Regional Smart Bus Demonstration Project

Evaluation Report

September 2002

Management Information and Transit Technology Section
Transit Division
King County Department of Transportation

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Executive Summary

I. Project Overview

Introduction

In October 2001 through January 2002, King County Metro Transit and Sound Transit conducted the Regional Smart Bus Demonstration Project – Phase 1, a short term, limited demonstration of off-the-shelf smart bus technology on two transit coaches. This report evaluates the results of the demonstration project, with an emphasis on technical approach, transit business impacts, and lessons learned from the demonstration. Another evaluation with a regional focus was conducted by a consultant hired by Sound Transit.

Purpose

The purpose of the Smart Bus Demonstration project was to:

- Demonstrate the capabilities of readily available "smart bus" onboard systems as the current level of technology available in the transit market;
- Obtain real world experience with the advanced onboard systems functions to:
  - Provide input for King County Metro's OnBoard Systems project requirements development effort;
  - Identify the potential impact of fleet wide implementation;
  - Identify the potential benefits of implementing the technology.

The demonstration project was conducted without a detailed requirements development process, with the goal of incorporating lessons learned from the demonstration into better informed requirements for a system wide OnBoard Systems project procurement.

As a short-term installation, the demonstration equipment was not subject to the extensive, iterative testing and fine-tuning typical of permanent installations. As a result, this report describes the outcome of a short-term, preliminary exercise conducted to provide King County Metro transit staff and riders experience with the technology. The project was not intended to demonstrate the full capabilities of the technology under the optimum conditions of a longer-term installation.

It should be noted that the demonstration vendor did not participate in the demonstration evaluation activities conducted by King County Metro Transit and Sound Transit. The conclusions reported in this document are based on King County Metro Transit's understanding of the demonstration technology and evaluation assessments and results.

Background

For the four-month demonstration, existing, integrated smart bus technology was installed on two transit coaches at the King County Metro Transit Central Base facility: one King County Metro New Flyer articulated coach which operated routes 5, 7, 54, 55 and 167, and a Sound Transit 40-foot Gillig coach, which operated Sound Transit Route 570.

The Smart Bus demonstration vehicles were equipped with an information system that determined the coach's location, schedule and time of day, and monitored the status of various vehicle components. An onboard network communicated and shared data among the components of the onboard system, and an onboard database collected the data generated by the systems in operation.

To limit the scope of the project, the demonstration equipment generally was not integrated with the existing onboard systems, such as the transit radio system. The demonstration system however, was integrated with the existing transit radio Mobile Data Terminal (MDT) to allow transit operators to initiate both systems with a single log in. The system monitored and collected data from existing vehicle maintenance systems, such as the transmission, engine and braking systems.

The onboard systems functions provided in the demonstration included:

- *GPS based vehicle location, schedule adherence, and on-route status;*
- *Automated vehicle maintenance (AVM) data;*
- *Automated passenger counting (APC) data collection;*
- *Wireless data on/off load system (WDOLS);*
- *Automated interior stop announcements of major stops and landmark information;*
- *Automated interior next stop displays;*
- *Automated exterior route and destination announcements;*
- *Automated exterior route and destination signs;*
- *The ability to transmit vehicle on-time status and passenger load to the King County Metro Transit Signal Priority (TSP) system.*

Detailed descriptions of the Smart Bus Demonstration functions may be found on page 2.

King County Metro Evaluation Purpose

The purpose of the King County Metro Regional Smart Bus Demonstration Evaluation was to examine the demonstration equipment's technical approaches as examples of smart bus technology, and to capture lessons learned, and issues raised by the demonstration in preparation for the system wide onboard systems requirements development, procurement and implementation effort at KC Metro.

Caveat: This evaluation was designed to provide an opportunity for King County Metro Transit staff to become better informed about the nature of advanced transit technologies. The evaluation does not attempt to quantify, prove or disprove the validity, accuracy, or appropriateness of any technology discussed in this report.

Evaluation Objectives

The following objectives were used to evaluate the demonstration:

Objective 1: Examine the functions and technical approaches of the smart bus off-the-shelf onboard equipment in the King County Metro Transit environment.

Objective 2: Assess customer satisfaction with the automated announcements and interior signs.

Objective 3: Obtain transit staff and transit operator feedback on the new functions: ease of use, advantages and disadvantages.

Objective 4: Identify issues, lessons learned, and recommendations for potential system wide implementation of the smart bus onboard equipment.

Objective 5: Identify the potential long-term benefits of implementing smart bus technology.

A detailed listing of the evaluation objectives and approaches used to evaluate the demonstration may be found on page 4 of this report.

II. Key Findings

Overall, the demonstration functions performed well in revenue service and received positive reactions from transit riders and King County Metro Transit staff who had an opportunity to experience the demonstration equipment. The demonstration allowed technical staff to learn how the various Smart Bus features could be deployed in the King County Metro operational environment.

Stakeholder Feedback

The Smart Bus Demonstration Project provided an opportunity to obtain feedback on smart bus functions from various stakeholder groups including:

Transit Riders

- In an onboard survey of 469 Smart Bus Demonstration riders, the vast majority of survey respondents rated the interior stop announcements, interior next stop displays and exterior route and destination announcements as very or somewhat helpful.
- *Automated interior stop announcements:* The vast majority of survey respondents indicated the announcements of major stops and transfer points typically were made at the right time, but a small percentage of respondents noted the announcements were made too late. Additional tuning of the Smart Bus system performance parameters is expected to further improve the timing of the announcements.
- *Automated interior next stop displays:* The vast majority of onboard survey respondents rated the next stop displays as "very easy to see," and considered the information accurate. The next stop displays were the most preferred demonstration function, selected by 43 percent of respondents.

Riders with Disabilities

Sound Transit’s Citizen's Accessibility Advisory Committee (CAAC) and the Deaf-Blind Workgroup provided the following feedback on Smart Bus Demonstration functions:

- *Automated interior stop announcements:* Discussion participants appeared satisfied with the interior stop announcements. Most participants rated the clarity and volume of the announcements, and the ability to hear the announcements over ambient noise, as good.
- *Automated interior next stop displays:* Participants expressed concerns with the interior next stop display lettering color and the speed at which the information changed on the display. Issues with sign visibility were noted from glare and the placement of the sign over the front window of the 40-foot Gillig.
- *Automated exterior route and destination announcements:* The exterior speaker on the 40-foot Sound Transit Gillig coach should be moved from mid-coach to near the front door to allow people with visual disabilities to orient themselves to the entrance of the coach and hear the announcements more clearly.

Transit Operators

- *Automated interior stop announcements:* Transit operators who participated in the demonstration debriefing reacted positively to this function, noting it allowed transit operators to focus on driving.

- *Automated exterior route and destination announcements:* Participants had mixed reactions to the automated exterior route and destination announcements. Some operators liked the announcements, as they saved operators the task of shouting the route number out the front door to waiting customers. Other operators recommended that the announcements only play once at a bus zone, regardless of the number of times the doors were opened.

- *Automated exterior route destination sign changes:* Transit operators who participated in the demonstration debriefing reacted very positively to this function, perceiving it as a timesaver for transit operators.

- *Automated public service announcements:* Participants reacted positively to this function, describing it as useful, but difficult to access on the demonstration Transit Control Head installed above the operator's compartment for the short-term demonstration installation.

- *Schedule adherence and on-route status:* Transit operator debriefing participants had a negative reaction to these functions, perceiving them as not useful. Participants noted determining the coach's schedule adherence and on-route status was their responsibility.

Vehicle Maintenance Staff

- Vehicle Maintenance staff participating in the demonstration debriefing noted the generic canned reports provided by the Automated Vehicle Monitoring functions generally were not useful to VM staff as presented. VM staff however, saw great potential in the functions, if they were more closely tailored to meet user needs to:

    - *Collect information required by King County Metro VM staff, especially discrete input/output data.* The demonstration Mobile TA tools and AVM web reports did not include input/output (I/O) data, which VM staff found more valuable than the data from the J1708 network, such as oil pressure, which are generally available through gauges or a laptop.

    - *Provide the ability to triage coaches needing repair as they return to the base* according to their need for maintenance. While the demonstration equipment provided this capability, the function would also need to identify out of tolerance components, and include discrete I/O data.

    - *Report detailed AVM data within an hour and in a user-friendly format.*

Technical Approaches

Good technical performance and potential, given a short-term effort

The technical performance assessments of the demonstration equipment conducted for this evaluation produced a range of results, understandable given the short duration of the demonstration. Most participating staff were impressed at how well the equipment performed, given the demonstration was conducted in advance of a full requirements development, procurement and acceptance testing process.

Significant findings related to the technical approaches employed by the demonstration equipment included:

<u>Automatic Passenger Counters (APC)</u>:

> In a comparison with passenger counts by onboard observers, the demonstration APC equipment performed well overall. The demonstration APC system met or exceeded 12 out of 18 current KC Metro APC performance criteria. APC staff anticipated the remaining specifications could be met if the supplier had been given time and approval to optimize the function.

<u>Automated Vehicle Monitoring</u>:

> In a limited test conducted by vehicle maintenance staff, the AVM data correctly reported a disabled 35 mph switch and radiator fan control switch, and observed values for oil temperature, oil pressure, cooling temperature, and voltage.

<u>Data Transmission to Transit Signal Priority (TSP) Equipment</u>:

> Schedule deviation and passenger load data were transmitted and read by the Transit Signal Priority system, demonstrating the real-time dynamic data from the onboard system could be transmitted to the TSP system.

<u>Automated Vehicle Location (AVL)</u>:

> When displayed on the King County Metro Transit GIS map, a small sample of demonstration onboard AVL data was well aligned with the coach's scheduled route, and the path taken in off-route operation.

Issues identified in the analysis included:

- The demonstration onboard AVL system identified a small percentage of bus stops that were located incorrectly by King County Metro on the Transit GIS map.
- Apparent problems in GPS signal reception on Third Avenue in downtown Seattle and in the Downtown Seattle Transit Tunnel did not impact the performance of the demonstration system in operation. However, the onboard data record did not include the final corrected GPS data available, which would be desirable in a system wide implementation.
- The on-/off-route status indicator was triggered immediately by significant changes in the direction of coach travel, but gradual changes in direction were slow to indicate a change in on-route status. In addition, off-route operation on a street parallel and in close proximity to the coach's expected route did not trigger off-route status. The Smart Bus system had many system parameters that could have been optimized to improve performance had the supplier been given an opportunity, as would be expected in a system wide implementation. The demonstration system capitalized on frequent stops to improve the onboard AVL processing with GPS. Additional evaluation and testing may be required for King County Metro service with few stops, such as express or night service.

Issues Identified, Lessons Learned and Next Steps

The Smart Bus Demonstration Project highlighted business process issues and future bodies of work required for system wide implementation of the technology at King County Metro, including:

- *Announcement timing and on-route status parameters:* The optimum settings of the performance parameters controlling the timing of the next stop announcements and the on-route status mechanism will need to be determined to provide the highest performance reliability across the KC Metro service area. Future decisions for system implementation at King County Metro include operational and policy impacts and transit operator training.
- *APC process change:* The implementation of smart bus integrated APC equipment will result in changes to the current APC process, notably reduced data post-processing, and increased volumes of data. Along with integrated APC technical requirements development, a significant next step in the effort will be defining APC business process changes and staff roles in an onboard systems environment.
- *Data management process change:* The demonstration highlighted significant future KC Metro efforts related to the data management process changes required for onboard systems implementation, including the data management process onboard the bus, the distribution of data from the onboard database to the user databases, and historical database design and maintenance issues.

- *Explore testing requirements, process for system acceptance:* The evaluation technical assessments highlighted the need to explore methods for rigorous AVL, AVM and other onboard systems acceptance testing, including establishing performance criteria, level of effort, and methods for processing the large volumes of data that would be required.

Benefits

Through their experiences with the demonstration project, King County Metro Transit staff were able to more clearly envision the benefits of the smart bus technology, including:

- *Enhancement to transit operator work environment:* Most transit operators participating in the demonstration debriefing perceived the automated next stop announcements, automated route destination sign changes, and automated public service announcements as enhancements to their work environment, allowing them to focus on the operation of the vehicle and customer relations.
- *More reliable APC equipment, more streamlined data processing:* APC project staff anticipate that implementation of technology similar to the demonstration APC units would provide a number of benefits to APC data processing including:
  - Fewer repairs on APC units: Infrared light beam technology is expected to be less prone to damage in the coach environment than the current mat-based units.
  - Easier repairs with new, modular APC equipment, less impact on data collection.
  - Less post-processing of data.
- *Enhancement to customer's riding experience:* While the Smart Bus announcements and displays were designed primarily to benefit riders with disabilities and to meet federal ADA requirements, other riders also found the functions useful. The onboard survey results suggest a potential that other customers may perceive the functions as enhancements to their riding experience.
- *More efficient triaging of coaches needing repair:* Vehicle Maintenance staff participating in the demonstration noted implementation of the Mobile TA Tools or similar function would allow them to identify coaches needing repair ("BO" coach) and park them were they can be easily accessed.
- *Accessible Vehicle Maintenance diagnostic data:* Through their experience with the demonstration AVM functions, participating Vehicle Maintenance staff envisioned the potential benefits of an AVM system if tailored more closely to staff needs. Quick access to diagnostic AVM data would enable staff to:
  - Manage fleet availability more effectively by identifying which coaches can go back into service and when;

- Manage staff work flow more effectively by identifying the expected duration of a repair job and staff availability to perform the work;
- Provide more preventive maintenance by utilizing the time saved from more efficient repairs.

III. Conclusions

In summary, the Smart Bus Demonstration equipment performed well overall, given the short duration of the demonstration, conducted in advance of a formal requirements development effort.

The demonstration provided a valuable opportunity for:

- identifying technical and business process issues and future bodies of work for the onboard systems effort;
- incorporating transit rider, transit operator, vehicle maintenance, and technical staff feedback into the requirements development process;
- identifying the benefits of the technology through users' hands-on experiences.

Regional Smart Bus Demonstration Project – Phase 1
Evaluation Report
King County Metro Transit

I. Overview

A. Introduction

In October 2001 through January 2002, King County Metro Transit and Sound Transit conducted the Regional Smart Bus Demonstration Project – Phase 1, a short term, limited demonstration of smart bus technology on two transit coaches. This report evaluates the results of the demonstration project, with an emphasis on technical performance, transit business impacts, and lessons learned from the demonstration. Another evaluation with a regional focus was conducted by a consultant hired by Sound Transit.

Background

The project team selected a vendor to install existing, integrated smart bus technology on two transit coaches for a five-month demonstration. The Smart Bus demonstration equipment was installed by the vendor at the King County Metro Transit Central Base facility on two Central Base transit coaches: one King County Metro New Flyer articulated coach which operated routes 5, 7, 54, 55, and 167, and a Sound Transit forty- foot Gillig coach, which operated Sound Transit Route 570. The demonstration vehicles rotated among twenty weekday vehicle assignments (blocks) to limit the number of operators who required training and to ensure transit operators and riders received adequate exposure to the demonstration features for evaluation purposes.

The Smart Bus demonstration vehicles were equipped with an information system that determined the coach's location, schedule and time of day, and monitored the status of various vehicle components. An onboard network communicated and shared data among the components of the onboard system, and an onboard database collected the data generated by the systems in operation.

To limit the scope of the project, the demonstration equipment generally was not integrated with the existing onboard systems such as the transit radio system. The demonstration system however, was integrated with the existing transit radio Mobile Data Terminal (MDT) to allow transit operators to initiate both systems with a single log in. The system also monitored and collected data from existing vehicle maintenance systems, such as the transmission, engine, and braking systems.

The onboard systems functions provided in the demonstration included:

- GPS based vehicle location, schedule adherence, and on-route status:

  The Smart Bus demonstration coaches were equipped with an onboard automated vehicle location (AVL) system that included global positioning satellite (GPS) technology. The onboard system was loaded with the coaches' expected schedule and route. When operating a scheduled vehicle assignment, the system calculated the coach's schedule adherence at each timepoint, and determined the coach's on-route status at regular intervals.

- Automated vehicle maintenance (AVM) data:

  The demonstration onboard system monitored and recorded the status of vehicle components such as the engine, transmission and braking systems. As the coach returned to the base, the AVM system flagged out of tolerance conditions to vehicle maintenance staff. The system also provided detailed web reports of the AVM data.

- Automated passenger counting (APC) data collection and integration:

  The system collected passenger count data utilizing infrared light beam equipment installed at each coach door. Passenger boardings and alightings (ons and offs) were recorded at each stop, as well as location, time of day, and other data.

- Wireless data on/off load system (WDOLS):

  The demonstration equipment included a wireless data on/off load system. The automated wireless communications system automatically transmitted vehicle performance data from the vehicle each time it returned to Central Base and provided automatic data and software updates to the vehicle.

- Automated interior stop announcements:

  The automated stop annunciation function announced major stops and landmark information to riders.

- Automated interior next stop displays:

  Interior LED signs displayed next stop information for all stops.

- Automated exterior route and destination announcements:

  The system automatically announced the coach's service route and destination as the coach opened its doors.

- Automated exterior route and destination signs:

  The demonstration system automatically changed the coach's exterior signage without operator intervention.

- The ability to transmit vehicle on-time status and passenger load to the King County Metro Transit Signal Priority (TSP) system:

  In addition to providing the Transit Signal Priority (TSP) system with data currently provided in traffic signal priority requests, such as route/ run, trip, and vehicle identification number, the demonstration system was designed to provide the AVI (automatic vehicle identification) tag with dynamic data, i.e. current passenger load and on-time status.

B. Demonstration Project Goals

As defined in the Regional Smart Bus Demonstration Project – Phase 1 (RSBD1) request for proposals, the demonstration project goals were to:

1. Assess both the technical feasibility and the cost/benefit of specific enhancements i.e. automated VM reporting, wireless on/off loading of data, and automated stop annunciation and signage.
2. Generate customer and operator feedback on service and operational impacts.
3. Expose the public and the decision-makers to the features and potentially improved functionality of new technologies.
4. Assess regional data sharing and integration opportunities.
5. Enable transit agency staff to get hands-on experience with the latest equipment and data.
6. Provide senior level management with real-world data and testimonies on Smart Bus performance in order to evaluate benefits such as improved fleet management, customer service, operator productivity and safety.
7. Generate functional and user requirements and cost estimates for the procurement of the Regional Smart Bus - Phase III systems to be installed on the Diesel-Hybrid/Smart Buses (DHSB).
8. Provide input to the functional and user requirements for the procurement of the next generation of on-board systems for the KCM fleet and KCM-operated ST buses.
9. Gain an understanding of the scaling issues and systems design challenges for managing and maintaining a smart bus system. Areas of interest include data management for seven bases, the management of operator changes in the middle of a block, re-assignment of a vehicle to a different route after it’s already in service and unplanned re-routes.

C. King County Metro Evaluation Purpose

The purpose of the King County Metro RSBD Evaluation was to examine the demonstration equipment's technical approaches as examples of smart bus technology, and to capture lessons learned, and issues raised by the demonstration in preparation for the system wide onboard systems requirements development, procurement and implementation effort at KC Metro.

D. Evaluation Objectives and Approach

The following objectives and methods were used to evaluate the demonstration:

Objective 1: Examine the functions and technical approaches of the smart bus off-the-shelf onboard equipment in the King County Metro Transit environment.

- *Evaluation approach:* APC Analysis

  In November and December 2001, KCM Automatic Passenger Counter program staff conducted onboard passenger count surveys on the demonstration coaches using onboard observers. Staff conducted an analysis comparing the demonstration APC data generated by the onboard systems equipment with observed counts.

- *Evaluation approach:* Transit Signal Priority (TSP) reader log assessment.

  Transit Signal Priority staff compared demonstration stop record data with TSP reader log data, to confirm lateness and passenger load data from the demonstration coach were transmitted and recorded by the Transit Signal Priority system.

- *Evaluation approach:* Automated Vehicle Monitoring (AVM) "Bug" Test

  On Jan. 12, 2002 Vehicle Maintenance staff created a set of out of tolerance conditions on the demonstration coaches to compare the data reported by the demonstration AVM function with actual observed conditions.

- *Evaluation approach:* GIS/AVL Assessment

  The performance of the onboard Automated Vehicle Location (AVL) system during on-route and off-route coach operation was assessed by mapping demonstration vehicle location data onto the Transit Geographic Information System (GIS) map.

- *Evaluation approach:* Staff debriefings

  The performance and reliability of the demonstration equipment was assessed by conducting debriefings with technical and field staff involved in the demonstration.

Objective 2: Assess customer satisfaction with the automated announcements and interior signs.

- *Evaluation approach:* Facilitated discussion with transit customers with disabilities.

  In November 2001, Sound Transit staff conducted a facilitated discussion with Sound Transit’s Citizen's Accessibility Advisory Committee and the Deaf-Blind Workgroup.

Participants were provided with a demonstration of the automated exterior route and destination announcement, automated interior stop annunciation and automated interior sign functions to obtain their feedback on the functions.

- *Evaluation approach:* Onboard survey of transit riders.

  An onboard survey of riders of the demonstration coaches was conducted in December 2001 by King County Metro staff and a consultant to obtain riders' feedback on the automated exterior route and destination announcement, automated interior stop annunciation and automated interior sign functions.

Objective 3: Obtain transit staff and transit operator feedback on the new functions: ease of use, advantages and disadvantages.

- *Evaluation approach:* Transit operator debriefing session

  Following completion of the demonstration, KCM staff conducted a facilitated session with transit operators who operated the demonstration coaches, to obtain their feedback on the automated stop annunciation and other Smart Bus demonstration functions.

- *Evaluation approach:* Debriefings with technical and vehicle maintenance staff.

  The purpose of the debriefing sessions was to discuss the demonstration functions and data with staff who used the demonstration equipment or data output, to obtain feedback on their experiences.

Objective 4: Identify issues, lessons learned, and recommendations for potential system wide implementation of the "smart bus" onboard equipment.

- *Evaluation approach:* Debriefings with technical staff, transit operators, vehicle maintenance staff.

  Participants in the debriefings noted above, identified potential issues and recommendations for improvements to the demonstration technology if it were implemented on the transit bus fleet. The discussion topics included equipment functions, user training, and potential business process changes.

- *Evaluation approach:* GIS/AVL Assessment

  The potential impacts of GPS based vehicle location on the Transit Geographic Information System (GIS) were assessed by mapping and analyzing demonstration vehicle location data.

Objective 5: Identify the potential long-term benefits of implementing smart bus technology.

- *Evaluation approach:* Debriefings with technical staff and vehicle maintenance staff.

  Participants' assessments of the potential long-term benefits of a full implementation of the demonstration equipment were discussed at the conclusion of the project.

II. Evaluation Results

The following section summarizes the results of the demonstration evaluation, reported by each demonstration function.

1. Automated Interior Stop Announcements

Objective 2: Customer Satisfaction

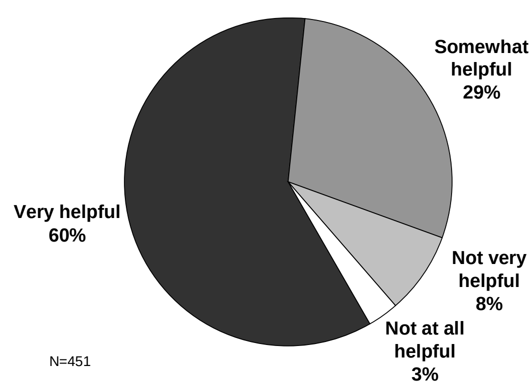
Transit rider onboard survey

An onboard survey of riders of the demonstration coaches was conducted in December 2001 by King County Metro staff and a consultant to obtain riders' feedback on the automated exterior route and destination announcement, automated interior stop annunciation and automated interior sign functions. Of particular interest was the reaction of regular riders to the automated announcement features. The survey was fielded on 25 Smart Bus demonstration trips. Four hundred seventy-nine completed surveys were collected, yielding a 69.7 percent response rate. The survey respondents tended to be regular riders, and were riding their usual route.

Automated interior stop announcements: The following are survey results related to the interior stop announcements function. The complete onboard survey report is available in the Appendix.

Figure 1

Helpfulness of Major Stop and Transfer Information Announced Inside the Bus



- The vast majority (89 percent) of survey respondents rated the interior stop announcements as very or somewhat helpful, with over half of respondents (60 percent) rating the functions as very helpful.

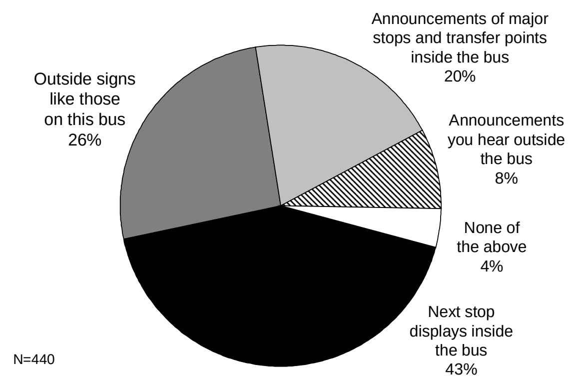
- While most (87 percent) of respondents said the announcements of major stops and transfer points were made at the right time, 11 percent of respondents said the announcements came “too late,” indicating an issue with the timing of the announcements.

- The interior announcements were rated as accurate by 82 percent of the respondents. Sixteen percent of respondents indicated they didn't know whether the information was accurate.

- Preferred Smart Bus Feature: When respondents were asked for their preference if only one of the Smart Bus features could be added, the interior stop announcements were rated as third among five possible options, selected by 20 percent of respondents.

Figure 2

If we were only able to provide one of these SmartBus features on new buses, which one feature would you most like to see?



ADA Rider Discussion

In November 2001, Sound Transit staff conducted a facilitated discussion with Sound Transit's Citizen's Accessibility Advisory Committee and the Deaf-Blind Workgroup. Eight participants with mobility, hearing and/or vision disabilities were provided with a demonstration of the Smart Bus signage and announcement functions to obtain their feedback and suggested improvements for the functions. A summary of the discussion provided by Sound Transit's evaluation consultant may be found in the Appendix of this report.

- Overall, discussion participants appeared satisfied with the interior stop announcements. Most participants rated the clarity, volume, and ability to hear the announcements over ambient noise, as good.

Objective 3: Transit Operator Feedback

A debriefing session was held on January 23, 2002 with transit operators who had operated Smart Bus demonstration coaches. The purpose of the session was to assess operator satisfaction with the Smart Bus demonstration functions and obtain operators' recommendations for a potential system wide implementation of the smart bus onboard equipment. KCM Research and Management Information staff facilitated the session. Fourteen Central Base transit operators participated in the session: nine full-time transit operators and five part-time transit operators. A discussion summary may be found in the Appendix.

- Most discussion participants liked the interior stop announcement function and stated it should be included in a smart bus system wide procurement. Some participants noted the function benefited operators by allowing them to focus on driving and gave them "one less thing to worry about."

- Participants noted that most of their passengers liked the stop announcements. Several operators received positive feedback from people with disabilities.

- Participants stated the function generally worked well, noting a few instances where the wrong announcement was made by the system, or no announcement was made.

- Some participants noted instances of advanced and delayed announcements, depending on the coach's speed and placement of stops. Some stop announcements were perceived as being made as the coach passed the stop, or after the coach passed the stop.

- Participants had varied opinions on the female voice used to announce stops in the demonstration. Some participants thought the voice was fine, others thought it was difficult to hear or not "assertive" enough.

Objective 4: Issues and Recommendations for Implementation

Announcement Timing:

Based on feedback from transit operators and the customer survey, the timing of stop announcements will need to be refined. The demonstration stop announcements were triggered 300 feet in advance of the stop, later adjusted to 400 feet. The 300-foot setting was problematic when the coach was traveling at a rapid speed, such as on the freeway, where the announcement was made too late. Transit operators suggested customizing the timing of announcements for each route, or that announcements should be made immediately after the doors close.

Other suggestions from transit operators included:

- Shortening the announcements, for example "California and Alaska" instead of "California Avenue Southwest and Southwest Alaska Street."

- Eliminating the "beep" the system makes prior to an announcement. Discussion participants noted instances where they mistook the beep for the stop requested bell, and inadvertently pulled into a stop when no stop was requested.

- Adding a "next stop will be an express stop" announcement for express trips;

- Using a variety of different types of voices to make the announcements.

Technical Staff Debriefing

At the completion of the demonstration project, a discussion was conducted with a group of KCM technical staff to identify technical lessons learned and implementation issues raised by the demonstration. A discussion summary may be found in the Appendix.

- The group identified transit operator training issues related to the stop annunciation function implementation including:
  - What does the system consider as off route operation and how will the system behave?
  - By what process will transit operators report errors in stop announcements?

2. Automated Interior Next Stop Displays

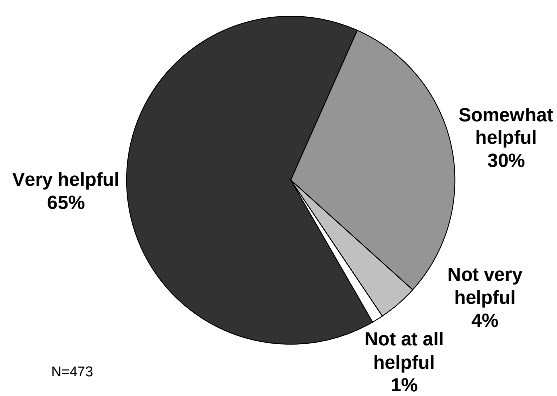
<u>*Objective 2: Customer Satisfaction*</u>

Transit rider onboard survey

- This function was highly rated by Smart Bus onboard rider survey respondents. If only one Smart Bus feature could be provided, the interior next stop displays were survey respondents' top choice, selected by 43 percent of respondents (see Figure 2).

- Ninety-five percent of respondents rated the interior next stop and landmark information displays as very or somewhat helpful. Sixty-five percent of respondents rated the function as very helpful.

Figure 3
Helpfulness of Information Displayed on Signs Inside the Bus



- The vast majority of respondents rated the signs as very easy to see (85 percent of respondents) and accurate (82 percent of respondents).

ADA rider discussion

- Participants in Sound Transit's Citizen's Accessibility Advisory Committee (CAAC) discussion had concerns with the color of the lettering and location of the interior next stop displays signs. According to several participants, the red lettering of the signs was difficult to read and could potentially trigger epileptic seizures in some individuals.
- As an alternative to the red lettering of the displays, CAAC discussion participants suggested bright yellow letters on a dark blue or black background, or blue-green dot matrix signs. A few participants suggested bolder or "less dotty" letters.
- A few participants noted glare interfered with the visibility of the signs from an overhead light and open roof hatch. Several participants found the display sign over the front window of the 40-foot Gillig coach was difficult to see from the left side wheelchair securement area.
- The speed at which the information on the signs changed was too fast for some participants.

3. Automated Exterior Route Destination Announcements

When the coach doors were opened, this function made an announcement to waiting riders at the bus zone, such as "Route 5 to Downtown Seattle via Greenwood."

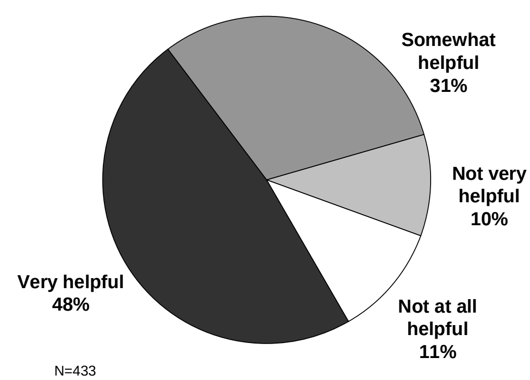
<u>Objective 2: Customer Satisfaction</u>

Transit rider onboard survey

- Over three-fourths (79 percent) of survey respondents rated the exterior route and destination announcements very or somewhat helpful, with 48 percent of respondents rating the function as very helpful.

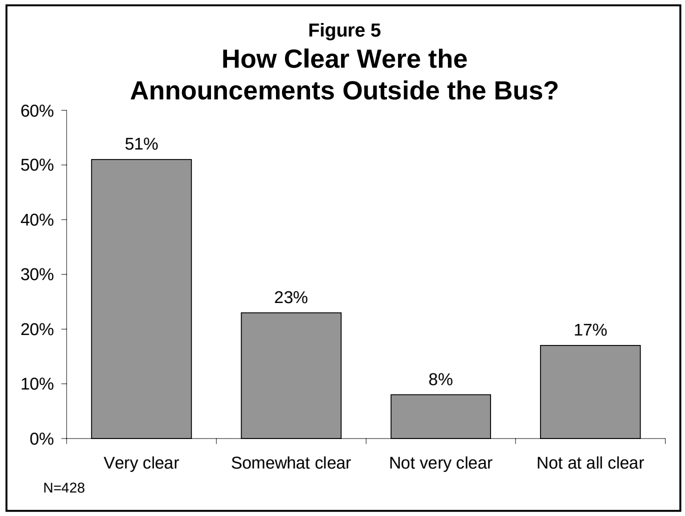
Figure 4

Helpfulness of Route Number and Destination Announcements Outside the Bus



- The vast majority (77 percent) of respondents rated the volume of the exterior route and destination announcements as "just right."

- Half (51 percent) of respondents indicated that the exterior route destination announcements were very clear, but 17 percent rated the announcements as "not at all clear," indicating a possible issue with the announcements.



- When asked to select their preferred Smart Bus feature, only 8 percent of respondents selected the exterior route and destination announcements, and rated them last of the four alternative functions (see Figure 2).

ADA rider discussion

- Participants in Sound Transit's Citizen's Accessibility Advisory Committee (CAAC) discussion noted the location of the exterior speaker between the front and rear doors on the 40-foot Gillig coach is problematic for sight-impaired passengers, as they expect route destination announcements, currently made by transit operators, to emanate from the front door.

<u>Objective 3: Transit Operator Feedback</u>

- The external route and destination announcement function received mixed reactions from transit operator debriefing discussion participants. A few participants stated that they liked this feature, as it saved them the task of "having to holler out the front door" to visually impaired riders and that the function was well liked by their visually impaired customers. Other operators found the announcements annoying and repetitive, as the announcement was repeated each time the front or back door opened in a bus zone.

- Most participants recommended that the announcement should play only once at a bus stop, to avoid replaying the announcement if the doors open again for late riders.

4. Automated Exterior Route Destination Sign Changes

Using the onboard automated vehicle location and schedule information, the Smart Bus demonstration equipment automatically changed the coach exterior route and destination signs without operator intervention.

Objective 3: Transit Operator Feedback

- Transit operator debriefing participants expressed enthusiasm for the Smart Bus automatic destination sign change capability, and wanted to see this feature as part of the future system procurement.

Objective 4: Issues and Recommendations for Implementation

- Some participants noted the current override requires too many keystrokes if the transit operator wishes to change route and destination signs manually, for example in case the system malfunctions, or the operator is required to operate an unexpected trip. The function would be improved, debriefing participants said, if the system were easier to override when an operator needs to manually change the coach's signage.

5. Transit Control Head: Schedule Adherence and On-Route Status

The demonstration Transit Control Head (TCH) was the operator user interface to the Smart Bus equipment, and was installed in the demonstration coaches above the operator's compartment. The TCH provided:

- Schedule adherence information, displayed as minutes ahead or behind schedule on the transit control head;
- An on-route or off-route status indicator, displayed on the transit control head;
- Recorded public service announcements that could be played to passengers at the operator's discretion;
- Controls to allow the operator to override the automated stop announcements and automatic destination signs.

Objective 3: Transit Operator Feedback

Schedule adherence status:

- In general, participants did not find this function helpful. None of the discussion participants relied on the schedule adherence function provided on the transit control head, which displays minutes ahead or behind schedule as of the trip's most recent timepoint. Most participants considered gauging the operation of their schedule as an essential aspect of their duties.

- Participants also indicated the information would not be useful to them if provided in an alternative format, such as predicted arrival time at their next timepoint.

On-route/off-route status:

- In general, participants did not find the on-and off-route status indicator on the transit control head useful, and recommended excluding it from a future system implementation. Participants considered being on-route as one of their key responsibilities in operating the vehicle, not requiring automated assistance.

Public Service Announcements:

- Participants described the public service announcements that could be played by the transit operator as a useful function, but difficult to access on the demonstration transit control head installed above the operator's compartment. Participants said they would use the function if it were easier to reach and required no more than two keystrokes.
- Suggested announcements included announcements of the fare structure, "Please the exit through the front door only," "Please have your fare ready," "Please move to the back," and "Please refrain from using profanity."

Objective 4: Issues and Recommendations for Implementation

- As they did not find the schedule adherence and on-route status information useful, transit operators participating in the debriefing session recommended that these features be excluded from a future onboard systems implementation.
  - A few participants expressed concern about the potential use of schedule adherence information for disciplinary purposes.
- Based on their experiences with the demonstration coaches, participants suggested the following features for a future Driver Display Unit:
  - An accurate clock, such as the clock provided on the demonstration TCH;
  - A list of ADA stops for use in case the stop annunciation function isn't working;
  - An automated display of run card information, showing next timepoint and scheduled time, one line at a time.
  - A more user-friendly system requiring fewer keystrokes to make it easier for operators to intervene if the system malfunctions, or if the operator wishes to make stop announcements themselves.

Operator Training

- Discussion participants said they received either a brief explanation from the training office staff and a printed handout, or the handout alone, to prepare them to operate the demonstration equipment. Generally participants indicated they felt adequately prepared for the basic log in procedure, but felt less prepared for system troubleshooting or other special circumstances that arose.

- Most participants stated they would like to see an operator training class offered if smart bus technology were implemented on the fleet. Other training related suggestions from participants included: instructions in The Book, a user-friendly instruction manual, posted instructions near the DDU, and a working training model of the equipment at the Training Center.

6. Automatic Passenger Counter

Objective 1: Technical Approach

In November and December 2001, King County Metro Automatic Passenger Counter project staff conducted passenger count surveys on the demonstration coaches equipped with an infrared passenger counting system. The purpose of the survey was to compare passenger ons and offs observed by staff riding the bus with passenger ons and offs recorded by the system. The assessment focused on the performance of the demonstration equipment at the stop level, and was not intended to assess APC performance for route level or system wide passenger counts.

A sample of 1,057 bus stop records was collected from coach 2399 for the analysis. A smaller sample of 178 bus stop records was collected from coach 9024, with the data following similar patterns, but was not included in the final analysis due to low ridership.

- APC project staff analysis indicated that the demonstration APC system had an overall accuracy of 105 percent for passenger ons and 91 percent for passenger offs, showing an overall tendency to overcount passenger ons by 5 percent, and undercount passenger offs by 9 percent from observed ons and offs.

  - This meets the current APC program specification and Smart Bus demonstration specification for overall accuracy of +/- 5 percent for passenger ons, but does not meet the +/- 5 percent specification for passenger offs.

- APC staff also compared the performance of the demonstration equipment to other current APC program specifications, that were not among the demonstration equipment procurement specifications:

- In stop-by-stop comparisons, the demonstration APC equipment at the back door met current APC specifications for zero allowed deviations from observed counts, but the front door equipment did not meet the specification.
- The demonstration passenger counter equipment on both the front and rear doors met current APC specifications in +/-1 and +/-2 categories, which allow counts reported by the system to be within +/-1 or +/-2 of the observed counts at a stop.

- In total, the demonstration equipment met or exceeded 12 out of 18 current King County Metro APC program specifications.
- KCM APC project staff described the demonstration technology as "encouraging," with acceptable accuracy likely to be achieved by working with the vendor to fine tune the hardware and software, if the equipment were purchased for system wide implementation, rather than as a short duration demonstration.

Objective 4: Issues and Recommendations for Implementation

Stop sequence data quality issue:

In the analysis of APC data, APC project staff identified some errors in the stop data associated with the APC counts. This highlights the importance of stop sequence data quality for onboard systems implementation. One of the goals of the current Stop Information System (SIS) project is to identify areas of potential error in the current stop data process and improve the process for downstream systems.

Technical Staff Debriefing:

- The ability to identify errors in KC Metro stop sequence data and correct them in a timely manner will be a critical implementation issue.

Assess impacts on work processes and tools:

- In an onboard systems environment, APC post-processing will be streamlined, but the volume of data managed by staff will increase. The impact on APC staff and work processes will need to be assessed including:
  - The data quality and troubleshooting processes;
  - The required toolset for managing and troubleshooting APC data;
  - Staffing requirements.

Objective 5: Potential Long-Term Benefits

APC project staff anticipate that implementation of technology similar to the demonstration APC units would provide a number of benefits to APC data processing including:

- *Fewer repairs on APC units:* The current mat-based APC system installed on the coach steps, is prone to damage from passenger foot traffic and water damage. An alternative technology such as the Smart Bus demo infrared light beam is expected to be less prone to damage in the coach environment.
- *Easier repairs, less impact on data collection:* If repairs are needed, new modular equipment will allow technicians to more readily remove the broken unit and replace it with a new one.
- *Less post-processing of data:* a considerable level of effort is involved in processing APC data after it has been collected from coaches. APC staff anticipate a new APC system that integrates stop data with passenger counts will streamline the process. Data quality emphasis is expected to shift to the front end of data collection to provide improved input to the process.

7. Automated Vehicle Monitoring (AVM)

Function description: The Smart Bus demonstration AVM functions installed at Central Base included:

Mobile TA Tools: Installed on a pc in the hostler's shack (vehicle maintenance dispatcher's office), this tool allowed VM staff to obtain a snapshot of several coach conditions as the demo coach returned to the base. Normal conditions were displayed on the screen as green, a temporarily out of tolerance condition was displayed as yellow, and a currently out of tolerance condition was displayed as red.

TA Tools: This tool provided VM staff with next day access to detailed AVM coach data via pre-defined web reports.

Custom data queries: Upon request, the Smart Bus demonstration vendor provided detailed printed data reports based on the Smart Bus demonstration data files.

Discreet Input/Output monitors: Sensors were installed at 24 selected points on the demonstration coaches to monitor for changes in equipment status, e.g. "doors open" or "doors closed." The data from the I/O sensors were not displayed on either version of the generic TA Tools.

Objective 1: Technical Approach

"Bug" test:

On January 12, 2002, Vehicle Maintenance staff created a set of out of tolerance conditions on the out of service demonstration coaches to compare the data reported by the demonstration AVM function with actual observed conditions. VM staff also recorded the observed oil temperature, oil pressure, coolant temperature, and voltage, and compared the observed readings with data reported by the TA Tools web reports. Of particular interest was the performance of the discreet input/output (I/O) sensors installed at the request of Vehicle Maintenance staff as part of the demonstration.

To conduct the test, VM staff disabled:

- The 35 mph switch on coach 2399, which is a monitored fail safe for the articulation dampening system that prevents trailer sway and jack-knifing at speeds over 30 mph;
- The radiator fan control switch on coach 9024.

Results:

- VM staff reported that the data from the AVM web reports matched the observed values for oil temperature, oil pressure, coolant temperature and voltage. Coach data reports provided by the vendor for the 35 mph switch and fan control accurately reported the disabled switches in an "off" state.

AVM debriefing:

A debriefing session was conducted on February 14, 2002 with Vehicle Maintenance staff involved in the demonstration to summarize Vehicle Maintenance staff experience with the demonstration AVM functions, lessons learned, and suggestions for improvements for system wide implementation. A detailed summary of the debriefing discussion is available in the appendix of this report.

Initial accuracy issues:

According to participants, both Mobile TA Tools and TA Tools displayed some inaccurate data in the first few weeks of the demonstration. These were identified as software data translation errors and were subsequently fixed by the vendor. Once the initial translation errors were fixed, participants considered the AVM data to have good overall accuracy.

Objective 3: Vehicle Maintenance Staff Feedback

Great potential, but user requirements needed:

In general, Vehicle Maintenance staff said they found great potential in the automated vehicle monitoring functions. To be useful to Vehicle Maintenance staff, the type of data collected by the system would need to carefully match staff needs, as well as the way the information is conveyed to VM staff.

Discrete I/O data more valued than J1708:

VM staff considered the demonstration data from discrete input/outputs (I/Os) as more valuable than information from the vehicle's J1708 network, such as oil pressure, which currently can be monitored by gauges or a laptop, and available via the demonstration TA Tools and Mobile TA Tools functions. The desired I/O data generally were available only through the custom data reports, available by special request from the vendor.

Examples of I/O data include: the 30 and 35 mph switches, fan control, rear door, and wheelchair lift cycles. VM staff identified exhaust back pressure and air intake restriction as useful I/O data items for a future AVM system, which would require additional sensors.

TA Tools web reports not user friendly:

The TA Tools next day web reports provided in the demo generally did not meet VM staff needs. Staff noted the user interface was clumsy and required the viewer to go through many screens to view the data they wanted. Participants considered the charts and scales difficult to read.

TA Tools data turnaround time too long:

As implemented in the short term demonstration, detailed AVM data were available in the web reports the day after the coach pulled in to the base. This was not soon enough to really be useful, debriefing participants said. Ideally, detailed diagnostic data would be available in real-time, or at most, an hour after the coach's pull in at the base.

Custom data queries emphasize need for exception reporting:

When participants requested special data queries from the vendor, they were surprised by the volume of data they received, for example, some measures were recorded every second. Upon viewing the reports, participants said they really wanted to see the exceptions or out of tolerance items, for example, all coaches with coolant temperatures above 250 degrees.

<u>Objective 4: Issues and Recommendations for Implementation</u>

Mobile TA Tools improvements:

VM staff noted the primary value of implementing the Mobile TA Tools or similar function would be the ability to triage buses returning to the base according to their need for maintenance. According to staff, the function would also need to indicate which component is out of tolerance, and include information from discrete I/Os.

Location of Mobile TA Tools:

Possible future locations at the base for Mobile TA Tools or similar type of equipment for triaging coaches included the hostler's shack the mechanics office, assuming the equipment is staffed around the clock. Locating the equipment at the fuel building has an advantage, as all coaches are fueled daily, or in a case of trolleys, have their fareboxes pulled.

AVM System Reports:

Based on their experience with the demonstration TA Tools web reports and vendor-provided custom data reports, debriefing participants said a fully implemented AVM system should provide:

- Data available in real-time or within an hour of coach pull-in.
- The ability for users to generate reports by selecting desired data elements from a menu;
- Reporting capabilities for discrete I/Os;
- Exception reporting;
- Preset or canned reports, as well as the ability for users to change the canned reports themselves if necessary.

Technical Staff Debriefing:

Participants noted installation of the 24 discrete input outputs (I/Os) on the demonstration coaches took the vendor a considerable amount of time. It is expected that with experience, the process can be streamlined and standardized, but is likely to remain labor-intensive.

Objective 5: Potential Long-Term Benefits

Mobile TA Tool—Better triage would save time and money:

According to debriefing participants, identifying coaches with out of tolerance conditions as they pull into the base would allow more coaches with problems to be parked in the "BO lane" or holding area for coaches with problems, rather than parked with the other coaches. Participants estimated that accessing BO coaches "buried" in the yard occurs at least once per shift at each base, requiring approximately 30 minutes of staff time per incident.

TA Tools (Historical web reports)

Potential benefits of diagnostic data:

Debriefing participants said quick availability of diagnostic information will help reduce the time mechanics spend diagnosing problems. With this information available, Vehicle Maintenance staff expect they will:

- Manage fleet availability more effectively by identifying which coaches can go back into service and when;
- Manage staff work flow more effectively by identifying the expected duration of a repair job and staff availability to perform the work;
- Provide more preventive maintenance by utilizing the time saved from more efficient repairs.

Ability to track fleet performance:

VM staff anticipated the AVM data would be valuable to vehicle maintenance chiefs in identifying performance trends by fleet type over time.

Wheelchair lift preventive maintenance (PM) process:

VM staff said they are interested in examining lift usage, rather than vehicle mileage, as a possible basis for scheduling PM. The potential cost savings could be large if wheelchair lift preventive maintenance could be done more efficiently, as each PM requires approximately eight hours of labor, according to participants.

8. Data Transmission to Transit Signal Priority (TSP) Equipment

Objective 1: Technical Approach

Transit Signal Priority staff conducted an analysis to compare demonstration stop record data for blocks operating the Route 7 with TSP reader log data, to confirm lateness and passenger load data from the demonstration system were transmitted and recorded by the Transit Signal Priority system.

- TSP staff reported the lateness and passenger load data were transmitted and read by the signal priority system on 34 out of the 52 scheduled runs of the Route 7, demonstrating the real-time dynamic data from the onboard system could be transmitted to the TSP system.
- The data were not received for 18 of the 52 runs, for undetermined reasons. In addition, the value of the lateness field was passed to the TSP tag as an increment of four. However, technical staff noted the issues could be resolved in a longer term effort.

Objective 5: Potential Long-Term Benefits

- Transit Signal Priority staff concluded the demonstration has successfully shown the capability to provide real-time lateness and ridership data to the AVI tag. The capabilities are anticipated to allow transit staff to maximize available priority time by giving coaches priority based on lateness and load.

9. Wireless Data On/Off Load System (WDOLS) and Data Management Process

Objective 1: Technical Approach

Technical staff debriefing:

Smart Bus Demonstration project staff reported that throughout the demonstration, data was communicated between the bus and base server via a wireless data on/off load system (WDOLS). Data was downloaded daily from the bus to server. A software and data update was transferred from the server to the bus to demonstrate the WDOLS reliability and bi-directional capability.

Objective 4: Issues and recommendations for implementation

Technical staff debriefing:

- WDOLS will require security measures to prevent hacking of the base servers, KC WAN, or the equipment on the buses.
- Adequate emergency power supply will be an issue as more systems are installed at the base facilities: security cameras, onboard systems, Smartcard.
- The number of systems sharing the base file servers will increase the need for server management and coordination.

- The set up of the stops and route database onboard the bus involved collecting GPS location coordinates for each bus stop and every 50 feet along the bus route. For system wide implementation, the project team is considering options for the system wide process, including collecting the information while buses operate in service, or using the Transit GIS map.
- The accuracy of transit stop sequence data remains an issue for the project. Various analysts identified some discrepancies in stop data throughout the course of the demonstration. A goal of the Stop Information System project is to increase the consistency and accuracy of stop sequence data.

OBS Data Management

Technical staff debriefing:

A large body of work exists to address the following onboard systems King County Metro data management issues:

- By what process are data from the onboard database parsed to the various user databases, for example APC, fare collection, etc?
- How much data will be stored on the bus before it is overwritten?
- The resulting historical database is potentially very large. Database issues include:
  - Database structure to allow comparison of planned vs. actuals;
  - How much data is stored and for what duration?
  - What data are stored in summary form, such as averages, vs raw data?
  - What are the legal requirements for historical data, such as L&I, safety?
  - How will the data be viewed by users?
- Implementation of the biweekly scheduling process in onboard systems environment. By what process will schedule versions be controlled and updated onboard?
  - The project team envisions an automated process for implementing current and next service change onboard, including a trigger for when the bus should use the next service change data set.

10. Onboard Automated Vehicle Location and On-Route Status

<u>Objective 1: Technical Approach</u>

GIS/Demonstration AVL Assessment:

Purpose:

The purpose of the GIS/Demonstration AVL assessment was to:

- Assess the performance of the demonstration onboard AVL and on-route status function during on-and off-route coach operation;
- Assess the potential impacts of utilizing data from a GPS based AVL system with the existing Transit Geographic Information System (GIS) map.

Caveat:

The assessment mapped demonstration onboard vehicle location data onto the Transit GIS map to analyze the relative positions of demonstration data as displayed on the GIS map. This limited analysis does not attempt to quantify the accuracy of the onboard AVL data, but provides insights into the demonstration system's logic, the KCM Onboard Systems requirements development effort, and potential Transit GIS map issues.

It should be noted that the onboard data used in this analysis did not include the final corrected GPS data available to the demonstration automated announcement and other features, and so is not representative of the actual performance of the demonstration vehicles in operation. In a full system deployment, it is expected that both the onboard data record and location data used by the onboard systems in operation would utilize enhanced GPS data.

The following summary provides highlights of the analysis conducted by MITT Geographic Information Systems staff.

<u>Assessment 1: On-route, in service demonstration data</u>:

GIS staff were provided with six days of data from two in-service blocks (167/11 and 7/60), taken from throughout the demonstration period. Demonstration on-board location data were mapped onto the Transit GIS map including:

- Serviced stop events or the location where the bus opened its doors at a bus stop;
- Unserviced stop events where the bus passed, but did not service a bus stop;
- Distance-based events or system record of the bus location every 500 feet.
  - Two days of 167/11 data were excluded from the analysis, as the stop locations were extremely out of range, suggesting a non-onboard system related data processing error or that the system was malfunctioning.

Results:

- Overall, when mapped on the Transit GIS map, the onboard stop event and distance-based event data were well aligned with the bus' expected route path.

- Overall, the demonstration stop event locations coincided fairly closely with the GIS map stop locations, averaging 64 feet from the GIS stops, and ranging from 3 to 398 feet. King County Metro Transit bus zone lengths generally range from 60 to 110 feet, with 110 feet being more typical. Eighty-eight percent of the onboard stop events were less than 110 feet from the GIS stop location, or within a bus zone length.

- The variability between onboard stop events and Transit GIS stops on 3rd Avenue in downtown Seattle, suggested the "urban canyon" effect of "raw," unenhanced GPS technology, where the global positioning satellite signal cannot be received by the vehicle if it is surrounded by tall buildings or hills.

  - The vendor AVL product provided an algorithm to correct the vehicle's determined location if the GPS signal was inadequate. In the demonstration installation, this feature was not used to correct the location data in the onboard data record, but only for the stop announcement and display functions, which worked well in downtown Seattle with no apparent urban canyon effect. The location data used in this analysis were uncorrected by the vendor's algorithm.

  - Areas outside downtown Seattle showed several instances of demonstration stop event data clustered hundreds of feet away from the GIS stop, suggesting the GIS stop location or street network may be in error. Investigation verified these stops were placed incorrectly on the GIS map by King County Metro.

Objective 4: Issues and Recommendations for Implementation

GIS impacts:

The assessment suggested areas of the King County Metro Transit GIS map where more precision is required in mapping bus stops onto the street network. The upcoming GIS transportation network upgrade is expected to improve the accuracy of the street network from approximately +/- 25 feet in incorporated King County and +/- 250 feet in unincorporated King County, to +/- 10 feet countywide. The increased accuracy is expected to contribute to more accurate placement of stops on the street network.

  - Technical Staff debriefing participants suggested that one option to explore would be to define a bus stop spatially as a zone or distance, rather than as a point, to improve the appearance of OBS stop data on the Transit GIS map, and to provide a more realistic representation of a bus stop.

Assessment 2: Off-route (out of service) data:

MITT staff conducted a limited assessment of the demonstration onboard equipment during off-route operation to assess the impact on the demonstration onboard automated vehicle location (AVL) function.

An out of service demonstration coach was logged on to a demonstration block, then operated off of its expected route at various points. GIS staff mapped the location of distance-based events, serviced and unserviced stop events, and on/off-route events recorded by the onboard system.

Results:

- Overall, when displayed on the Transit GIS map, the onboard location data collected during off-route operation matched the actual path taken by the coach.
- Data collected during off-route operation in the downtown Seattle Transit Tunnel suggested the ability of the demonstration equipment to accurately track the coach location degraded as the coach traveled farther into the tunnel, as GPS signals are not received underground. The Tunnel provided an example in the KC Metro operating area where a mechanism is needed for determining vehicle location when the GPS signal is not available.
- As noted above, the vendor AVL product provided an algorithm to correct the vehicle's determined location if the GPS signal was inadequate. In the demonstration installation, this feature was not used to correct the location data in the onboard data record, but only for the stop announcement and display functions, which worked well in downtown Seattle with no apparent urban canyon effect. The location data used in this analysis were uncorrected by the vendor's algorithm.
- The future OnBoard Systems implementation should provide a mechanism for determining vehicle location in the downtown Seattle Transit Tunnel where the GPS signal is unavailable, and provide the corrected location data to the onboard data record.

Off route status trigger:

  - The on-/off-route status indicator was triggered immediately by significant changes in the direction of coach travel, but gradual changes in direction were slow to indicate a change in on-route status. In addition, off-route operation on a street parallel and in close proximity to the coach's expected route did not trigger off-route status.
  - The Smart Bus system had many system parameters that could have been optimized to improve performance had the supplier been given an opportunity, as would be expected in a system wide implementation.

- Data analysis indicated continuous on-route operation of the coach without servicing a stop produced an incorrect shift in the coach location data in the direction of travel. The demonstration system capitalized on frequent stops to improve the onboard AVL GPS processing. Additional evaluation and testing may be required for King County Metro service with few stops, such as express or night service.

Objective 4: Issues and Recommendations for Implementation

Technical staff debriefing:

- Technical staff debriefing participants suggested a mechanism to trigger more frequent synchronization with GPS should be explored, such as changes in heading (direction of travel) from the gyroscope.

III. Conclusions

Objective 1: Examine the functions and technical approaches of the smart bus off-the-shelf onboard equipment in the King County Metro Transit environment.

Conclusion: Good technical performance and potential, given a short-term effort

- The technical performance assessments of the demonstration equipment conducted for this evaluation produced a range of results, understandable given the short duration of the demonstration. Most participating staff were impressed at how well the equipment performed, given the demonstration was conducted in advance of a full requirements development, procurement and acceptance testing process.
- Some technical performance issues identified by staff, for example, in the APC and TSP assessments, were regarded as fixable by additional effort that would be justified by a permanent installation.

  <u>Automatic Passenger Counters</u>:

  The demonstration APC equipment performed well overall. With no optimization or iterative "fine-tuning" the demonstration APC system met or exceeded 12 out of 18 current KC Metro APC performance criteria. However APC staff noted the criteria would be met if the effort were allowed more time to fine-tune the demonstration equipment.

  <u>Data Transmission to Transit Signal Priority (TSP) equipment</u>:

  Vehicle schedule deviation and passenger load data were transmitted and read by the signal priority system, demonstrating the real-time dynamic data from the onboard system could be transmitted to the TSP system.

  – Data were not received for 18 of the 52 runs, for undetermined reasons. The TSP tag design required that the value of the lateness field was passed to the TSP tag as increments of 4. However, technical staff noted the reliability and accuracy issue could be resolved if warranted by a longer term effort.

- While the AVM and AVL technical assessments were not intended to quantify the accuracy of the demonstration functions, the limited assessments were valuable in providing staff with increased insights into the functions.

<u>Automated Vehicle Monitoring</u>:

In the limited "bug" test conducted by vehicle maintenance staff, the AVM data correctly reported the disabled 35 mph switch and radiator fan control switch, and observed values for oil temperature, oil pressure, cooling temperature, and voltage.

Automated Vehicle Location:

A small sample of demonstration onboard AVL data displayed on the Transit GIS map, indicated the location data were well aligned with the coach's scheduled route, and the path taken in off-route operation.

Issues identified in the analysis included:

- The demonstration onboard AVL data identified a small percentage of bus stops which were located incorrectly on the GIS map.
- Apparent problems in GPS signal reception on Third Avenue in downtown Seattle and in the tunnel, which did not impact the performance of the demonstration system in operation.
- The on-/off-route status indicator was triggered immediately by significant changes in the direction of coach travel, but gradual changes in direction were slow to indicate a change in on-route status. In addition, off-route operation on a street parallel and in close proximity to the coach's expected route did not trigger off-route status. The Smart Bus system had many system parameters that could have been optimized to improve performance had the supplier been given an opportunity, as would be expected in a system wide implementation.
- The demonstration system capitalized on frequent stops to improve the onboard AVL GPS processing. Additional evaluation and testing may be required for King County Metro service with few stops, such as express or night service.

Conclusion: Increased technical understanding for requirements development

The demonstration technical assessments provided staff with an opportunity to further their understanding of the technical attributes of the Smart Bus demonstration equipment, such as the onboard AVL and on-route status mechanisms, and their potential impacts on operations, as well as the APC and other demo equipment. With increased understanding, transit staff are better prepared to develop specifications and performance criteria for the future system procurement.

Conclusion: Technical issues and suggested next steps

The demonstration was helpful in identifying technical issues and suggesting future bodies of work including:

- *Explore testing requirements, process for system acceptance:*

Issue: While several evaluation technical analyses were limited in scope due to time and staffing constraints, and the temporary nature of the demonstration, they were nevertheless, labor-intensive efforts.

Next steps: The assessments highlighted the need to explore methods for more rigorous AVL, AVM and other onboard systems acceptance testing, including establishing performance criteria, level of effort, and methods for processing the large volumes of data that would be required. The AVL testing approach should include a representative sample of transit service routes and locations, as well as potentially challenging areas such as hills, tall buildings and heavily wooded areas.

- *Onboard systems requirements development:*

The GIS/AVL assessment has highlighted areas of emphasis for onboard systems requirements development to meet the needs and special conditions found in the King County Metro Transit environment including:

  - A downtown Seattle urban canyon;
  - The Downtown Seattle Transit Tunnel;
  - Off-route operation, such as short-term reroutes;

- *On-route status mechanism setting:*

As adjustable features of the demonstration equipment, determining the optimum settings for the on-route status function will represent a challenging decision for system implementation. If the off route parameters were set too loosely, under some circumstances, a rerouted bus could be more likely to fail to recognize its off-route status, and continue to make stop announcements in error. If the parameters were set too tightly, the system, could be more likely to erroneously determine small changes in heading and distance traveled as off-route status, causing the system to cease automated stop announcements and displays.

Implications for adopting this type of technology include teaching operators what actions will trigger off-route status, and what coach conditions will require operators to make stop announcements.

- *GIS stop assessment:*

Issue: The GIS/AVL assessment suggested areas of the Transit GIS map where more precision is required in mapping bus stops onto the GIS street network. The upcoming GIS transportation network upgrade is expected to improve the accuracy of the street network from approximately +/- 25 feet in incorporated King County and +/- 250 feet in unincorporated King County, to +/- 10 feet countywide. The increased accuracy is expected to contribute to more accurate placement of stops on the street network.

Next step: Additional analysis should be conducted to determine whether the GIS transportation network upgrade will resolve the issue of imprecisely mapped stops, or if a more precise method of locating bus stops on the street network will be required, such as determining location coordinates of bus stops in the field.

- *Urban canyon assessment:*

  Issue: The GPS urban canyon effect was observed in the analysis of onboard demonstration AVL data collected along Third Avenue in downtown Seattle.

  Next step: As the urban canyon effect has been problematic in AVL implementations at other transit properties, an assessment to confirm the extent of an urban canyon in downtown Seattle should be conducted as soon as possible, and the results incorporated into the system requirements development effort.

Objective 2: Assess customer satisfaction with the automated announcements and interior signs.

Conclusion: Valuable feedback from customers for improved specifications

The demonstration project provided a valuable opportunity to obtain customer feedback on the proposed announcement and display functions for the OnBoard Systems Project requirements development effort. Most respondents to the transit rider survey and Sound Transit CAAC discussion participants reacted favorably to the demonstration functions and identified areas for further improvement.

Automated stop announcements:

- The vast majority (89 percent) of survey respondents rated the interior next stop announcements as very or somewhat helpful, with over half of respondents (60 percent) rating the function as very helpful.
- Overall, Sound Transit's Citizen's Accessibility Advisory Committee and the Deaf-Blind Workgroup discussion participants appeared satisfied with the interior next stop announcements. Most participants rated the clarity, volume, and ability to hear the announcements over ambient noise, as good.

Issue: Timing of the stop announcements:

While most (87 percent) of survey respondents indicated the announcements of major stops and transfer points were made at the right time, 11 percent of respondents said the announcements came "too late," indicating an issue with the timing of the announcements. As an adjustable setting, the particular distance parameter setting used by the demonstration equipment for determining the timing of the next stop announcements will need to be examined in light of KC Metro's operating needs, and incorporated into OnBoard Systems project requirements development.

Automated next stop displays:

- The vast majority of onboard survey respondents rated the next stop displays highly in helpfulness and visibility, and considered the information accurate. The next stop displays were the most preferred demonstration function, selected by 43 percent of respondents.

Issue: ADA customer needs

Participants in Sound Transit's CAAC discussion expressed concerns with the display lettering color, and the location and speed at which the information changed on the display. Issues with sign visibility were noted from glare and the placement of the sign over the front window of the 40-foot Gillig.

Automated exterior route and destination announcements

While generally rated as very or somewhat helpful by three-fourths of survey respondents, this function was considered less helpful than the interior next stop displays and announcements. Seventeen percent of survey respondents rated the announcements as "not at all clear." The function was least likely to be selected by respondents if they could choose only one feature, selected by 8 percent of respondents.

Issue: Gillig exterior speaker location

The mid-coach placement of the exterior speaker on the 40-foot Sound Transit Gillig coach is problematic for people with visual disabilities, as noted by CAAC discussion participants. The speaker location should be moved to near the front door to allow people with visual disabilities to orient themselves to the entrance of the coach and hear the announcement more clearly. Placing the speaker at a consistent location near the front door of all coaches would be more practical.

Conclusion: Continue to incorporate customer feedback into the design process

A continuing challenge for the project will be achieving the optimal balance in qualities of the announcements and displays: volume, display lettering color, brightness - to meet the varied needs of a diverse rider population. As the project continues to refine system requirements, customer feedback will continue to be critical in the design decision-making process.

Specifically, more work will be required to:

- Refine the placement of the signs in the various fleet types to minimize glare and maximize visibility.
- Find the optimum rate at which the information on the signs change, requiring more research. Ideally, the product eventually purchased will allow vehicle maintenance or other technicians to control the speed settings.
- Find an alternative sign lettering format that meets the needs of people with disabilities, and is not distracting to other riders. Customer research and examination of designs used by other transit properties can help address this issue.

Objective 3: Obtain transit staff and transit operator feedback on the new functions: ease of use, advantages and disadvantages.

Conclusion: Mostly positive feedback from transit operator participants; unmet needs, but good potential for Vehicle Maintenance.

The demonstration project provided a valuable opportunity for transit staff to obtain hands on experience with the demonstration functions in their work environment. Most of the demonstration functions were well received by transit operators who participated in the demonstration debriefing. The generic, canned reports of the demonstration AVM functions were not useful to vehicle maintenance staff as provided, but showed good potential.

Transit operator feedback:

- Automated stop announcements: Transit operators who participated in the demonstration debriefing reacted positively to this function, noting it allowed transit operators to focus on driving;
- Automated exterior route destination signs changes: Transit operators who participated in the demonstration reacted very positively to this function, perceiving it as a timesaver for transit operators.
- Automated public service announcements: Transit operators reacted positively to this function, describing it as useful, but difficult to access on the demonstration transit control head installed above the operator's compartment.
- Exterior route and destination announcements: Operators had mixed reactions to the function. Some operators liked the announcements, as they saved operators the task of shouting the route number out the front door to waiting customers. Other operators found the announcements annoying and repetitive, as the announcement was repeated each time the front or back door opened in a bus zone.
- Schedule adherence and on-route status: Transit operator debriefing participants had a negative reaction to these functions, perceiving them as not useful.

Vehicle Maintenance staff feedback on AVM functions:

- Vehicle Maintenance staff found the data from the discrete input/outputs (I/Os) more valuable than the data from the J1708 network, such as oil pressure, which are generally available through gauges or a laptop.
- The demonstration Mobile TA tools and AVM web reports did not include I/O data.
- VM staff found the web reports cumbersome to use and difficult to read. The web report data were not available until the following day.

Objective 4: Identify issues, lessons learned, and recommendations for potential system wide implementation of the "smart bus" onboard equipment.

Over the course of the demonstration, participating staff identified a number of issues and suggested improvements if functions similar to those provided in the demonstration were implemented system wide. These observations also suggest future bodies of work for the On Board Systems project and related efforts. Among the more significant issues, lessons learned, recommendations and next steps identified in the course of the demonstration were:

Lesson learned: Gap between demonstration functions and VM needs

The demonstration offered an opportunity for Vehicle Maintenance staff to react to an actual AVM product prior to the development of user requirements. VM staff saw great potential in the functions, if they were more closely tailored to meet user needs to:

- Collect information required by King County Metro VM staff, especially discrete input/output data;
- Provide the ability to triage coaches needing repair as they return to the base;
- Report detailed AVM data within an hour;
- Generate reports in a user-friendly format.

Lesson Learned: AVM for coach repair triage

VM staff noted the primary value of implementing the Mobile TA Tools or similar function would be the ability to triage buses returning to the base according to their need for maintenance. The function would also need to indicate which component is out of tolerance, and include information from discrete I/Os. VM staff also had suggestions for the location of a Mobile TA tools or similar type of installation at the base.

Next Step: A large body of work highlighted by the demonstration will be an examination of the current vehicle maintenance coach lane assignment process and BO coach ("bad order" or coach needing repair) process to develop requirements for the Mobile TA Tools or similar function. Along with system requirements, a recommended revised business process will need to be developed.

Lesson Learned: Fewer keystrokes for operator controls

While the Smart Bus demonstration Transit Control Head (TCH) was not fully integrated with existing coach functions, such as the radio, the TCH provided a mechanism for testing operator reactions to potential new function control features. Transit operators participating in the demonstration found overriding the next stop announcements and destination signs, or operating the public service announcements required too many keystrokes. A key factor in achieving transit operator acceptance of a future system will be easy to use operator controls.

Lesson learned: Value-added features for transit operators

Transit operators participating in the demonstration debriefing perceived the automated stop announcements, the automated exterior route destination signs changes, and the automated public service announcements as demonstration functions that enhanced their ability to focus on safe coach operation and customer service. In contrast, the schedule adherence and on-route status functions were generally less valued by participants, and some found the repetitive nature of the exterior route destination announcements irritating.

Next step: Emphasize value added functions for transit operators in the design of the future system to increase the likelihood of the effort's operational success. Consider providing operators with some control over the exterior route destination announcements function, or other alternative for improving operator satisfaction with the function.

Lesson Learned: Continued operator involvement in DDU design

Although implemented for the short-term demonstration without KCM transit operator input, the demonstration Transit Control Head provided a physical product for transit operators to react to, and provide feedback for the development of requirements for the future Driver Display Unit. A key challenge for implementing the next generation of onboard technology functions will be the design of a user-friendly DDU, formally within the scope of the Smartcard project. To date, transit operator involvement has been incorporated in the initial DDU design efforts.

Next Step: Transit operator input throughout the DDU planning, design, and implementation efforts, will play a critical role in the operational success of the effort. Continue to involve transit operators in the DDU design development effort.

Issue: Stop sequence data quality

A systemic issue identified by staff who analyzed the demonstration data was a small percentage of errors found in the demonstration stop sequence data, originating from KCM sources. Due to discrepancies in the stop sequence data, technical staff involved in the demonstration had difficulty setting up the onboard stops database and using the data collected on the coaches. Although few in number, the stop data errors generated incorrect stop announcements and displays during operation of the demonstration coaches. The demonstration experience suggests that while the current data quality is high, onboard systems will require more stringent data quality as the data are used more widely throughout the agency, and any errors are highly visible to customers.

Next step: Providing the onboard systems with correct stop sequence data will be critical to successful implementation of the automated stop announcements and display, and APC functions. The Stop Information System (SIS) project, currently in progress, has the goal of addressing this issue, including determining a stop sequence data quality process, and staff roles and responsibilities.

Issue: APC process change

As noted in the APC assessment and technical staff debriefing, the implementation of smart bus integrated APC equipment will result in changes to the current APC process, notably elimination of some data post-processing, and increased volumes of data.

Next step: Along with integrated APC technical requirements development, a significant next step in the effort will be defining APC business process changes and staff roles in an onboard systems environment.

Issue: Data management process change

The demonstration has highlighted significant future efforts related to the King County Metro data management process changes required for onboard systems implementation including the:

- Data collection and data management process for the stops and route database onboard the bus;
- Implementation of the biweekly scheduling process and version control in an onboard systems environment;
- Distribution of data from the onboard database to the KCM user databases, such as APC, fare collection;
- Historical database design and maintenance issues such as database structure, data storage, data format, and data access.

Objective 5: Identify the potential long-term benefits of implementing smart bus technology.

Conclusion: Benefits to work environment and business processes identified through demonstration experiences.

Through their experiences with the demonstration project, King County Metro Transit staff were able to more clearly envision the benefits of the demonstration functions if implemented. Specific examples of the potential benefits of implementing smart bus onboard systems identified by staff during the demonstration project included:

Enhancement to transit operator work environment

Most transit operators participating in the demonstration debriefing perceived the automated next stop announcements, automated route destination sign changes, and automated public service announcements as enhancements to their work environment. According to the transit operators, the functions allowed them to focus on the operation of the vehicle and customer relations. In a work environment with a number of devices needing the operator's attention, the automated destination sign changes were "one less thing to worry about." A goal of the Onboard Systems and Smartcard projects is to streamline the operation of several devices used by transit operators: the radio, destination signs, and the proposed Smartcard and Security Camera systems, through an integrated Driver Display Unit (DDU).

More reliable APC equipment, more streamlined data processing

APC project staff anticipate that implementation of technology similar to the demonstration APC units would provide a number of benefits to APC data processing including:

- *Fewer repairs on APC units:* The current mat based APC system, installed on the coach steps, is prone to damage from passenger foot traffic and water damage. An alternative technology such as the Smart Bus demo infrared light beam, is expected to be less prone to damage in the coach environment.
- *Easier repairs, less impact on data collection:* New, modular APC equipment will allow technicians to more readily remove and replace the broken unit.
- *Less post-processing of data:* A considerable level of effort is involved in processing APC data after it has been collected from coaches. APC staff anticipate a new APC system that integrates stop data with passenger counts will streamline the process.

Enhancement to customer's riding experience

While the Smart Bus announcements and displays were designed primarily to benefit riders with disabilities and to meet federal ADA requirements, other riders also found the functions useful. Approximately 90 percent of survey respondents found the interior next stop displays and the interior stop announcements helpful. While the demonstration transit routes did not constitute a representative sample of all King County Metro transit service routes and their riders, the survey results suggest a potential that other customers may perceive the functions as enhancements to their riding experience.

More efficient triaging of coaches needing repair

Vehicle Maintenance staff participating in the demonstration noted implementation of the Mobile TA Tools or similar function would allow them to identify coaches needing repair ("BO" coach) and park them were they can be easily accessed. Staff report BO coaches are frequently parked in a lane with other coaches, and accessing a BO coach requires that surrounding coaches are moved out of the way by VM staff. Participants estimate this happens at least once per shift at each base, taking approximately 30 minutes of staff time per incident.

Even if this scenario occurs only half as frequently as estimated by participants (and at six of the seven bases, as Bellevue Base has stall parking rather than lane parking) Vehicle Maintenance staff spend an estimated 31.5 hours per week or 1,638 hours annually accessing "buried" BO coaches. This represents a large potential time savings system wide if the process can be conducted more efficiently.

Accessible Vehicle Maintenance diagnostic data:

Through their experience with the demonstration AVM functions, participating Vehicle Maintenance staff envisioned the potential benefits of an AVM system if tailored more closely to staff needs. Quick access to diagnostic AVM data would enable staff to:

- Manage fleet availability more effectively by identifying which coaches can go back into service and when;
- Manage staff work flow more effectively by identifying the expected duration of a repair job and staff availability to perform the work;
- Provide more preventive maintenance by utilizing the time saved from more efficient repairs.

Alternative for scheduling wheelchair lift preventive maintenance

Wheelchair lift preventive maintenance is currently scheduled by mileage. If an AVM function were implemented, VM staff suggested monitoring wheelchair lift use as an alternative method for scheduling PM. The potential benefit is possibly quite large if the reliability of the lifts were increased. 1,477 trouble calls were generated in 2001 as a result of wheelchair lift problems, requiring the dispatch of VM staff to assist a coach in the field.

IV. Appendix

Detailed Reports:

A. Rider Onboard Survey

B. Automated Vehicle Monitoring Debriefing

C. Transit Operator Debriefing

D. Technical Staff Debriefing

E. Smart Bus Accessibility Review

APPENDIX A

SmartBus On Board Passenger Survey

Regional SmartBus Demonstration Project Evaluation

March 2002

Management Information and Transit Technology Section
Transit Division
King County Department of Transportation

SmartBus On-Board Passenger Survey

Purpose: In the fall of 2001, King County Metro and Sound Transit began the joint Regional SmartBus demonstration project to evaluate on-board bus electronics and data systems. The project implemented SmartBus technology on two transit coaches (one KC Metro and one Sound Transit); and included visual and audio announcements of the route number, destination, major stops and landmarks. In order to obtain feedback and to assess customer satisfaction with these features, an on-board passenger survey was conducted. Of particular interest was the reaction of regular riders to the automated announcement features. While not formally a SmartBus feature, feedback was also solicited on the brighter exterior route destination signs.

Methodology: The SmartBus on-board survey was fielded during weekdays from December 3-17, 2001. Twenty-five SmartBus trips from 11 blocks of work were sampled for the study. The sampled trips included AM, Midday and PM time periods; operating on Metro routes 5, 54, 55, 7, 7E and 167 and Sound Transit's Route 570.

King County Metro hired a consultant—Northwest Research Group—to handle the on-board data collection. The questionnaire was designed by Metro staff (see Appendix A). Distribution of questionnaires to/from passengers and collection, occurred on both in-bound (coaches traveling toward downtown Seattle) and out-bound (coaches traveling away from downtown Seattle) service; with no data collection occurring within the Ride Free Area. The number of surveys collected was 479, which yielded an overall response rate of 69.7 percent.

Caveats:

- The SmartBus technology was installed on both 40' and 60' coaches. Review of the survey results has shown that the difference in coach type was not a factor in the results; so the findings will not be broken out by type.
- After the surveying was completed, a problem was found with some of the questionnaires. Specifically, some of the questionnaires omitted question #3b, "Where on the bus did you sit?"

Summary of Key Findings:

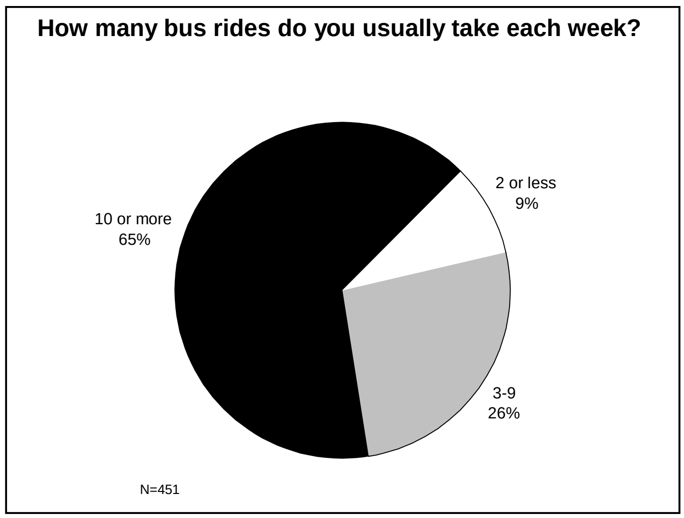
- Respondents tended to be regular riders, taking an average of 10.4 one-way rides per week.
- The vast majority of respondents (89 percent) were riding their usual route.
- Overall, the passenger survey indicated that the respondents liked the SmartBus features.
- It's important to note that the change in the outside signage, which was both larger and brighter than standard signs, was considered very helpful by 72 percent of the respondents.

- Seventy-seven percent of the respondents reported the volume of the bus announcements outside the bus was just right. Half (51 percent) of the respondents said the announcements were very clear, but 17 percent said they were “not at all clear.”
- The vast majority of respondents found the interior next stop announcements and displays and the exterior route and destination announcements very or somewhat helpful.
- The interior announcements were reported by the vast majority (87 percent) of respondents to be made at the right time.
- When the respondents were asked for their preference if only one of the SmartBus features could be added, the interior display signs were chosen by 43 percent of respondents, with 26 percent selecting the exterior route destination signs.
- The survey identified some areas for improvement, such as fine tuning the timing of next stop announcements and clarity of external route and destination announcements.

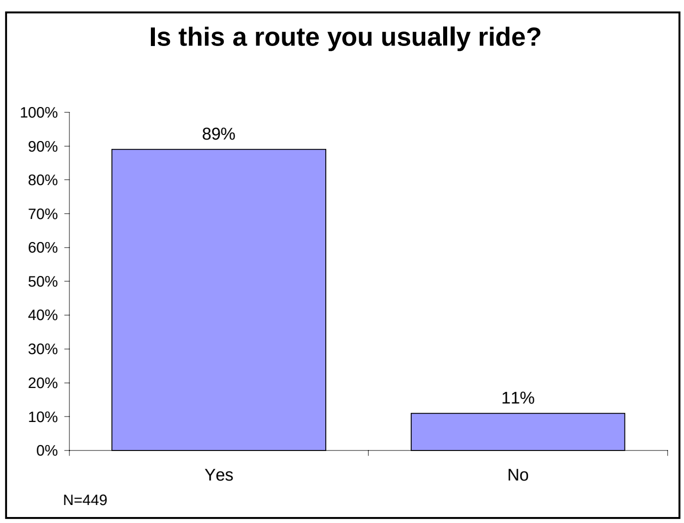
Detailed Results

Respondent Characteristics:

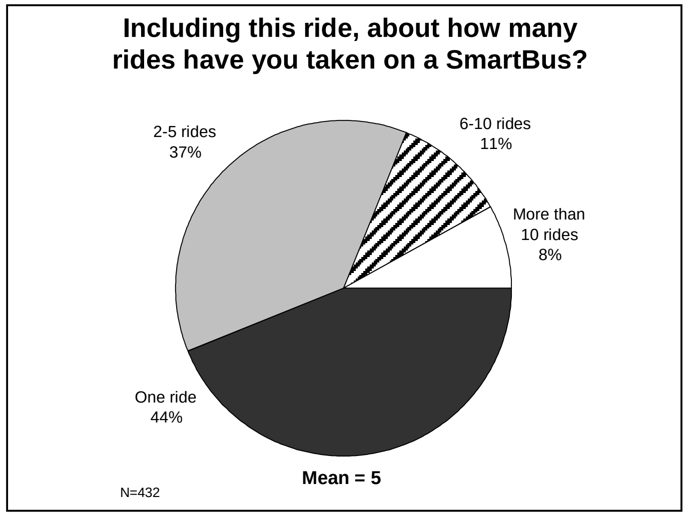
The vast majority (91 percent) of respondents indicated they were frequent riders, taking 3 or more one-way bus rides per week. Respondents took an average of 10.4 trips per week.



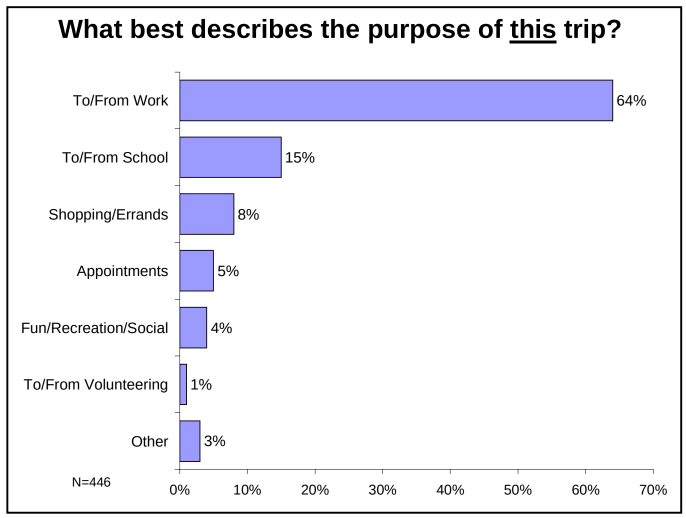
The vast majority (89 percent) of respondents indicated they were riding their usual route. Eleven percent of respondents were not riding their usual route.



Over half (56 percent) of respondents reported taking more than one ride on a SmartBus. Respondents took an average of five rides on a SmartBus demonstration coach.

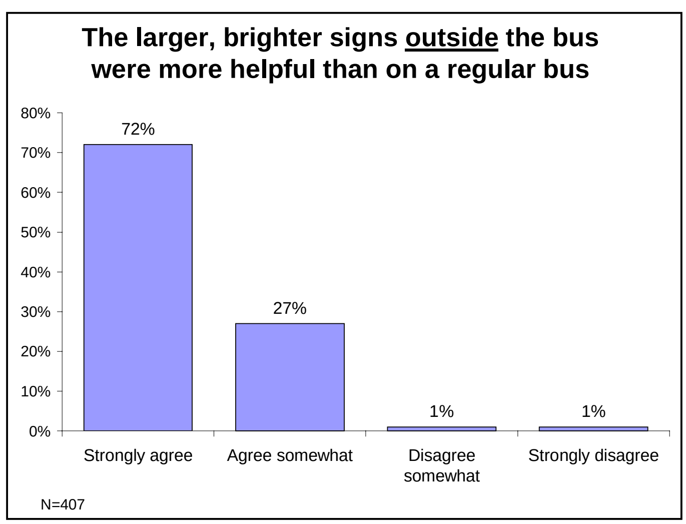


The majority (64 percent) of respondents said that the purpose of their trip was to commute to or from work. Another 15 percent of respondents were traveling to or from school.

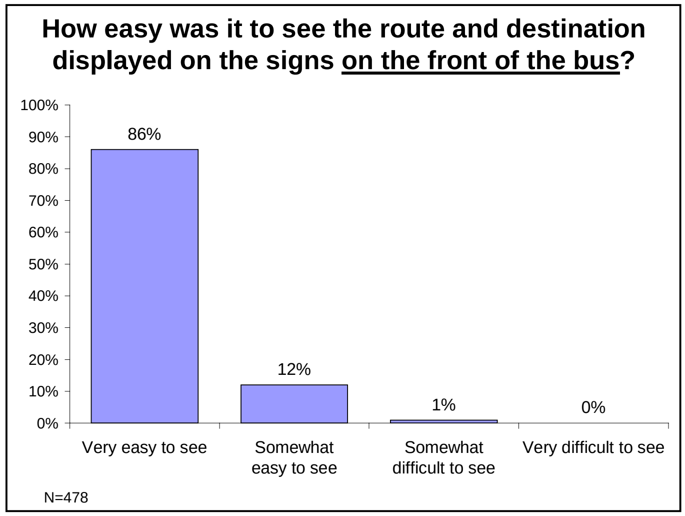


SmartBus Features:

A large majority (72 percent) of respondents strongly agreed that the larger, brighter signs <u>outside</u> the bus were more helpful than on a regular bus.

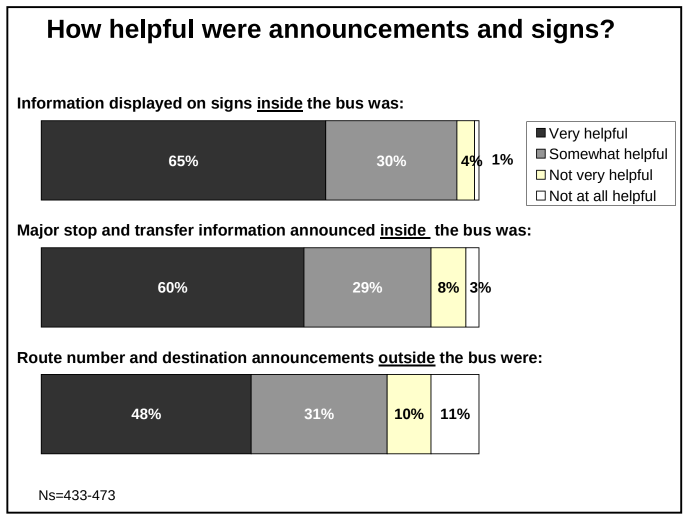


The vast majority (86 percent) of respondents said the exterior route and destination signs were very easy to see.

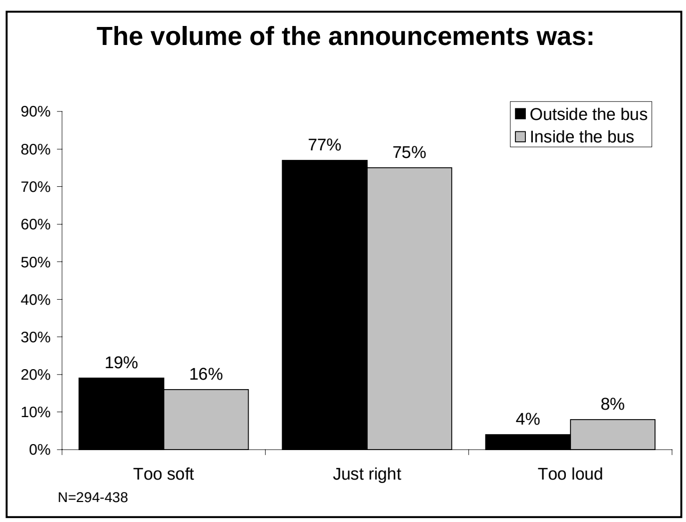


Respondents generally had a positive reaction to the SmartBus announcements and signs. About 90 percent of respondents found the interior next stop displays and announcements and exterior route and destination announcements very or somewhat helpful.

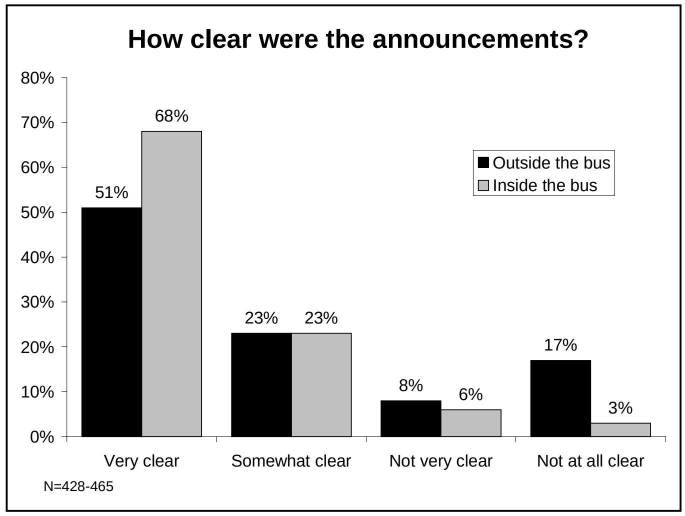
Almost 80 percent found the exterior route and destination announcements very or somewhat helpful.



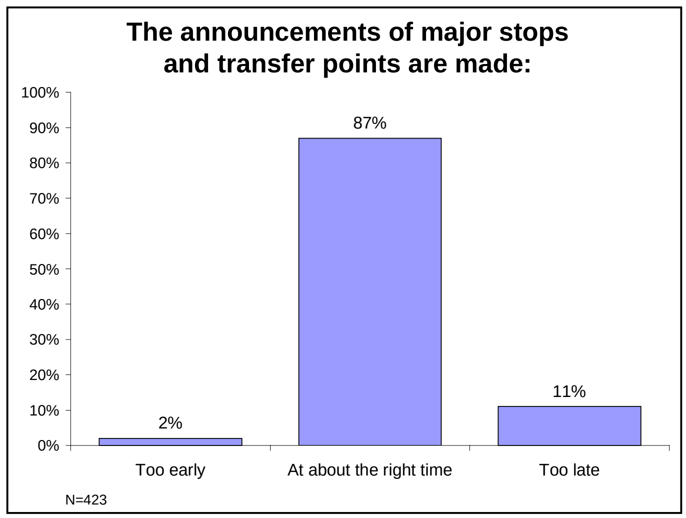
Three-quarters of respondents indicated the volume of the exterior route destination announcements and interior next stop announcements was "just right."



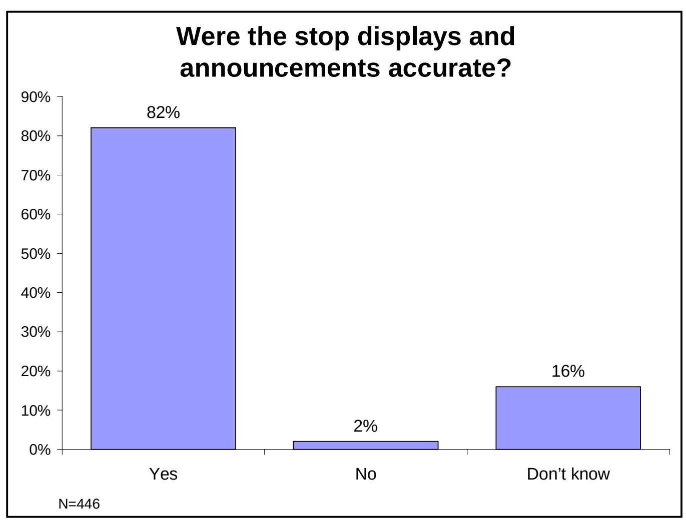
Sixty-eight percent of respondents said that the interior next stop and landmark announcements were very clear. Half (51 percent) of respondents indicated that exterior route destination announcements were very clear, and 17 percent rated the announcements as "not at all clear."



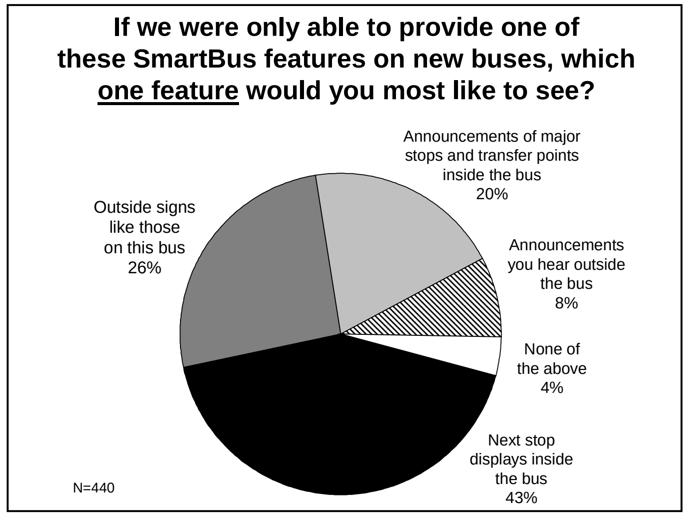
The vast majority (87 percent) of respondents said the interior announcements of major stops and transfer points were made at the right time. Eleven percent of respondents said the stop announcements came "too late."



The interior announcements were rated as accurate by 82 percent of the respondents. Sixteen percent of respondents said they "don't know" if the information was accurate.



Preferred SmartBus Feature: When asked if only one feature of the SmartBus were added, 43 percent of respondents chose the interior display signs. Notably 26 percent of respondents selected the exterior route destination signs, and 20 percent selected the interior next stop announcements.



Appendix A—Questionnaire with Responses
Welcome to the SmartBus!

King County Metro and Sound Transit are currently evaluating the next generation of on-board bus electronics, called the SmartBus. This bus is equipped with features designed to help riders reach their stop.

Please take a moment to provide us with your comments on the **automatic stop announcement system** and **signage** on this bus. Please return your completed survey to the person who handed it to you. Thank you!

Please answer these questions if this is the FIRST TIME you have been given this survey. If you have responded to this survey before, please return this to the survey worker.

Please rate each of the following SmartBus features:

1. Outside the Bus

a. How easy was it to see the route and destination displayed on the signs on the front and side of the bus? (n=478)

86% Very easy to see
12% Somewhat easy to see
1% Somewhat difficult to see
0% Very difficult to see

b. The larger, brighter signs outside the bus were more helpful than on a regular bus: (n=407)

72% Strongly agree
27% Agree somewhat
1% Disagree somewhat
1% Strongly disagree

c. The volume of the route number announcements outside the bus was: (n=294)

19% Too soft
77% Just right
4% Too loud

d. How clear was the route number announcement outside the bus? (n=428)

51% Very clear
23% Somewhat clear
8% Not very clear
17% Not at all clear

e. The route number and destination announcements on the outside of the bus were: (n=433)

48% Very helpful
31% Somewhat helpful
10% Not very helpful
12% Not at all helpful

2. Inside the Bus

a. How easy was it to see the signs displaying next stop and landmark information inside the bus? (n=475)

85% Very easy to see
11% Somewhat easy to see
2% Somewhat hard to see
1% Very hard to see

b. The information displayed on the signs inside the bus was: (n=473)

65% Very helpful
30% Somewhat helpful
4% Not very helpful
1% Not at all helpful

c. The volume of the announcements inside the bus was: (n=438)

16% Too soft
75% Just right
8% Too loud

d. How clear were the announcements inside the bus? (n=465)

68% Very clear
23% Somewhat clear
6% Not very clear
3% Not at all clear

e. The major stop and transfer information announced inside the bus was: (n=451)

60% Very helpful
29% Somewhat helpful
8% Not very helpful
3% Not at all helpful

2. Inside the Bus (continued)

f. The announcements of major stops and transfer points are made: (n=423)
- 2% Too early
- 87% At about the right time
- 11% Too late

g. Were the stop displays and announcements accurate? (n=446)
- 82% Yes
- 2% No
- 16% Don't know

3. Tell Us More…

a. How did you get on this bus? (n=461)
- 95% By the front door
- 5% By the back door

b. Where on the bus did you sit? (n=164)
- 40% The front of the bus
- 33% The middle of the bus
- 27% The back of the bus

c. If we were only able to provide one of these SmartBus features on new buses, which *one feature* would you most like to see? (n=440)
- 43% Next stop and displays **inside** the bus
- 26% **Outside** signs like those on this bus
- 20% Announcements of major stops and transfer points **inside** the bus
- 8% Announcements you hear **outside** the bus
- 4% None of the above

d. How many bus rides do you usually take each week? (n=451)
- 9% 2 or less
- 11% 3-5
- 15% 6-9
- 35% 10
- 18% 11-15
- 8% 16-20
- 4% 21 or more

e. Is this a route you usually ride? (n=449)
- 89% Yes
- 11% No

f. Including this ride, about how many rides have you taken on a Smart Bus? (n=432)
- 44% One
- 37% 2-5
- 11% 6-10
- 3% 11-15
- 2% 16-20
- 1% 21-30
- 3% 31 or more

g What best describes the purpose of this trip? (Choose one.) (n=446)
- 64% To/From Work
- 15% To/From School
- 1% To/From Volunteering
- 8% Shopping/Errands
- 5% Appointments
- 4% Fun/Recreation/Social
- 3% Other

h. What is your age? (n=458)
- 10% 16-19
- 15% 20-24
- 29% 25-34
- 20% 35-44
- 16% 45-54
- 7% 55-64
- 3% 65 or older

APPENDIX B

Vehicle Maintenance Staff Debriefing
Regional Smart Bus Demonstration Project Evaluation
Management Information & Transit Technology Section
Transit Division
King County Department of Transportation
March 2002

Purpose:

As part of the Regional Smart Bus Demonstration Evaluation conducted by King County Metro Transit, a discussion was held on February 14, 2002 with King County Metro Transit Vehicle Maintenance staff involved in the demonstration. The purpose of the discussion was to summarize Vehicle Maintenance staff experience with the demonstration automated vehicle monitoring (AVM) functions, lessons learned, and suggestions for improvements for system wide implementation. Management Information & Transit Technology staff facilitated the session.

The Smart bus demonstration AVM functions installed at Central Base included:

> Mobile TA Tools: Installed on a PC in the hostler's shack (vehicle maintenance dispatcher's office), this tool allowed VM staff to obtain a snapshot of several coach conditions as the demo coach returned to the base. Normal conditions were displayed on the screen as green, a temporarily out of tolerance condition was displayed as yellow, and a currently out of tolerance condition was displayed as red.
>
> TA Tools: This tool provided VM staff with next day access to detailed AVM coach data via pre-defined web reports.
>
> Custom data queries: Upon request, the Smart Bus demonstration vendor provided detailed printed data reports based on the Smart Bus demonstration data files.
>
> Discreet Input/Output monitors: Sensors were installed at 24 selected points on the demonstration coaches to monitor for changes in equipment status, e.g. "doors open" or "doors closed." The data from the I/O sensors was not available on either version of TA Tools.

Discussion Summary

AVM Data:

Great potential, but user requirements needed

In general, Vehicle Maintenance staff said they found great potential in the automated vehicle monitoring demonstration functions, but found little utility in the functions as implemented in the demonstration. To be useful to Vehicle Maintenance staff, the type of information collected by the system would need to carefully match staff needs, and improved reporting and data analysis tools would need to be provided.

Initial accuracy issues

According to participants, both Mobile TA Tools and TA Tools displayed some inaccurate data in the first few weeks of the demonstration. These were identified as software data translation errors and were subsequently fixed by the vendor. In the meantime, users lost confidence in the system and stopped using Mobile TA tools, but continued to work with the vendor on improving the TA Tools web reports.

Overall accuracy

Once the initial translation errors were fixed, participants considered the AVM data to have good overall accuracy. Apparent false readings turned out to be accurate when investigated further, but some looked unusual at first because the data required some interpretation, participants said.

Use of AVM data to identify problems

When asked if the system was ever used to identify a vehicle problem, participants noted the system indicated a yellow status "out of range" reading on coach 9024 for oil pressure. This was identified upon inspection by mechanics as a pressure switch problem, as well as low coolant. These problems, if unattended, had potential for eventually generating a road call, participants said.

Discrete I/O data most valuable

Demonstration data from discrete input/outputs (I/Os) provided the most valuable type of information as opposed to information from the vehicle's J1708 network, which currently can be monitored by gauges or a laptop, participants said. Examples of I/O data include: the 30 and 35 mph switches, fan control, rear door, and wheelchair lift cycles. Participants identified exhaust back pressure and air intake restriction as other useful I/O data items for a future AVM system. These would require the addition of sensors.

Sensors required for I/O data

Participants said some AVM I/O data items described by the vendor were not actually available, such as coolant level. The capabilities of the system are limited by the hardware installed on a coach. If there are no sensors installed on coach to collect the information, the system can't report it, participants said.

Coordinate with coach procurement for I/O sensors

In order to monitor discrete I/Os, participants said, sensors will need to be installed. By coordinating with Vehicle Procurement, new coaches could be specified with the sensors installed for each I/O of interest. Participants anticipated needing about twenty four I/Os.

Sensors could be moved if needed for equipment testing or monitoring a specific I/O on a specific coach type.

Lessons learned: data definitions need VM input

One of the lessons learned by participants from the demonstration was that more work is required in defining what items are monitored and how. Participants mentioned wheelchair lift use as an example. "The vendor is monitoring that power went to the lift, but we want to know whether the lift was deployed. We have different expectations of what 'monitoring' a wheelchair lift means."

Mobile TA Tools:

Discussion participants said the Mobile TA Tools function was not useful as provided for the demonstration because the information was generally available through dashboard gauges, such as the oil pressure gauge, and other readily available indicators.

Participants described the Mobile TA Tools function that displays coach status as red, yellow or green as "idiot lights" without an associated measure, such as degrees of pressure. In order to obtain detailed diagnostic information on the coach, VM staff still needed to plug a laptop into the coach (current VM practice), participants said.

Mobile TA Tools improvements

While data accuracy issues led to an early abandonment of Mobile TA Tools by VM staff, participants believed the concept is still a good one. The primary value of implementing such a function would be the ability to triage buses returning to the base according to their need for maintenance. According to participants, the function would need to provide:

- An indication of conditions red, yellow or green, with red and yellow indicating out of tolerance conditions (as the demo system did).

- Out of tolerance conditions would need to be accompanied by data indicating which component is having a problem.

- The data would need to include information from discrete I/Os.

Better triage would save time and money

Identifying coaches with out of tolerance conditions as they pull into the base, before the coach is parked, would allow more coaches with problems to be parked in the "BO lane" or holding area for coaches with problems, rather than parked with the other coaches, participants said.

Current process generally relies on the transit operator to tell the hostler if the coach is "BO" (needs work) and needs to be parked in the BO lane. Participants said sometimes transit operators fail to mention problems, or they are not apparent to the operator, as in the case of equipment monitored by discrete I/Os. Coaches that require work are parked with the other coaches. If later identified as a BO coach, either through an operator request form (OR) or other means, the coach must be moved, requiring that surrounding coaches are moved out of the way. Participants estimate this happens at least once per shift at each base, taking approximately 30 minutes of staff time per incident.

Location of Mobile TA Tools

Participants discussed possible future locations at the base for Mobile TA Tools or similar type of equipment for triaging coaches. If located in the hostler's shack, the equipment would need to be staffed around the clock, so someone would be there to see the information displayed by the system. Participants saw similar staffing needs if the equipment was installed in the lead mechanic's office. Locating the equipment at the fuel building has an advantage, participants said, as all coaches are fueled daily, or in the case of trolleys, have their fareboxes pulled.

Electronic "BO" notification

Participants reacted positively to the proposal of providing transit operators with the ability to flag a coach problem by selecting a pre-coded item from the menu on the operator's driver display unit (DDU). This would not replace the current Operator Request (OR) or BO form, as a detailed description of the problem would still be needed by Vehicle Maintenance staff. Participants said this would be another means to help ensure problem coaches are identified.

Participants noted the coach's data and BO status would need to be cleared out, perhaps by a reset button or some other mechanism, to give the coach a "clean slate" following repair, to allow the coach to go out again. Otherwise, participants were concerned that a repaired coach might still appear in the system as BO or out of tolerance if the coach was repaired quickly and sent back on the road.

TA Tools (Historical web reports):

The TA Tools web reports provided detailed AVM data to staff through canned reports distributed on the vendor's Internet site.

Data turnaround time

AVM data were available in the web reports the day after the coach pulled in to the base, not soon enough to really be useful, participants said. Ideally, detailed diagnostic data would be available in real-time, or at most, an hour after the coach's pull in at the base. This implies a server at each base, participants said.

Web reports not user friendly

The TA Tools next day web reports provided in the demo generally did not meet their needs, participants said. Participants noted the user interface was clumsy and required the viewer to go through many screens to finally view the data they wanted. The charts and scales were difficult to read, participants said.

Custom Data Queries:

Emphasis on exception reporting

When participants requested some special data queries from the vendor, they were surprised by the volume of data they received, for example, some measures were recorded every second. Upon viewing the reports, participants said, they really wanted to see the exceptions or out of tolerance items, for example all coaches with coolant temperatures above 250 degrees. In addition, some information makes more sense when viewed along with other data, participants noted, such as the 30 and 35 mph switch data should also include coach road speed.

Next System Reports:

Discussion participants said that in the next system, they would want to generate reports themselves by selecting desired data elements from a menu. The system must include reporting capabilities for discrete I/Os.

Participants said they will want some preset or canned reports, as well as the ability to develop customized reports themselves if necessary.

<u>AVM Data Access</u>

Participants expected the AVM data would be valuable to vehicle maintenance chiefs in identifying performance trends by fleet type over time. They expected chiefs, leads, and mechanics would need to query AVM data on a daily basis.

Potential benefits of diagnostic data:

Participants said quick availability of diagnostic information will help reduce the time mechanics spend diagnosing problems. Vehicle Maintenance staff will be better able to identify which coaches can go back into service and when, allowing staff to more effectively manage fleet availability. In addition, participants said, VM staff would be able to manage their work flow more effectively by being able to identify the expected duration of a repair job and staff availability to perform the work. Participants expected more efficient repairs would allow them time to do more preventive maintenance.

<u>Wheelchair lift use and PM</u>

From the demonstration data, participants learned how little the wheelchair lift was used on coach 9024. Vehicle maintenance currently maintains wheelchair lifts through a preventive maintenance schedule based on vehicle mileage. Participants said they are interested in looking at lift usage vs. mileage as a possible basis for scheduling PM. The potential cost savings could be large if wheelchair lift preventive maintenance could be done more efficiently, as each PM requires approximately eight hours of labor.

Training important to success:

As some Vehicle Maintenance staff are not PC literate, participants noted, user training will be an important aspect of the project system wide implementation as well as "easing folks into it."

APPENDIX C

Transit Operator Debriefing Summary
Regional Smart Bus Demonstration Project Evaluation
Management Information & Transit Technology Section
Transit Division
King County Department of Transportation
February 2002 revised 6/20/02

Introduction

As part of the Regional Smart Bus Demonstration Project evaluation conducted by King County Metro Transit, a debriefing session was held on January 23, 2002 with transit operators who had operated Smart Bus (aka Intellibus) demonstration coaches. The purpose of the session was to assess operator satisfaction with the Smart Bus demonstration functions and obtain operators' recommendations for a potential system wide implementation of the Smart Bus onboard equipment. The session was facilitated by Research & Management Information staff. Fourteen Central Base transit operators participated in the session: nine full-time transit operators and five part-time transit operators.

The Smart Bus demonstration functions discussed in the session included:

- The automated stop annunciation function that announced major stop and landmark information to riders;
- Exterior route destination announcements that announced the coach's service route and destination;
- Automatic route destination signs, designed to automatically change the coach's exterior signage without operator intervention;
- Schedule adherence information, displayed as minutes ahead or behind schedule on the transit control head;
- An on route or off route status indicator, displayed on the transit control head;
- Recorded public service announcements that could be played to passengers at the operator's discretion.

Discussion Highlights

<u>Interior stop announcements</u>:

Most discussion participants liked the interior stop announcement function and stated it should be included in a smart bus system wide procurement. Some participants noted the function benefited operators by allowing them to focus on driving and gave them "one less thing to worry about."

Participants noted that most of their passengers liked the stop announcements. Several operators received positive feedback from people with disabilities.

Participants stated the function generally worked well, noting a few instances where the wrong announcement was made by the system, or no announcement was made.

Route 570 operators noted problems with the stop announcements at the airport.

The timing for next stop announcements needs further refinement, participants noted. Depending on the route and the coach's speed, the announcement may be made as the coach is passing the stop, or after the coach has passed the stop. Suggestions from participants included customizing the timing of announcements for each route, or that announcements should be made immediately after the doors close.

Other suggested improvements included adding a "next stop will be an express stop" announcement for express trips, shortening the announcements, and eliminating the "beep" the system makes prior to an announcement. Participants noted times when they mistook the beep for the stop requested bell and inadvertently pulled into a stop when no stop was requested.

Some operators felt that the automated announcements would be improved if more concisely worded, for example "California and Alaska" instead of "California Avenue Southwest and Southwest Alaska Street."

Participants also requested a more user-friendly system requiring fewer keystrokes to make it easier for operators to intervene if the system malfunctions, or if the operator wishes to make announcements themselves.

<u>Voice used for automated announcements</u>

Participants had varied opinions on the female voice used to announce stops in the demonstration. Some participants thought the voice was fine, others thought it was difficult to hear or not "assertive" enough. One suggestion was to have a variety of different types of voices making announcements.

A few participants suggested that announcements should be made by someone from the Northwest to provide a more regional pronunciation of locations.

<u>External route and destination announcements</u>:

The external route and destination announcement function received mixed reactions from discussion participants. A few participants stated that they liked this feature, as it saved them the task of "having to holler out the front door" to visually impaired riders. The function was well liked by their visually impaired customers, these participants said. Most participants found the announcements repetitive, and recommended that the announcement should play only once at a bus stop, to avoid replaying the announcement if the doors open again for late riders.

Automated destination signs

Participants expressed enthusiasm for the Intellibus automatic destination sign change capability, and wanted to see this feature as part of the future system procurement. One participant noted he had trouble getting the signs to change at his terminal and needed to repeat the log in process. Other participants noted the current override requires too many keystrokes. The function would be improved, participants said, if the system was easier to override when an operator needs to manually change the coach's signage.

Schedule adherence status

In general, participants did not find this function helpful. None of the discussion participants relied on the schedule adherence function provided on the transit control head, which displays minutes ahead or behind schedule as of the trip's most recent timepoint. Most participants said they had "checked out" the function, but found it to be either not consistently reliable or not useful to them. Participants indicated the information would not be useful to them if it was more reliable, or if provided in an alternative format, such as predicted arrival time at their next timepoint. Most participants stated that gauging the operation of their schedule is an essential aspect of their duties. Typical comments from participants included "It's our job to know how to drive the route on time," "There are too many variables in operating a schedule: construction, traffic. We are familiar with the route and know a wheelchair rider will be at the next stop."

A few participants expressed concern about the potential use of schedule adherence information for disciplinary purposes.

On route/off route status

In general participants did not find the on and off route status indicator available on the transit control head useful, and recommended excluding it from a future system implementation. Participants expressed the view that they considered being on route as one of their key responsibilities in operating the vehicle, not requiring automated assistance. "We have *The Book* for that," "Our passengers will know if we are off route if we don't know," were typical comments.

A few operators noted the function would be useful "if it provided a map to tell us how to get back on route."

Public Service Announcements

Participants described the public service announcements that could be played by the transit operator as a useful function, but difficult to access on the demonstration transit control head. Participants said they would use the function if it was easy to get to, requiring no more than two keystrokes. Suggested announcements included announcements of the fare structure, "Please the exit through the front door only," "Please have your fare ready," "Please move to the back," and "Please refrain from using profanity."

Suggestions for next Driver Display Unit (DDU)

Based on their experiences with the Intellibus demo, participants suggested the following features for a future DDU:

- An accurate clock;
- A list of ADA stops for use in case the stop annunciation function isn't working;
- An automated display of run card information, showing next timepoint and scheduled time, one line at a time.

Operator Training

Discussion participants said they received either a brief explanation from the training office staff and a printed handout, or the handout alone, to prepare them to operate the demonstration equipment. Generally participants indicated they felt adequately prepared for the basic log in procedure, but felt less prepared for system troubleshooting or other special circumstances that arose.

Most participants stated they would like to see an operator training class offered if Smart Bus technology is implemented on the fleet. Other training related suggestions from participants included: instructions in The Book, a user-friendly instruction manual, posted instructions near the DDU, and a working training model of the equipment at the Training Center.

APPENDIX D

Smart Bus Demonstration Evaluation
Technical Staff Debriefing Summary

Participants: Reta Smith, Wayne Watanabe, Martha Woodworth, Tony Longo, Ruth Kinchen, Tamara Davis, Brad Kittredge, Bob Syslo-Seel, Dan Overgaard

As part of the Smart Bus Demonstration project evaluation, a discussion was conducted on April 15, 2002 with a group of King County Metro Transit technical staff to identify technical lessons learned and system wide implementation issues raised by the demonstration.

The group was provided with an update on the technical results of the demonstration:

- Onboard and base equipment start up and operation;
- APC assessment;
- GIS assessment

The updates were followed by discussion of the potential implications for the OnBoard Systems project implementation.

Discussion Highlights

The following discussion highlights present key issues and observations identified by the discussion participants. Detailed results from the APC and GIS assessments noted below will be available in separate sections of the Smart Bus Demonstration Evaluation report.

Demonstration On Board equipment

Overall, the hardware and software installed on the bus worked reliably and did not break down.

The dynamic data on the bus was stored on a PCMCIA card, as opposed to the vehicle logic unit (VLU). The demonstration equipment configuration did not test the VLU as the primary storage and processing mechanism for dynamic data.

Implementation issues and considerations:

- Installation of the 24 discrete input outputs (I/Os) on the demonstration coaches took the vendor a considerable amount of time. It is expected that with experience, the process can be streamlined and standardized, but is likely to remain labor-intensive.

- The set up of the stops and route database onboard the bus involved collecting GPS location coordinates for each bus stop and every 50 feet along the bus route. How will this be accomplished in implementation? The project team is considering options for the system wide process, including collecting the information while buses operate in service, or using the Transit GIS map.

- The accuracy of transit stop sequence data remains an issue for the project. Discrepancies in stop data were identified throughout the course of the demonstration by various analysts. A goal of the Stop Information System project is to increase the consistency and accuracy of stop sequence data for the OnBoard Systems project.

- The group identified transit operator training issues related to the stop annunciation function including:
  - What does the system consider as off route operation and how will the system behave?
  - By what process will transit operators report errors in stop announcements?

WDOLS and base equipment

Throughout the demonstration, data was communicated between the bus and base server via a wireless data offload system (WDOLS). The automated wireless communications system automatically transmitted vehicle performance data from the vehicle each time it returned to Central Base and provided automatic data and software updates to the vehicle.

Implementation issues and considerations:

- WDOLS will require security measures to prevent hacking of the base servers, KC WAN, or the equipment on the buses.

- Adequate emergency power supply will be an issue as more systems are installed at the base facilities: security cameras, onboard systems, Smartcard.

- The number of systems sharing the base servers will increase the need for server management and coordination.

- The base servers are not expected to be managed by base staff but rather by King Street Center staff.

APC Assessment

The group reviewed the results of the APC assessment. The demonstration APC equipment performed well overall, but did not fully meet current APC program specifications.

Implementation issues and considerations:

- The need for clean source data was highlighted in this analysis, as errors were seen in the stop sequence data. The ability to identify errors in stop sequence data and correct them in a timely manner will be a critical implementation issue.

- In an onboard systems environment, APC post processing will be eliminated, but the volume of data managed by staff will increase. The impact on APC staff and work processes will need to be assessed including:
  - the data quality and troubleshooting processes;
  - the required toolset for managing and troubleshooting APC data;
  - staffing requirements.

OBS Data management

Implementation issues and considerations:

A large body of work exists to address the following onboard systems data management issues:

- By what process are data from the onboard database parsed to the various user databases, for example APC, fare collection, etc?

- How much data will be stored on the bus before it is overwritten?

- The resulting historical database is potentially very large. Database issues include:
  - Database structure to allow comparison of planned vs. actuals;
  - How much data is stored and for what duration?
  - What data are stored in summary form, such as averages, vs raw data?
  - What are the legal requirements for historical data, such as L&I, safety?
  - How will the data be viewed by users?

- Implementation of the biweekly scheduling process in onboard systems environment. By what process will schedule versions be controlled and updated onboard?

- The project team envisions an automated process for implementing current and next service change onboard, including a trigger for when the bus should use the next service change data set.

GIS Assessment

For this assessment, demonstration onboard stop event data was mapped onto the Transit GIS map. Overall, the demonstration stop event locations coincided fairly closely with the GIS stop locations, averaging 72 feet from the GIS stops, with a standard deviation of 64 feet, and a range of 3 to 510 feet.

<u>Implementation issues and considerations:</u>

- The variability between onboard stop events and Transit GIS stops on 3rd Avenue in downtown Seattle, suggested the "urban canyon" effect of "raw," unenhanced GPS technology, where the global positioning satellite signal cannot be received by the vehicle if it is surrounded by tall buildings or hills. The vendor AVL product provided an algorithm to correct the vehicle's determined location if the GPS signal was inadequate. In the demonstration installation, this feature was not used to correct the location data in the onboard data record, but only for the stop announcement and display functions, which worked well in downtown Seattle with no apparent urban canyon effect.
    - Overcoming the potential urban canyon effect will be a significant challenge for the effort. Options suggested by the group included retaining some signposts from the current AVL system, or supplementing the CAD interface with a "snap to" function with additional logic.

- Areas outside downtown Seattle showed several instances of demonstration stop event data clustered hundreds of feet away from the GIS stop, suggesting the GIS stop location may be in error. Stops are placed on the Transit GIS map relative to the street network, not map coordinates collected in the field, and are the more likely source of error.

- One option to explore would be to define a bus stop spatially as a zone or distance, rather than as a point, to improve the appearance of OBS stop data on the Transit GIS map, and to provide a more realistic representation of a bus stop.

Demonstration Automated Vehicle Location (AVL)

Discussion participants noted that while not yet confirmed by the Smart Bus Demonstration vendor, it appears the onboard AVL function relies heavily on its odometer and gyroscope readings to determine location, corrected by GPS data when the coach opens its doors at a stop. It was noted during off route operation of the demonstration coach that the stop announcements feature resumed when the coach returned to its expected route and had serviced a zone. If this is the case, such a "synching" mechanism would not work well for routes with few stops or during night service.

Implementation issues and considerations:

- A mechanism to trigger more frequent synchronization with GPS should be explored, such as changes in heading (direction of travel) from the gyroscope.

APPENDIX E

WASHINGTON STATE
TRANSPORTATION
CENTER

This memo presents a summary of findings from the Smart Bus accessibility issues review. Members of Sound Transit's Citizens' Accessibility Advisory Committee and the Deaf-Blind Workgroup participated in the review November 20, 2001.

QUESTIONNAIRE RESULTS

Most of the individuals participating in the accessibility review (and all those who completed questionnaires) had full or partial mobility, hearing and/or sight impairments. Following a familiarization ride through downtown, eight participants completed a questionnaire regarding their reactions to the features and performance of the Smart Bus customer information technologies. The questionnaire responses highlighted all of the aspects of the Smart Bus discussed during the familiarization ride. Many of the concerns raised by the participants were related to features of the bus itself such as flooring, stop request strips, and overhead racks. The results reported here relate only to the Smart Bus customer information features, specifically the following:

- Interior next stop display
- Interior next stop announcement
- Exterior route and destination announcement
- Exterior destination signs[1]

The questionnaire responses are detailed in two charts attached to this memo. The first chart reports the ratings for each feature and the second lists clarifying comments made by the respondents. Pictures of the interior and exterior signs are also attached.

[1] Although not technically a Smart Bus component, an advanced exterior destination sign was used on the Smart Bus demonstration buses and customer reaction to it is being evaluated along with the Smart Bus features.

Interior Next Stop Display

Participants were asked to rate on a scale of 1 to 5 (1=poor, 3=fair, 5=good) the size, contrast, clarity, and location of the interior next stop display. Of these, the color of the lettering and the location of the sign raised the most concern. Several participants indicated that the red LED (light emitting diode) letters were very hard to read and could potentially cause epileptic seizures in some individuals. Bright yellow lights on a dark blue or black background or blue-green dot matrix signs were suggested as preferred alternatives. One respondent noted that the overhead light in the bus interfered with the visibility of the sign. Comments received from another CAAC member who was unable to participate in this review session indicated that glare from an open roof hatch made the sign very difficult to read.

The interior sign on the demonstration bus (a 40-foot Gillig) was located directly above the front window. Several participants reported that the sign was difficult to see from the left side wheel chair securement area and from the seating directly behind the driver.

The pace with which the messages on the sign changed was a concern to several participants who indicated that it was difficult to read because it changed too fast. Other suggestions to improve the usability of the signs included making the lettering bolder, bigger and less "dotty."

When asked about the visibility of the interior sign from the forward seating area, responses ranged from poor to good. Most of the participants sat in the front section of the bus but those who responded to questions about visibility in other areas of the bus generally indicated that it was poor.

Interior Next Stop Announcement

Most respondents rated the interior next stop announcements as "good" and comments included "very good" and "excellent." The only suggestion related to the interior announcements was to announce street names whenever the bus makes a turn during service outside of the downtown area.

Exterior Route and Destination Announcement

Unfortunately, some of the review participants were not able to experience the exterior announcement feature due to the logistics of loading the bus. However, for those who were in a position to hear the announcement, it became clear that the location of the exterior speaker was inappropriate for this Smart Bus feature. While intended to identify the bus to waiting passengers, the speaker on the 40-foot Gillig buses is located between the front and back doors, not at the front door where it would be useful for sight impaired passengers. Participants also noted that the announcement was not loud enough.

Exterior Destination Signs

As part of the Smart Bus demonstration, new destination signs were installed on the front and side of the bus. Again, loading logistics made it impossible for most participants to determine the visibility of the sign as the bus approached. However, most of those who saw the sign rated it "good" and one participant even noted that it was "the best I have seen!" Comments included concerns about visibility in sunlight and a note that it was difficult to read the first time but might get easier with time.

Table 1: Smart Bus Accessibility Review Questionnaire – Feature Ratings

		Respondent A	B	C	D	E	F	G	H
External Announcements	Clarity of announcement	1	5		1				1
	Volume	1	5		1				1
	Ability to hear over ambient noise	1	4		1				1
Internal Announcements	Clarity of announcement	5	5	5	5				3
	Volume	5	5	5	5				3
	Ability to hear over ambient noise	5	5	4	5				3
Exterior Destination Signs	Size of display					4	5	5	4
	Contrast of lettering to background					3	5	5	4
	Clarity of type					1	5	5	4
	Clarity of display on approaching bus						4		4
Interior Next Stop Displays	Size of display		3		2	1	5	3	4
	Contrast of lettering to background				2	1	5	4	4
	Clarity of type		3		3	1	5	4	4
	Able to see from the forward seating area		2		3	3	5		1
	Able to see from the middle seating area		3/4				1		
	Able to see from the rear seating area		1				1		
General	These features improve the accessibility of transit services for me	Y	Y	Y	Y	Y	Y/N	Y/N	N

Rating scale: 1=Poor, 3=Fair, 5=Good

Table 2: Smart Bus Accessibility Review Questionnaire – Comments

Respondent	Subject	Comments (related to Smart Bus)
A	External speaker location and volume	Speaker outside the bus is difficult to hear because of ambient noise, place speakers outside of doors instead of in the middle
A	Interior sign color	Bright red or green lights can cause epileptic seizures
A	Interior sign location	Beware of headroom if you move the sign at the front of the bus (interior) back a little
B	+ Interior announcement content	Voice announced ADA stops, requested stops very good.
B	Interior sign color	Red interior sign needs to be blue green, dot matrix style. Red signage hard to read.
B	Interior sign location	Electronic interior sign -- move behind driver to permit easy viewing from all handicap seating and better viewing angle from middle seats.
B	Interior sign pace, content	Pace of announcements brisk. Too much information possible - eliminate time announcement.
C	+ Interior announcement content	Interior announcements were excellent.
C	External speaker location and volume	External announcement speaker not working. I look forward to hearing it when it is available.
D	External speaker location and volume	External speakers need to be by the doors and louder.
D	Interior announcement frequency	Suggest making announcement of streets whenever bus turns when operating outside Metro area.
D	Interior sign color	Internal board should be bright yellow on dark blue or black background.
E	+ Interior sign content	Display sign worked because it repeated frequently. If I miss it, keep watching, will catch it.
E	Exterior sign clarity	Exterior sign clarity of type -- too many dots
E	Exterior sign color	Exterior sign contrast -- blue dots might be better, hard first time, may improve when used to it
E	Interior sign clarity	Interior sign clarity -- too "dotty"
E	Interior sign color	Interior sign contrast -- red is too dark, prefer green or blue
E	Interior sign size	Interior sign should be taller and wider
E	Interior sign visibility	Overhead light interfered with ability to see interior display
F	Exterior sign visibility	Exterior sign -- not sure about contrast in sun, today was overcast, I would like to assess the contrast under sunny conditions and see if it is still bright enough
F	Interior sign font	Interior display -- suggest more bold type, similar to outside
F	Interior sign location	Display in front of bus -- I like the forward location directly over the window. I tend to sit in first seat. If sign were moved back nearer to seats, it would be difficult for me to see it so close overhead.
F	Interior sign size, font	Size of interior display - understand that I need to sit in front of bus to make use of the type
G	+ Exterior sign visibility	Exterior destination signs -- The best I have seen!
G	Interior sign location	Not able to see interior sign -- only if I stand close
H	Interior sign location	Internal signage difficult to read from left wheelchair securement area.
H	Interior sign pace	Internal announcement board changes a little too fast