are not used. There are several transit agencies, including the New York City Metropolitan Transit Agency (MTA), the largest transit provider in the United States, that do not use FTA Capital Grant funding to procure buses. By choosing not to use FTA Capital Grant monies, these agencies have exempted themselves from the Buy America provisions. Likewise, the National Park Service (NPS) would be exempt from the Buy America regulations if it does not use FTA Capital Grant funds to procure transportation vehicles. There may, on the other hand, be political reasons for the NPS to require that all transportation vehicles purchased meet the Buy America regulations. If the NPS chooses to follow the Buy America regulations, a plan needs to be developed to conduct both pre-award review and post-delivery audit of vehicles that are procured. The Volpe Center can assist the NPS in developing a plan to meet Buy America requirements if one is needed.

Existing fleet compatibility

The existing fleet, which includes transit vehicles and other park maintenance and service vehicles, must also be able to use the fueling and maintenance infrastructure. Space, staff, and financial constraints need to be considered in relation to supporting a limited number of new transit vehicles with a different fuel or propulsion system from the rest of the fleet. It may also be possible to introduce a new, compatible fuel into an existing fleet. The U.S. Department of Energy has identified staff buy-in as critical to the success of any

[10] http:/www.law.du.edu/dempseyweb/transit_law.htm p. 26
[11] ibid. p. 26

alternative fuel fleet. A significant factor in achieving buy-in is the percentage of the total vehicle fleet that is of a given fuel or propulsion type.

Maintenance and Procurement Partnering

In national parks where only a limited number of vehicles are used, or where maintenance and fueling infrastructure are limited or are politically difficult or cost prohibitive, options exist to partner with, or procure these services from, outside organizations. Piggybacking on procurements with other national parks or transit operators who are purchasing identical or nearly identical vehicles may result in simplified procurement procedures, reduced costs, and a greater response on the part of the manufacturers. Contracting for maintenance and fueling outside a national park offers several potential tangible benefits. However, the additional travel time and disconnect from a given operation may have drawbacks.

Intelligent Transportation Systems

Intelligent transportation systems are an important way to enhance park visitor experience and improve ridership. These systems integrate modern communications and tracking systems with visual displays and media. The technologies and their application are covered in detail in Appendix B.

Air quality

U.S. EPA and local or regional air quality mandates may require that the vehicles meet certain emissions requirements, and therefore may require the use of an alternative fuel or propulsion system. Additionally, societal values may dictate the environmental performance of the vehicle.

EPACT

The federal government requires that a percentage of a federal agency's light-duty fleet be alternative fuel vehicles. Current legislation provides that the vehicles can be bi-fuel. Under current EPACT legislation only alternative fuels (Biodiesel, NG, LPG, Ethanol, Methanol, Hydrogen) qualify. An individual park should confer with its chief council to determine how current legislation will affect fleet requirements and purchases.

Appendix A: Comparison Table of Vehicle Types

The table below details four different models of the 40-foot transit style bus.

Fuels	Tank Size (gas or diesel)	Turning radius outside front body corner	Floor	Doors	Windows	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	100 - 200 gallons	40 ft. to 45 ft.	Regular/kneeling	Multiple options.	Multiple options	260 in. to 285 in. avg.	40ft.	96 in. and 102 in.	114 in. to 140 in.	39 to 45 seated	Wheelchair lift

The table below details four different models of the rapid transit articulated bus.

Fuels	Tank Size (gas or diesel)	Turning radius outside front body corner	Floor	Doors	Windows	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	100 - 200 gallons	40 ft. to 45 ft.	Regular/kneeling	Multiple options.	Multiple options	200 in. to 300 in. x 2	60 ft.	102 in.	112 in. to 130 in.	65 seated	Wheelchair lift

The table below details four different models of the 30-foot transit style bus.

Fuels	Tank Size (gas or diesel)	Turning radius	Floor	Doors	Windows	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	60 - 130 gallons	28 ft. to 35 ft.	Regular/kneeling/low floor	Multiple options.	Multiple options	215 in. to 250 in. x 2	30 ft.	96 in. and 102 in.		37 seated optional	Wheelchair lift

The table below details four different models of the sub 30-foot shuttle style bus.

Fuels	Tank Size (gas or diesel)	Turning radius	Floor	Doors	Windows	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	35 - 80 gallons	26 ft. to 36 ft.	Regular/kneeling/low floor	Multiple options.	Multiple options	130 in. to 240 in. x 2	30 ft.	84 in. and 96 in.	112 in. to 122 in.	27 seated optional	Wheelchair lift

The table below details four different models of Trolley Replica style bus.

Fuels	Tank Size (gas or diesel)	Turning radius	Floor	Doors	Windows	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	60 - 90 gallons	28 ft. to 31 ft.	Regular Kneeling	Front and rear	Multiple options	150 in. to 190 in. x 2	28 - 33 ft.	96 to 102 in.	110 in. to 134 in.	30 seated optional	Wheelchair lift

The table below details four different models of Trams.

Fuels	Tank Size (gas or diesel)	Turning radius	Floor	Doors	Range	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	60 - 90 gallons	20 ft. to 31 ft.	Regular Low floor	optional	40 – 70 miles	50 in. to 60 in	20-25 ft. per car	50 to 80 in.	110 in. to 134 in.	80 seated optional	Wheelchair lift

Below are two examples of different school buses.

Fuels	Tank Size (gas or diesel)	Turning radius	Floor	Doors	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	33 - 45 gallons	28 ft. to 31 ft.	Regular	24” x 70” double leaf entry door, positive over center locking door control. 32” x 52” rear emergency door with upper glass and warning buzzer.	139 in. to 280 in.	Up to 40 ft.	82 to 102 in.	100 in. to 120 in.	72 seated optional	Wheelchair lift

The table below details four different models of 45-foot intercity buses.

Fuels	Tank Size (gas or diesel)	Turning radius outside front body corner	Floor	Wheelbase	Exterior lengths	Exterior widths	Exterior heights	Capacity	Optional paratransit
Multiple options	180 - 250 gallons	41 ft. to 47 ft.	Regular Kneeling	300 in. to 340	45 ft.	102 in.	137 in. to 145 in.	57 seated	Wheelchair lift

Door Multiple options include but are not limited to the following:

- Extra wide, inward opening slide-glide front door. Narrow or wide outward-opening rear doors, or extra wide slide-glide rear door. Rear doors glazed top and bottom, or top only. Vapor mechanisms and controls, with driver and/or passenger control features.

Windows

- Bright or black aluminum sash with FMVSS-217 emergency egress capability. Windows openable for ventilation at top only, bottom only, full height, or non-operable. Glass or plastic glazing.

Representative Vehicle Manufacturers

Advanced Vehicle Systems	http://www.avsbus.com
Bluebird	http://blue-bird.com
Champion	http://www.championbus.com
Collins Bus Corporation	http://www.collinsbus.com
Diamond Coach Corporation	http://www.diamondcouch.com
Ebus	http://www.ebus.com/ebus.htm
El Dorado National	http://www.enconline.com/
Federal Coach	http://www.federalcoach.com
Gillig	http://www.gillig.com/
Goshen Coach	http://goshencoach.com
Glavel Bus Inc	http://www.glavelbus.com
New Flyer Industries	http://www.newflyer.com
North American Bus Industries	http://www.nabiusa.com
Nova Bus	http://www.novabus.com
Optima Bus Corp	http://www.optimabus.com
Orion Bus Industries	http://www.orionbus.com/orion
Private Motor Coach Inc	http://www.privatemotorcoach.com
Starcraft	http://www.starcraftcorp.com
Supreme Corporation	http://supremeind.com
Thomas Built Buses	http://www.thomasbus.com
Transbus International Dennis	http://www.dennisbus.com
TransTeq	http://www.transteq.com
Van Hool	http://www.vanhool.com/home.asp
World Trans	http://www.wtrans.com

Appendix B: Intelligent Transportation Systems[12]

The Federal Transit Administration created the Advanced Public Transportation Systems (APTS) program as its part of the U.S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS). The APTS program was established to encourage the use of current and emerging technologies in the fields of electronics, information processing, information displays, computers, and control systems to improve the quality and usefulness of public transportation services. Effectively integrated and deployed, APTS technologies can enhance safety and security, transportation mobility, operational efficiency, and environmental protection. The technologies discussed herein have all been installed by at least some transit agencies and are in full operation at those sites.

The following APTS technologies are discussed:

- Automatic Vehicle Location
- Operations Software
- Mobile Data Terminals
- Silent Alarms/Covert Microphones/Surveillance Cameras
- Automatic Passenger Counters
- Automated Passenger Information
- Vehicle Diagnostics
- Traffic Signal Priority
- Electronic Fare Payment

Although not a technology itself, integration is also discussed since it is a major factor in the successful implementation of APTS and is usually the most difficult implementation issue.

[12] Section provided by Mathew Rabkin, Volpe National Transportation Systems Center, U.S. DOT.

APTS TECHNOLOGIES

The following sections describe the various APTS technologies, their benefits, their level of deployment, and their costs (where available).

Automatic Vehicle Location

Automatic vehicle location (AVL) is a computer-based tracking system. For transit, the actual real-time position of each transit vehicle is calculated and relayed to a control center. The three principal methods of determining vehicle position are: using signals from signposts, dead-reckoning, and using signals from Global Positioning System (GPS) satellites.

In the signpost system, a series of radio beacons or signposts are placed along the routes. A short-range communication device on the vehicle receives the identification signal transmitted by the signpost. Since the location of each signpost is known, the location of the vehicle at the time of passing the signpost is determined. The distance traveled since passing a signpost, as measured by the vehicle odometer, is used to estimate the vehicle position along its route at any given time. However, this method is limited by the fact that signposts are placed at fixed locations. Thus, changes in routes could require the installation of additional signposts. Additionally, the system is incapable of tracking vehicles that stray off-route.

Dead-reckoning is a method of determining vehicle position by measuring the distance traveled from a known location through odometer readings and the direction of travel through compass headings. Because this method of position determination is less precise than the others, GPS or a few strategically placed signposts to recalculate position at certain intervals usually supplement dead-reckoning.

GPS technology uses signals transmitted from a network of satellites in orbit around the earth and received by a GPS antenna placed on the roof of each vehicle. A GPS receiver connected to the antenna calculates position by measuring the antenna's distance (the travel time of radio signals) from at least three satellites. However, there are inaccuracies in the signal due to reflections by the atmosphere or from tall buildings. To correct for these errors, a measured GPS signal offset is used to adjust the calculated position. As a result of this differential correction, many GPS receivers can calculate position to within a few meters. GPS is the method of choice for most new AVL systems.

The two most common methods of transmitting location data to dispatch are through polling and exception reporting via wireless communications. In polling, the computer at dispatch polls each vehicle in turn, asking for its location. Once all the vehicles have been polled, the computer starts again with the first vehicle and repeats the cycle. With exception reporting, each vehicle reports its location to dispatch only at specified intervals or when it is running off-schedule beyond selected tolerances. Exception reporting makes more efficient use of available radio channels, which are often scarce commodities. Many agencies use a combination of polling and exception reporting.

AVL is the basic building block for other transit APTS applications that depend upon knowing the location of vehicles. AVL provides the location data needed for operations software, silent alarms, automatic passenger counters, real-time passenger information, in-vehicle signs and annunciators, and traffic signal priority based on schedule adherence. AVL has provided transit agencies with much more and better data than they could previously afford to collect by manual means. Vehicle location data are used by many transit agency personnel, including dispatchers, vehicle operators, schedulers, planners, maintenance staff, customer information staff, and street supervisors. A major benefit of AVL is the dispatcher's ability to send response personnel quickly to the precise location of an incident or emergency. AVL-equipped buses can also act as probes for the monitoring of traffic flow on freeways and arterials. Another major benefit reported by transit agencies was improved schedule adherence.

Operations Software

Operations software is used to develop and display information for a variety of transit decision-making activities. Software is a key element of APTS installations, and a Geographic Information System (GIS) is a major software component.[13] AVL system software can combine vehicle location data with map data, and display these data on dispatchers' computer monitors together with whatever attributes the transit agency desires (e.g., vehicle status, vehicle operator, schedule adherence, and incident information).

Software programs can assist transit agencies in the performance of a number of functions. Software programs currently support bus dispatchers in making real-time service adjustments (when service begins to deteriorate) and in directing response to vehicle incidents and emergencies. Software programs prioritize calls from vehicle operators for response by the dispatchers, and automatically record and print reports of AVL and various other information desired by the agency. Software can provide the data to coordinate the intra- or inter-modal transfer of passengers from one vehicle to another where services intersect, either through dispatcher involvement or direct vehicle to vehicle contact. Software programs can calculate whether traffic signal priority should be requested based on schedule adherence and, in more advanced concepts, on the bus (note: is this "busload factor" or "bus's load factor" or "buses' load factor?")load factor (if real-time information is available from an automatic passenger counter). Programs can assemble and analyze data from different sources to provide assistance to schedulers in adjusting schedules; to planners in adding or reducing service; to maintenance staff in

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[13] GIS is a special type of computerized database management system in which databases are related to one another based on a common set of locational coordinates.

programming preventive maintenance or identifying vehicles with potential maintenance problems; to customer information staff for answering information requests or providing trip itineraries; to street supervisors for monitoring service; to administrative staff for generating reports; and to operations staff to play back vehicle runs for checking operator performance or customer complaints.

Mobile Data Terminals

A mobile data terminal (MDT) is an in-vehicle device that has a small screen for display of messages and time, plus a series of buttons that will send preset messages to the dispatch center. Where installed, MDTs are the primary communication means between operators and dispatchers. In AVL-equipped vehicles, the MDT type device is usually augmented by a computational capability (note: that calculates vehicle location, compares the location and time to the schedule, and determines the vehicle's schedule adherence (which can be displayed on the screen). This combination is commonly called an in-vehicle logic unit. For purposes of this discussion, the term "mobile data terminal" will represent both devices.

The ability to send preset messages by the push of a button makes it easy for operators to report certain occurrences to the dispatch center. Examples include: mechanical problems; vehicle stuck; fare dispute; lift not working; relief not arrived; etc. The "Request to Talk" and the "Priority Request to Talk" buttons are the means by which the operators notify the dispatchers that they wish to talk via the radio. Dispatchers contact operators via either radio or messages sent to their MDTs. Voice or MDT messages can be directed to an individual bus, specific groups of buses, or the entire fleet.

Use of the MDTs has reduced the amount of voice radio traffic. This voice traffic reduction may decrease the number of voice channels an agency may require. A reduction in voice traffic can be an important result where available radio frequencies are scarce and highly sought after by other agencies, as is the case in many locations.

MDTs are also used to coordinate vehicle-to-vehicle transfers of passengers on intersecting routes. MDTs allow the vehicle operators to coordinate the transfers directly, without involvement of dispatchers. Connection coordination can be an important customer satisfaction consideration, since missed connections, especially on long headway routes, can discourage future patronage by the affected riders.

MDTs are also useful in providing routing instructions and messages to demand-response vehicles. MDTs can provide an electronic manifest of customer pick-ups and drop-offs. The use of MDTs can also facilitate additions or deletions to the vehicle's otherwise predetermined route. MDTs are particularly useful for those agencies dispatching in real time.

Silent Alarm/Covert Microphone/Surveillance Cameras

Silent alarms, covert microphones, and surveillance cameras are features that enhance the safety and feeling of security of operators and passengers in vehicles on which these devices are installed. The silent alarm system consists of a button placed in a concealed location near the driver, which, when pushed, activates an alarm in the dispatch office. With most AVL systems, the vehicle from which the alarm was sounded is tracked more frequently than the normal polling interval, and the dispatcher has the ability to open a secret microphone on the vehicle to try to ascertain the problem. What the dispatcher hears via the microphone is useful in helping to decide what assistance to send to the vehicle. The AVL system provides the vehicle location so response personnel can proceed to its exact position.

Surveillance cameras can take the picture of individuals who cause incidents and may discourage criminal activity. The pictures have also been used to check the validity of personal injury claims made by persons alleging to have been injured on the vehicles. The images may be stored on the vehicle for later download, or relayed to dispatch in near real time.

Automatic Passenger Counters

Automatic passenger counters (APCs) are devices that automatically collect data on passenger boardings (getting on to) and alightings (getting off of) . APCs have three basic components: a method of counting each passenger boarding and alighting, and which distinguishes between the two; a technology capable of determining vehicle location at the time boardings and alightings occur; and a data management system capable of transmitting the data in real time, or storing the data for later transfer and use. Counters are usually treadle mats placed on the steps, or infrared beams projected horizontally or vertically at each doorway.

APCs provide much more ridership data and at a lower cost than collected manually. They can also provide data that are more accurate than those collected manually. Ridership data may be used in several ways, including route analysis and planning, adjustments to schedules, and new passenger shelter positioning. These data could also be used to monitor load factors in real time for the possible insertion of additional vehicles when circumstances warrant.

Automated Passenger Information

There are several types of passenger information and methods of delivery. Information can be provided to customers and potential customers before they begin their trip, while they are en-route but not on board a transit vehicle, or after they are on board a transit vehicle. Overall, automated information is widely deployed.

Pre-trip information can consist of routes, maps, schedules, fares, fare media (note: does this mean “fare payment methods” or “broadcast information about fares?”), and park-and-ride lot locations. Information can include real-time vehicle arrivals and full trip planning itineraries. Devices used to obtain pre-trip information include the telephone, the Internet, pagers, personal digital assistants, and cable TV. (Depending on their location, kiosks could also provide pre-trip information.)

Automated pre-trip information is consistent and more accurate than that relayed by information operators. Accurate information, especially real-time information, reduces the anxiety of transit use and is particularly important for longer headway routes. Real-time vehicle arrival information allows passengers to time their arrival at stops, thereby reducing their wait time and exposure to weather and to criminal elements.

Telephone and the Internet are the methods of obtaining pre-trip information available to the most people and are the most utilized. Many transit agencies now have a site on the World Wide Web.

Access by hand-held devices and TV are used to a much lesser degree as there is low market penetration of hand held devices, and the number of locations that display transit information on TV is very small

En-route information such as vehicle arrival times (scheduled or predicted) can be provided by electronic signs, monitors, and kiosks. Signs and monitors are usually placed in passenger shelters or at transfer centers. Kiosks are usually placed at major activity centers served by transit.

The principal benefit of en-route devices is the elimination of the uncertainty of vehicle arrivals, which makes the passenger more comfortable using transit and may increase ridership. One liability has been that travelers have often found kiosks frustratingly slow or out of service.

In-vehicle information is provided by electronic signs and automated voice announcements (annunciators) of stops and transfer opportunities. Electronic signs are usually placed at one or two high-visibility locations inside the vehicle.

Signs and annunciators relieve the operator of the responsibility of announcing stops as required by the Americans with Disabilities Act. These devices provide better information to the passengers as not all operators announce stops, and some who do may be difficult to hear. Additionally, signs help hearing-impaired passengers. Since operators can concentrate on driving without having to make announcements, they should be able to drive more safely.

Vehicle Diagnostics

Vehicle diagnostics provide information to the dispatch center and the maintenance department of the transit agency concerning the condition of certain vehicle components. This information is acquired through sensors connected to the components to be monitored. Items often monitored include engine temperature, oil pressure, brakes, and tire pressure. Diagnostic information can be relayed to the dispatch center and/or the maintenance department in real time (which allows a vehicle to be taken out of service immediately if the problem is severe) or stored on the vehicle for later retrieval.

Diagnostic information warns of impending component failures when readings begin to exceed normal operating ranges. Attention to problems identified before failures occur should improve the reliability of service by reducing the number of vehicle breakdowns and the resulting service delays. Early detection can also prevent potentially serious situations or costly repairs or replacements.

Traffic Signal Priority

The provision of priority at traffic signals allows transit vehicles to progress along their routes with less delay at signalized intersections. A transit vehicle approaching a signalized intersection transmits a signal to the traffic signal controller. Depending upon the traffic signal phase at the time the signal from the vehicle is received, the controller grants an extension of the green phase until the vehicle passes or an advancement of the next green phase. The signal from the vehicle to the traffic signal controller can be sent manually or automatically (if the vehicle is AVL-equipped). In a similar manner, transit vehicle priority can be employed at signals that meter the flow of traffic at freeway ramp entrances. Another method of transit priority is to provide an exclusive transit lane at the intersection and give that lane an advance green phase so that transit vehicles can start ahead of the remainder of the traffic

Signal priority produces faster, more reliable transit service and reduced operational cost. If enough running time is saved, a reduction in the number of vehicles needed to operate service may even be possible. However, resistance is often encountered from traffic departments, since granting priority for transit may degrade traffic flow. Granting transit vehicles priority would have a greater impact on streets with progressive signal timing. The impact can be mitigated by requesting priority only when transit vehicles are behind schedule by a certain amount, or when behind schedule and carrying a sufficient number of riders.

Electronic Fare Payment

Electronic fare payment systems (EPS) for transit are of two types - those that use magnetic stripe cards and those that use smart cards. (Fareboxes that count and display the value of coins or tokens deposited are not considered APTS.) Magnetic stripe cards require a contact between the card's stripe and a device that verifies that the card is valid for the trip taken (i.e., a monthly pass) or a read-write device that can deduct the fare from the value stored on the card and put the remaining balance back on the card. A smart card, which contains a micro processor, may interface with the reader by direct contact or by radio frequency. A smart card can have both contact and contactless interfaces. Smart cards have greater security, higher reliability, and higher resistance to fraud than magnetic stripe cards, but are more costly. A major convenience of a contactless card is that the card need not be removed from a wallet or purse as long as it passes close to the reader.

Smart card systems provide the added benefits of security for lost or stolen cards (if they are registered with the agency), discounts for frequent transit use, more flexibility in fare products, a reduction in paper transfers, and reduced equipment maintenance (due to fewer fare-collection equipment moving parts). Smart cards permit the collection of more detailed ridership data for use in route planning and travel time studies, and the development of seamless regional, multi-agency, and multi-application systems, including parking and retail. Contactless cards also result in faster throughput.

Integration

The difficulty of getting systems to work together continues to be a major obstacle to successful APTS installation. The more APTS elements an agency is implementing, the more difficult the integration task becomes. The integration problem has been the cause of many of the delays encountered. Recent transit APTS systems have been implemented more rapidly. Both the equipment and the software have become more "off the shelf." Nevertheless, these improvements do not guarantee that implementations will proceed smoothly, on budget, or on schedule.

A principal integration problem involves software. For early systems, the software had to be newly developed—an arduous task. As experience with more systems has been gained, the basic software has become more standardized and transferable. Nevertheless, since transit agencies do not all want the same features or capabilities, a certain amount of customization is necessary at each location. The less customization specified by a transit agency, the easier and quicker the installation is apt to be. Also, developing the input data for the software can be a considerable undertaking.

Additional Information

Volpe National Transportation Systems Center http://www.volpe.dot.gov

American Coalition for Ethanol http://www.ethanol.org

American Petroleum Institute http://www.api.org

American Public Transportation Association http://www.apta.com

Bureau of Transportation Statistics http://www.bts.dot.gov

Electric Transit Vehicle Institute http://www.etvi.org

Federal Transit Administration http:///www.fta.dot.gov

Methanol Institute http://www.methanol.org

National Alternative Fuel Data Center http://www.afdc.nrel.gov/

National Biodiesel Board http://www.biodiesel.org

National Fire Prevention Association http://www.nfpa.org

National Hydrogen Association http://www.hydrogen.org

National Park Service Alternative Transportation Program
http://www.nps.gov/transportation/alt/index.htm

National Petroleum Gas Association http://npga.org

Natural Gas Vehicle Coalition http://www.ngvc.org

Additional Resources

U.S. DOT Federal Transit Administration Clean Air Program Design Guidelines for Bus Transit Systems, and Safety in Transit Operations Documents.

The documents are available for each alternative fuel and propulsion technology through the U.S. DOT Volpe National Transportation Systems Center.

List of Acronyms

ADA	Americans with Disabilities Act
AV	Audio Visual
BTS	Bureau of Transportation Statistics (U.S. DOT)
CARB	California Air Resources Board
CDL	Commercial Drivers License
CI	Compression Ignition
CH_2	Compressed Hydrogen
CNG	Compressed Natural Gas
Dge	Diesel Gallon Equivalent
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
EV	Electric Vehicle
FC	Fuel Cell
FMVSS	Federal Motor Vehicle Safety Standard
Gge	Gasoline Gallon Equivalent
FTA	Federal Transit Administration
HVAC	Heating Ventilation and Air Conditioning
ICE	Internal Combustion Engine
ITS	intelligent Transportation Systems
LH_2	Liquid Hydrogen
LNG	Liquefied Natural Gas

LPG (Propane)	Liquid Petroleum Gas
NG	Natural Gas
NPS	National Park Service
OEM	Original Equipment Manufacturer
PSI (pressure)	Pounds per Square Inch
SI	Spark Ignition
SOC	State of Charge