Advanced Transportation and Congestion Management Technologies

Final Report

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Background

The Greater Cleveland Regional Transit Authority (RTA) provides public transit, bus, and rail service in the Greater Cleveland area. In order to provide safe and efficient service, RTA has radios and computers installed on each vehicle. This technology provides communication to each operator along with vehicle location.

In 2001, the previous radio system was installed with Enhanced Digital Access Communication System (EDACS); this technology was in the middle to late periods of its life cycle at the time it was implemented. This system was obsolete, and RTA needed to invest in a new system. The majority of the mobile equipment and radios could not be repaired since parts were no longer manufactured. Repairs were made with used and/or cannibalized parts from other out of service units. RTA was informed there were critical tower parts that could not be replaced in the event of a failure.

In order for the Computer Aided, Automated Vehicle Locator (CAD/AVL) system and radio system to function properly, the hardware and software must be maintained and operational. If one software component fails, it affects the system and, in many cases, causes the other areas of the software to fail. RTA relies on the radio system to support the CAD/AVL system; without a functioning radio system, RTA cannot visually see or communicate with operators. When these systems are not functioning properly our bus and rail vehicles must be reviewed by our Maintenance staff and cannot be released into service; potentially causing services to be reduced.

In 2013, RTA decided it was in the best interest of the authority to replace the current radio system and onboard equipment. The radio system was obsolete, unsupported by most vendors and many components could not be purchased/replaced. RTA's communication continued to weaken as equipment continued to fail creating major safety issues for RTA. In 2016, RTA had a major radio failure which resulted in our rail system being non-operational for 2 days.

Prior to purchasing a new communications system, RTA hired IBI Group to conduct a study to identify the best communications method to meet our operators and customers' needs. The goal of the study was to evaluate each solution and make a selection, so RTA is "shovel ready" when funding became available.

While conducting the study, RTA was notified it received a federal FHWA award through the Advanced Transportation Congestion and Management Technology Deployment (ATCMTD) Program. The ATCMTD grant is meant to develop model deployment sites for large-scale installation and operation of advanced transportation technologies to improved safety, efficiency, system performance, and infrastructure return on investment. These goals were precisely in line with RTA's vision to upgrade our CAD/AVL system. Outcomes such as improved safety and real-time information would be a direct result of upgrading our system. The ATCMTD grant provided RTA the funding necessary to complete the project. Had RTA not received the grant, the initial project wouldn't have started until 2021. Instead, the project was completed in 2020.

Objective and Mission

This project set out to replace and upgrade RTA's communication and CAD/AVL system to provide safe and reliable radio communication while enhancing technology for our riders.

Scope

In order to replace RTA's aging radio infrastructure, RTA needs to replace multiple components. These components are categorized into three main areas:

1. Radio Replacement: The new radio system consists of three components. Communication goes between the state's radio system and two dispatcher centers, and then it goes from the dispatch centers to RTA's vehicles, as shown in Figure 1. The radio system provides a 700/800 MHz radio communication.

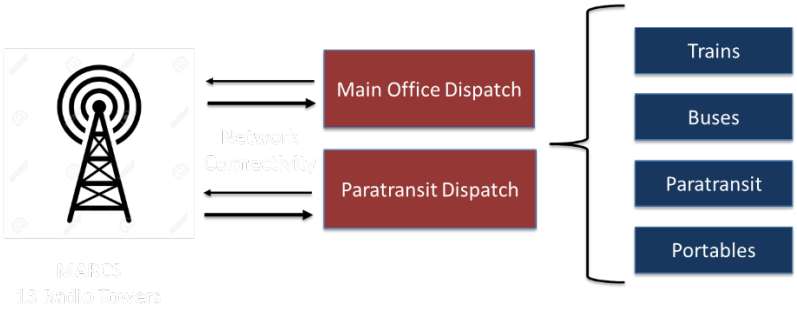

Figure 1. Radio Communication Workflow.

2. On-board Computer Equipment: Buses were equipped with a new computer, mobile data terminal (MDT), mobile router, mobile radio, and vehicle intelligence technology, as shown in Figure 2. This equipment was provided by Motorola, Trapeze, and Sierra Wireless. Each piece of hardware also has an operating system/plug that controls the equipment. This equipment was procured according to the findings in the IBI Group study that identified the best communications method to meet our operators and customers' needs.

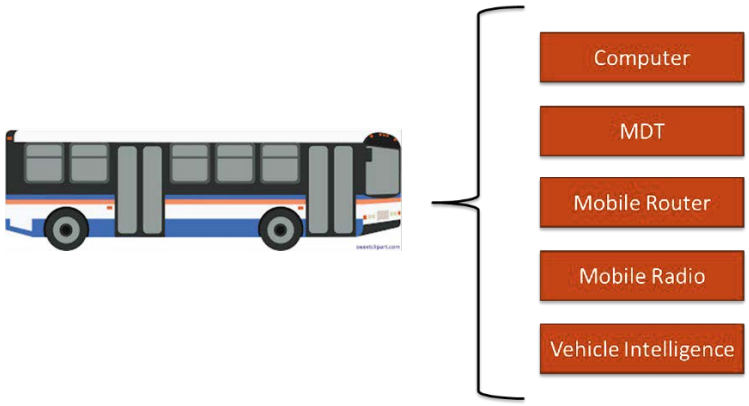

Figure 2. New Radio System Bus Equipment.

3. Utilization of Multi-Agency Radio Communication System (MARCS) and Cellular Service (shown in Figure 3): Utilizing cellular service, data is transmitted to our vehicles. The mobile routers provide the data connection to operate the onboard equipment. The data is unlimited and un-throttled by ATT.

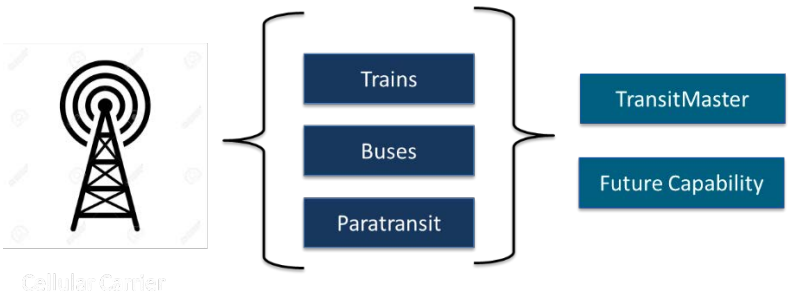

Figure 3. Data Sharing Communication Workflow.

Pre-Vehicle Installation Work

Prior to installing any equipment on vehicles, RTA completed multiple tasks to support the overall project. These tasks included upgrading infrastructure, training team members on new equipment, programming routers and radios, and ensuring proper vehicle designs.

Wireless Network

RTA's old vehicle network used a Proxim/disk operating system (DOS) programming platform. RTA used this network to send updates to the vehicles and upload/download information. The new platform uses 802.11 and required RTA to install a new network.

RTA performed a coverage test in each garage and installed access points (inside and outside). The new Cisco access points allow for remote monitoring and troubleshooting. The new network also significantly improved the download time for vehicles. Prior to the upgrade, it took RTA two weeks to send updates to all vehicles. The new system reduced that amount to less than two days.

More than 20 access points were installed inside and outside RTA garages.

Cellular Coverage Test

Prior to selecting a cellular provider, RTA performed a cellular coverage test. Team members installed a router with multiple carrier subscriber identity modules (SIMs) in it. The router and antennas were temporarily installed on a pool vehicle and operated throughout the entire RTA service area.

The coverage between the carriers was tested as part of the Request for Proposal (RFP) process.
At the completion of the RFP process, RTA selected ATT.

Figure 4 is the pool car with antennas temporarily placed on the roof for coverage testing.
The pool car was driven throughout the county and to all major stations to ensure the cellular coverage met our expectations.

Figure 4. Pool Car with Temporary Antennas.

Programming Routers

RTA's old radio system processed voice and data communication through the radio system. This created multiple issues; in the event the radio system had issues, the entire system would fail.

When designing the new system, RTA chose to separate the data and voice capabilities. In addition to the onboard Motorola radios, RTA purchased Sierra Wireless MG90 routers. The team programmed 524 routers to be installed on each of the vehicles. The routers were programmed to be secure and provide multiple operational benefits.

Each router has two SIM cards. For operational use, RTA uses an unlimited, un-throttled, FirstNet ATT card. This provides priority over the general ATT network in addition to an easy-to-use portal for management. For passenger Wi-Fi, RTA purchased an unlimited ATT commercial SIM. The passenger Wi-Fi traffic goes directly to the internet to reduce any security risks.

FirstNet Cellular Network

FirstNet is a cellular network created for first responders. RTA hired AT&T for both FirstNet and commercial cellular networks. All RTA buses and trains are equipped with the FirstNet cellular network which allows priority service in the event of a big event and/or emergency. If cellular towers are inundated with requests which will take them down (which occurred with the Boston Marathon

bombing), RTA has priority. RTA is the first transit system in the state of Ohio to install FirstNet on its buses and trains. Additionally, the FirstNet portal allows for easy activation, paying bills, reporting, and troubleshooting.

Inventory Rack

RTA built a new inventory rack specifically for this project due to the large volume of equipment. The RTA team received, inventoried, and stored more than 70 skids of equipment throughout the project. The skids contained thousands of parts that required individual inventory-keeping to ensure all parts were received. With the project complete, RTA now uses the rack for spare parts and as a staging area for future project equipment.

Programming Radios

Motorola provided three different radio types. Each of these radio types helped to create a comprehensive and enhanced radio system. RTA purchased 670 Motorola APX 4500 radios for vehicles, 225 APX4000 portable radios for supervisors/management, and 12 MCC7500 dispatch consoles for the control center.

Each of the radios were programmed individually with developed radio channels. The radios were programmed for ease of use while making them cross-functional across the authority.

Dispatch consoles

RTA's old dispatch consoles failed frequently. With the consoles being obsolete, no replacement parts were available. RTA would remove parts from spares to install in other consoles to keep the system operational. This system had multiple failures each month resulting in operational impacts.

The new Motorola consoles are reliable, available 24/7, and capable of remote monitoring. Motorola can remote into the system at any time to repair the issue, which allows RTA to be operational 24/7 with limited operational impacts.

Multi Agency Radio Communication System (MARCS)

In 2013, RTA hired a vendor to maintain our radio towers. Although the towers were obsolete, the authority needed support to respond to failures, troubleshoot issues. and replace parts if necessary. In 2017, parts became unavailable, and RTA began to remove parts from other towers to keep the radio system operational.

RTA hired MARCS and Agile to create a multi-tier system for redundancy. The old radio system had no redundancy in the event of a failure. The new system has a 3-tier system to ensure effective communication in the event of failures.

Each of the Motorola radios uses the MARCS radio system as their backbone. Utilizing MARCS provided RTA Operations with interoperability with our Transit Police department. MARCS is operated by the

state of Ohio and was designed for first responders. With the transition to the MARCS radio system, RTA was able to increase the radio coverage, is no longer responsible for any radio tower maintenance, and now has robust interoperability capabilities.

MARCS provided a significant increase in coverage throughout the county. Figure 5 shows previous radio coverage in the greater Cleveland area. Figure 6 shows current radio coverage post-MARCS installation.

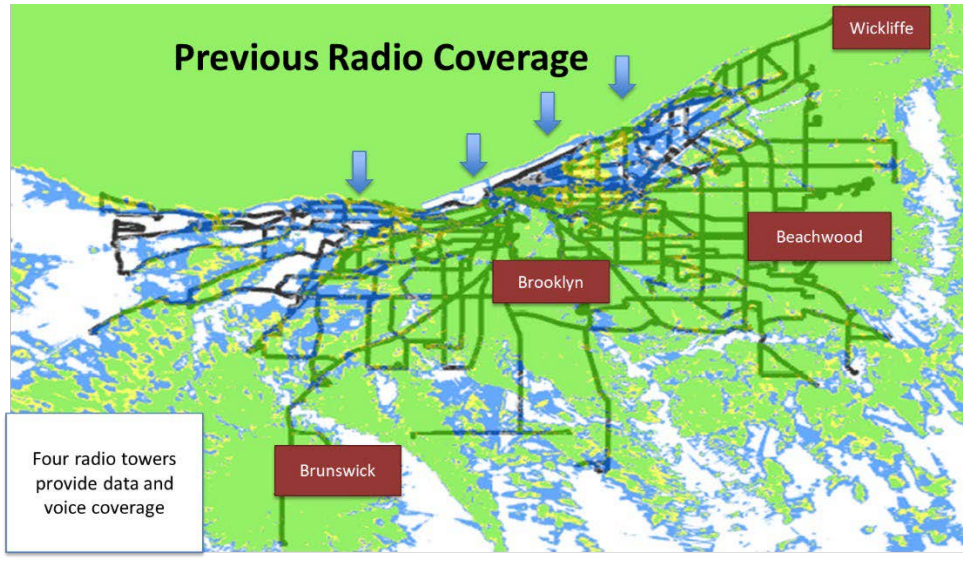

Figure 5. Map of Previous Radio Coverage.

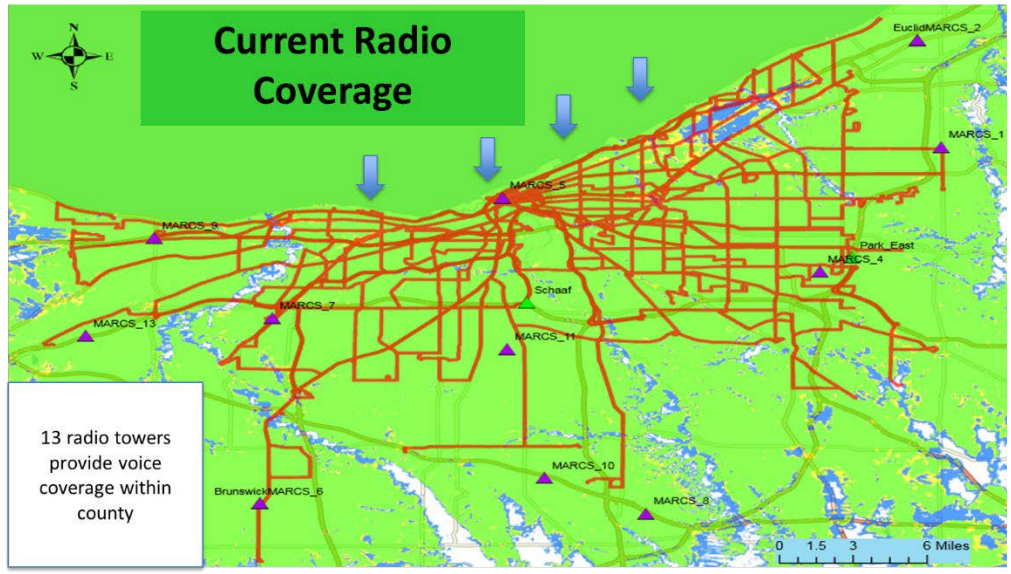

Figure 6. Map of Current Radio Coverage.

Vehicle Design Review

Prior to installing equipment on vehicles, RTA created a design review process with Trapeze. RTA operates multiple fleet types, which required individual reviews. Reviews included electronic schematics, onboard equipment placement, and external equipment placement. Each review was approved by the Safety, Intelligent Transportation Systems (ITS), Electronic Repair, and Fleet Engineering departments.

During vehicle installation, the teams reviewed schematics to ensure all buses were installed in a uniform fashion.

Wiring and Equipment Pre-Check

Prior to installation, the Electronic Repair team led the review of every vehicle. Technicians would review each component of the vehicle. This ensured that all components were working prior to installation.

Operator and Technician Training

Trapeze provided seven Bus-in-a-bus (BIAB) units. These units include the same equipment installed in a small test unit. RTA used these units to train everyday bus and train operators as well as maintenance staff members.

Vehicle Installation Work

Daily Coordination

RTA worked with each bus and rail district to create a sustainable process for installing the new equipment. The team was able to complete an average of six vehicles installations per day. We met with key team members each day to ensure the impact to the daily operation was limited.

Each vehicle type is different and requires various installation processes. For example, the majority of RTA's fleet required fall protection. When the installer was removing/adding antennas to the vehicle, they had to climb on top of the vehicle. This required backing the vehicle into a specific bay (not all bays have fall protection) for this task. The project team had to coordinate the movement of vehicles with standard pull-in/pull-out, routine maintenance, and vehicle availability. The project team worked at the garages every day to ensure proper communication and efficient installations.

The team also had to work closely with the supply chain team. With more than 500 vehicles, the team inventoried, stored, and transported more than 70 pallets of equipment. The equipment was programmed, tagged, and staged for installation each day. All the equipment was logged to ensure the team could maintain the equipment located on each vehicle after installation.

Test Protocols

RTA and Trapeze developed an Acceptance Testing Protocol (ATP). This created a standard test for each vehicle to ensure all components were successfully installed and functioning properly. Key items included vehicle alarms, antennas installation, odometer reading, radio communication, etc. RTA received a signed report for each vehicle prior to the vehicle being released for operation. Both the Trapeze technician and designated RTA team member signed off on the vehicle before being released.

COVID-19 Delay

At the end of the first quarter of 2020, RTA had to stop the project due to COVID-19.
Our vendors had to stop installation. RTA employees were encouraged to work from home, and no vendors could be on property. RTA reduced service by 15% due to low ridership.

During that time, the RTA project team came to the office each day. The team utilized the break to inventory equipment, create processes for repairing/reporting issues, and program additional equipment.

After a 45-day delay, we continued the installations and finished all our fixed route buses (352). Even with the 45-day delay, RTA finished the project months of ahead of schedule. The installation covered more than 500 vehicles.

System Enhancements

The new system created significant operational benefits for RTA. Upgrading a system to modern technology allows RTA to manage service and creates multiple safety benefits and rider amenities. These benefits aligned with the Fixing America's Surface Transportation (FAST) Act goals outlined the grant.

The FAST Act goals include:

- Improved safety
- Reduced congestion and/or improved mobility (e.g., travel time reliability)
- Reduced environmental impacts (e.g., emissions and /or energy)
- Improved system performance/optimized multimodal system performance
- Enhanced access to transportation alternatives
- Effectiveness of providing integrated real-time transportation information to the public to make informed travel decisions
- Reduced costs
- Institutional or administrative benefits (e.g., increased inter-agency coordination)

Table 1 outlines key benefits of the new system along with the FAST act goal they accomplished.

Table 1. RTA Feature Enhancements and Alignment with FAST Act Goals.

Feature	FAST Act Goal	Previous Technology	Enhanced Technology
Vehicle Alarms	**Improved Safety**	Audio-only covert alarms	Coverts alarms are audio and visual. The visual video will allow RTA to perform a live look into the vehicle during police and medical emergencies. RTA management and Transit Police can immediately identify issues in the vehicle.
Priority Cellular Service	**Improved Safety**	No cellular service	With FirstNet, if there is a major event or catastrophe, RTA has priority over the public. Our cell service won't slow-down/go out due to high capacity.

Table 1. RTA Feature Enhancements and Alignment with FAST Act Goals.

Feature	FAST Act Goal	Previous Technology	Enhanced Technology
Radio Communication	**Improved Safety and Improved System Performance**	4 Radio Tower with significant coverage gaps	13 towers that covers the entire county and utilizes towers across the state. RTA utilizes the state's MARCS system created for first responders. RTA can now communicate with first responders in the event of an emergency.
Paratransit Contractors	**Improved Safety and Improved System Performance**	No direct communication or scheduling of vehicles	Each contractor has a tablet with software application managed by RTA dispatchers, enabling direct scheduling of manifests with contractors.
Navigation	**Reduced Cost, Improved System Performance, and Reduced Emissions**	No navigation available. Route books and maps are utilized.	Turn-by-turn navigation is now available, including re-routes, special events, etc.
Pre-Trip Inspection	**Reduced Cost and Improved System Performance**	Operators review their vehicle and complete paper forms for defects.	Operator performs the inspection (paperless) on the new vehicle tablet. RTA is saving 240,000 sheets of paper annually.
Predictive Maintenance	**Reduced Cost and Improved System Performance**	Limited monitoring tools	Real-time predictive maintenance and monitoring of vehicle components allows RTA to monitor vehicles and inform operators/maintenance of errors before the vehicle breaks down.
Vehicle Location	**Integrated Real-Time Information**	Poll rate was 1 minute.	Poll rate is now 15 seconds, providing reliable real-time data for Transit App.
Equipment Maintenance	**Administrative Benefits**	No maintenance available due to obsolete parts	Long-term maintenance contracts with all vendors have been executed.
Wi-Fi	**N/A**	No Wi-Fi	Complimentary Wi-Fi is now available on all RTA buses and trains.

Table 1. RTA Feature Enhancements and Alignment with FAST Act Goals.

Feature	FAST Act Goal	Previous Technology	Enhanced Technology
Enhanced Data	**Administrative Benefits and Improved System Performance**	Significant loss of reliable data	Accurate data including (but not limited to) ridership, cellular usage, real-time information, vehicle diagnostics, etc. Fields Available for App Developers: 1. Vehicle Number 2. Vehicle Latitude and Longitude 3. Vehicle Odometer 4. Vehicle Speed 5. Vehicle Type 6. Vehicle Position 7. Trip Updates 8. Alert and Delay Updates 9. Stop Time Updates 10. Bus Load/Bus Load %

Improved Radio Defect Reporting

RTA's old radio system had poor radio coverage. During operation, operators would experience "dead zones" similar to cell phone service losses. In these zones, operators would be unable to talk with dispatchers. As a result, they would report radio defects as "no audio." After the upgrade to Motorola and MARCS, RTA experienced an 86% reduction in "no audio" defects, as shown in Figure 7.

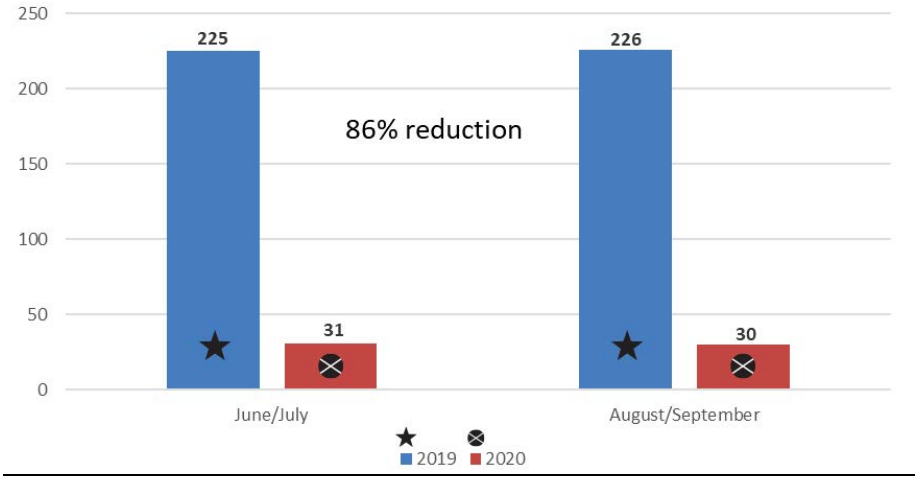

Figure 7. Reductions in "No Audio" Defects.

Passenger Wi-Fi

All RTA fixed route and rail vehicles have complimentary Wi-Fi for riders. When we were designing this project, we wanted to offer additional services to the community to assist in bridging the digital divide. One in five homes in Cuyahoga county lack reliable internet access in their homes; this became more apparent during the COVID-19 pandemic.

Without purchasing additional equipment, we were able to provide complimentary Wi-Fi to our community. Riders continue to utilize Wi-Fi on a daily basis. Wi-Fi was a new feature added to our vehicles in March 2020. As vehicles received the new equipment, Wi-Fi was offered to our customers for that vehicle. Usage from March 2020 to March 2022 is shown in Figure 8.

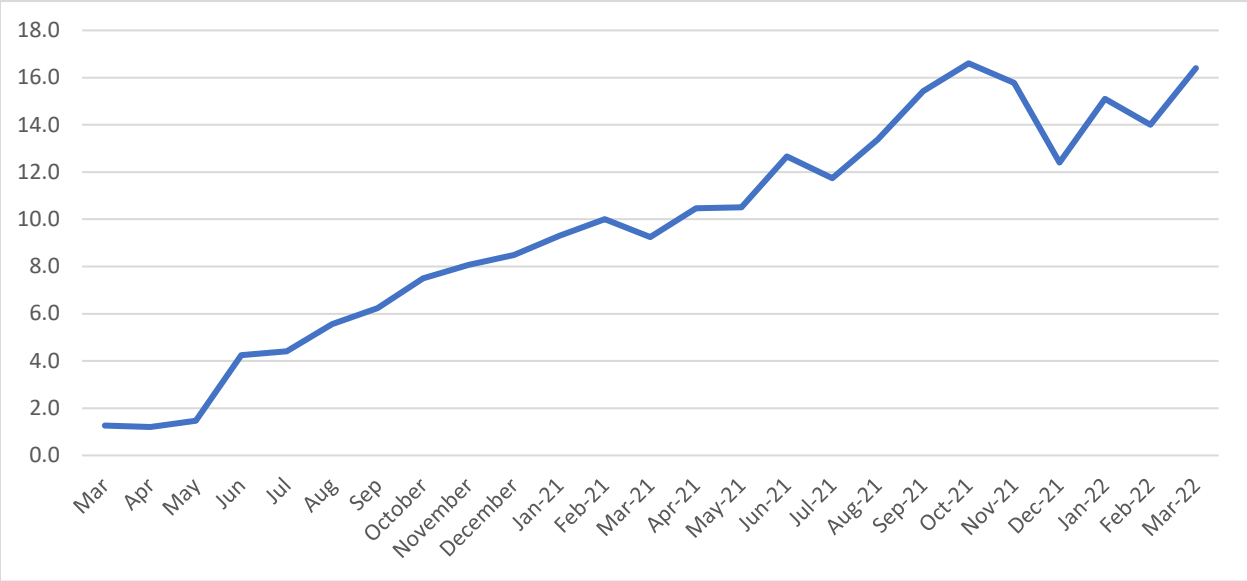

Figure 8. RTA Wi-Fi Usage (in Terabytes).

Improved On-Time Performance

Prior to the upgrade, RTA could only utilize 50-60% of our on-time performance data. Due to an obsolete radio system and poor radio coverage, the majority of the data was lost. This resulted in a lack of information for operators and planners to make system adjustments.

Since the upgrade, RTA's usable data has increased and as a result, on-time performance has significantly increased. RTA's On-time Performance goal has been 80% in recent years. Due to the improvements, we are increasing our goal to 85%. Figure 9 shows usable data available was around 80% since upgrades were made.

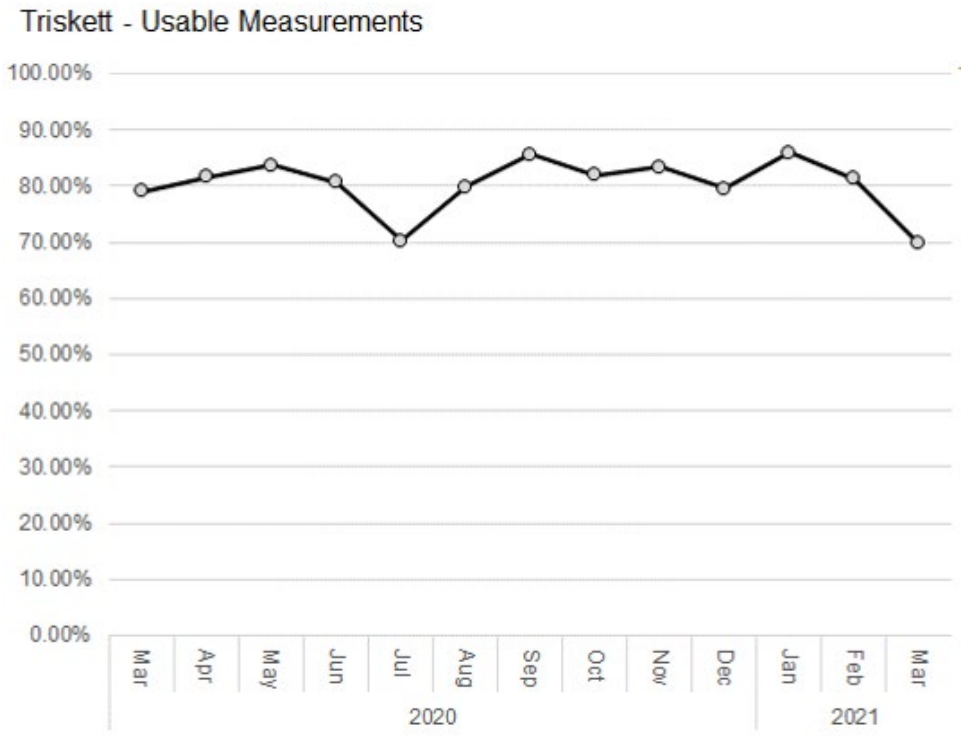

Figure 9. Measurements of Usable Data, 2020 and 2021.

Figure 10 shows the amount of missing data decreasing between 2019, which was prior to the upgrade, and 2020 after upgrades were made. This result in more usable data for RTA.

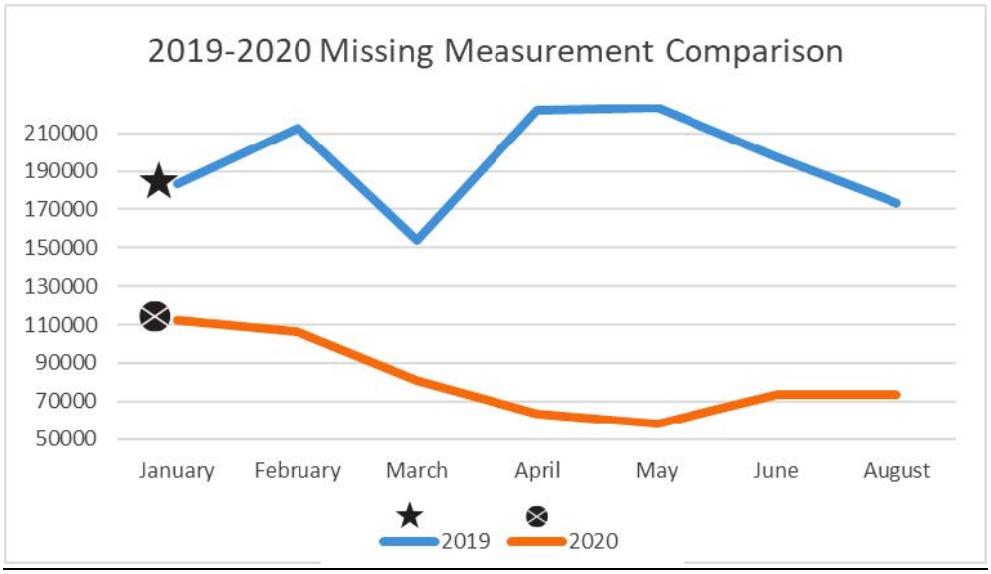

Figure 10. Missing Data Measurement Comparison, 2019 and 2020.

RTA monitors on-time performance and develops route specific information to make adjustments as necessary. When RTA identifies a route that is underperforming, our team analyzes to make necessary changes. The average for the Hayden garage in 2021 was 90% on-time.

Our previous equipment and systems were not capable of recording the detailed on-time performance by route that our new equipment offers.

On-board Touch Screen

With the upgraded system, RTA installed 10-inch color touch screens. These devices provide various benefits including easy navigating options, bright/dimming features, turn-by-turn navigation, and pre-trip inspection. The previous system did not have these benefits and were hard to read with no navigational benefits. Operators used map books to review their routes.

Paperless, Pre-Trip Inspection

In spring 2020, RTA rolled-out paperless pre-trip inspections. RTA's old process was to have an operator use paper each day to record any issues with their vehicle (scratches, broken mirror, etc.). Operators reviewed their vehicle and marked any defects. Each piece of paper was turned into the maintenance team for corrective action at the end of the day when the bus returned to the garage. This process did not allow for efficient reports, metrics, or issue tracking.

With the paperless pre-trip inspections, the operator now records the information on their color, 10-inch tablet. The information is recorded in our database, and a daily report is provided to the maintenance staff. This provides an efficient reporting model and historical tracking, and the new process saves more than 240,000 pieces of paper each year.

The new system has all the information recorded and immediately available in a database that can be easily reviewed and analyzed by the maintenance team in a timely manner. RTA has reportable data, where prior it was all on paper with no reporting method. This upgrade benefits both the operator and maintenance staff by ensuring all data is received, corrected, and tracked for quality assurance.

Real-time Information

For years, the number one request from riders was real-time information. They wanted to know when their bus and train would arrive. RTA however could not provide that information due to the old system and lack of reliable GPS. After the system upgrade, RTA polls each vehicle in 15-second intervals.

The real-time information is more than 90% accurate and provides reliable real-time information, trip planning, and for future capabilities for our riders. Transit App is the nation's top real-time transit app. It is used in cities across the country. There has been a steady increase in the number of riders downloading and utilizing Transit App since its deployment with the new communication systems. 15% of all RTA riders utilize the app for more than 500,000 trips per month.

In early 2020 RTA added rider capacity to our real-time information. This allows for riders to view the number of passengers are onboard the vehicle in real-time. Benefits and some features are shown in Figure 11.

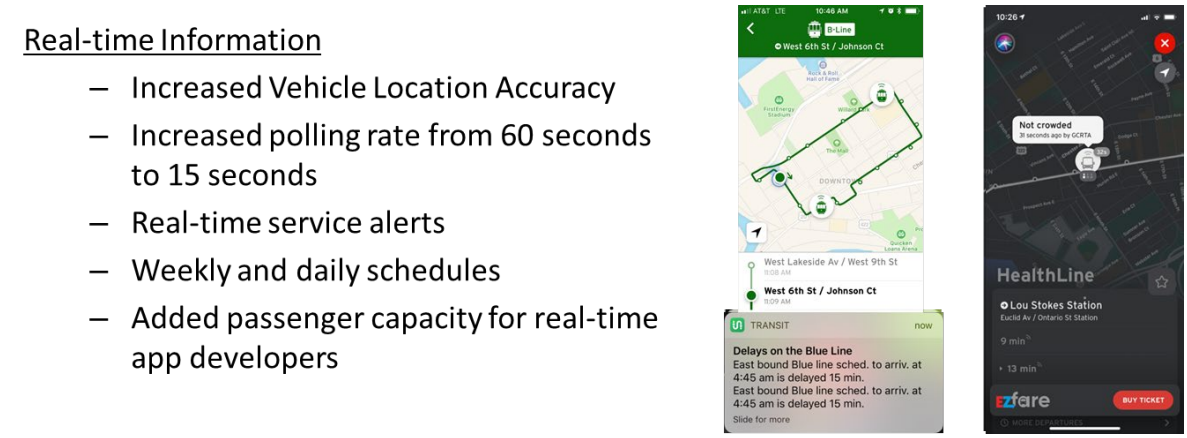

Figure 11. Benefits and Features for Riders Due to Improved Real-Time Information.

CAD/AVL Information

RTA operates a CAD/AVL software called TransitMaster. TransitMaster allows RTA to visually see, communicate, and manage bus and rail service. Trapeze-Vontas is the vendor and was the lead installer and provider of the onboard equipment.

During the upgrade, all of the main vehicle components (ITS) were reviewed and tested. Prior to the upgrade, many items didn't work such as automated passenger counters (APC), vehicle discretes (wheel chair ramp notification), etc. During the installation phase, RTA and Trapeze tested every aspect of the ITS features to ensure they were operational. From TransitMaster, supervisors gain information in real-time regarding location, amount of passengers onboard, odometer, speed, schedule adherence, etc.

Vehicle Intelligence

As part of the vehicle upgrade, RTA implemented a telematics system called "Vehicle Intelligence." The onboard computer is connected to the Controller Area Network (CAN) of the bus through the J1939 network. This allows RTA to gain maintenance information in real-time. Major components such as air pressure and engine temperature are monitored. In the event of an issue, the system notifies RTA staff members for corrective action. An example would be an overheating engine. Vehicle Intelligence also provides historical information on each vehicle for analysis and troubleshooting.

Device Management

Trapeze-Vontas developed a new software called "Device Management." This software provides real-time health monitoring for our onboard ITS equipment. RTA's current process requires bringing a vehicle into the garage to download files and troubleshoot the device. The computer memory card is physically removed for review.

Due to the majority of our vehicles being in operation most of the day, it requires team members to catch vehicles during late evening/early morning hours or ask the districts to hold the vehicle the next morning.

With device management, RTA will be able to monitor our vehicles in real-time and troubleshoot issues remotely. RTA will be able to download log files and push software fixes to the vehicles while in operation which will greatly increase the efficiency of our operation.

During the pilot of "Device Management," the following benefits were identified:

- Real-time health monitoring of onboard equipment
- Ability to troubleshoot and repair vehicles remotely
- Remote software updates
- Performance metric tracking

Budget

RTA's project was ahead of schedule and under budget. There were no major budget revisions. The planning and execution of the RTA team allowed for minimal delays and/or change orders. As a precaution, RTA established a 25% retainage on the entire Trapeze contract.

There have been no changes to the SF-424A due to no project budget revisions, as shown in Table 6. The RTA Board of Trustees passed every resolution for project task action, and the funding associated with each is shown in Table 7.

Project Award

Following the completion of the project, Michael Lively received the "Most Innovative" award at the annual user conference. This was a result of the transformation in RTA's operation. The agency had one of the oldest CAD/AVL systems in the nation. In a short timeframe, RTA became a leader in the industry for technology.

Project Award – Trapeze-Vontas Think Transit Conference

RTA Named "Most Innovative" at the 2021 Trapeze-Vontas Conference

Apr 27, 2021

CLEVELAND, OH – The Greater Cleveland Regional Transit Authority (RTA) was presented with the Innovation Award from Trapeze-Vontas at its 2021 virtual Think Transit Conference today.

The award is for "the most innovative and forward thinking person or organization", and was granted to RTA for the development, design and implementation of a new on-board and integrated communications system.

The new system eliminated outdated technology and replaced it with a number of new features including, state-of-the-art vehicle alarms, priority cellular service, new radio communications towers and a turn-by-turn navigations system.

In 2019, RTA was operating one of the oldest radio and computer systems of all the public transit authorities nationwide. Installed in the mid-2000s, the onboard system was obsolete, difficult to maintain and offered limited capabilities to the riders, says Michael Lively, project manager, and RTA's Manager of ITS.

With the help of grant funding, a bold vision and a small, dedicated team, RTA now operates one of the most advanced systems in the country. "With the help of grant funding, a bold vision and a small, dedicated team, RTA now operates one of the most advanced systems in the country. Within a 14-month period (July 2019 – September 2020), RTA was able to transform its operation by removing and installing new onboard equipment on more than 500 vehicles," said Lively.

RTA worked with six vendors to coordinate, program and launch the new system while minimizing the impact to day-to-day operations. The last vehicle installation was completed months ahead of schedule, and the overall project was under budget.

"This award is a well-deserved celebration of the months of hard work, which would be challenging under the best of circumstances," said Dr. Floun'say Caver, RTA's interim CEO and General Manager.

"But since most of the installations were carried out during the pandemic, this shows a level of dedication by Mike and his team that we all would do well to emulate. We are proud to have such dedicated staff on board, and we share our hearty congratulations for all they did to earn such a prestigious award."

Conclusion and Lessons Learned

The ATCMTD grant was a success in Cleveland. The project was completed six months ahead of schedule. The only change orders for the project (two) were planned for administrative purposes. No change order was executed due to lack of funding, time, or poor planning.

Lessons Learned

RTA had a three-person team dedicated to the system. Each team member had a full-time job they were performing while managing the project. This team worked 11 to 13 hours days for a year to ensure the project was implemented successfully. Despite personnel changes and COVID-19 restrictions, the project was completed on-time and successfully.

For future agencies, dedicated team members are advised to ensure quality assurance and delivery. When implementing new systems, it's also recommended to manage the project internally. RTA managed the project internally which allowed team members to understand the system inside-and-out. If an outside consultant was hired, RTA staff would know less and wouldn't be able to manage the system as effectively as they do today.

Additional Projects

Since the completion of the communication project, RTA has used the technology and methodology for additional systems at RTA. The ATCMTD grant allowed RTA to create a foundation used for future projects.

At the conclusion of the project in 2020, the ITS team immediately began working on new projects. The team developed a strategic plan consisting of four main pillars: maintenance, service delivery, customer experience, and safety. Each of these pillars directly affected the agency through "Technology in Transit."

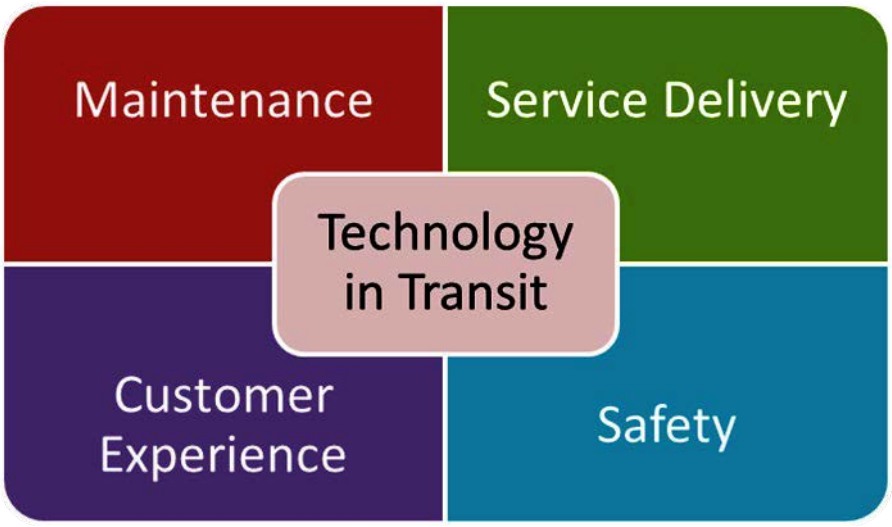

Figure 12." Technology in Transit" Pillars.

Table 2 shows projects which were part of the Technology in Transit plan. All projects have been completed.

Table 2. Technology Projects Addressing Technology in Transit Pillars.

Pillar	Technology Projects
Customer Experience	Improved Real-time Information More than 10% of all riders utilize real-time applications to monitor vehicle departures. Passenger Wi-Fi Riders utilize RTA vehicles for complimentary Wi-Fi. Riders average a total of 16 Terabytes of data per month.
Safety	Police Radios Replaced 130 radios with Motorola APX4000s. Radios include extended coverage areas, warranties and new accessories. Police Consoles Replaced dispatch consoles. Radios include extended coverage areas, warranties and new accessories. Police Body Worn Cameras Issuing 130 body worn cameras for the first time at RTA. All video is stored in a cloud based system with unlimited storage.

Table 3. Technology Projects Addressing Technology in Transit Pillars.

Pillar	Technology Projects
Maintenance	Real-time Maintenance All major components on fixed route vehicles are monitored in real-time. Alerts are sent to key team members prior to critical failures. Digital Pre-trip Inspections Replaced paper pre-trip cards with digital format. This format allows for tracking and saves more than 240,000 pieces of paper annually.
Service Delivery	Improved Vehicle Location On-time performance is at its highest level due to improved vehicle location data. More than 500 vehicles are tracked every 15 seconds.

Appendix A: Budget Tables.

Table 4. Major Trapeze Milestone Payments: Fixed Route.

Milestone	MS Amount
Project Kickoff and Schedule Development	$ 169,018.00
Delivery of Vehicle Survey Documentation	$ 338,036.00
Delivery of Network WLAN Design Document	$ 338,036.00
Bus-in-A-Bus (Test units) and Proof of Concept	$ 507,053.00
Pilot Installation (10 vehicles)	$ 338,036.00
Fixed Route equipment delivery - Invoiced Monthly	$ 1,014,106.00
Acceptance of Equipment (ATP Testing per vehicle)	$ 676,069.00
Project Acceptance (Overall acceptance - 25% retainage)	$ 1,126,783.00
Total	**$ 4,507,137.00**

Table 5. Major Trapeze Milestone Payments: Rail.

Milestone	MS Amount
Project Kickoff and Schedule Development	$ 101,458.61
Rail Car Schematics	$ 202,917.23
Rail Car Prototype	$ 304,375.84
Train-the-Trainer	$ 202,917.23
Pilot Installation/Completion	$ 304,475.84
Fixed Route equipment delivery - Invoiced Monthly	$ 507,293.06
Acceptance of Equipment (ATP Testing per vehicle)	$ 405,834.45
Project Acceptance (Overall acceptance - 25% retainage)	$ 676,390.63
Total	**$ 2,705,662.89**

Table 6. SF-424A Budget Lines.

	Original SF-424A:	Revised SF-424A
Personnel	90,080	90,080
Fringe Benefits	37,203	37,203
Travel	0	0
Equipment	9017500	9017500
Supplies	0	0
Contractual	1662500	1662500
Construction	-	-
Other	550,000	0
Total Direct Charges	**11,357,283.04**	
Indirect Charges	0	0
Totals	**11,357,283**	**11,357,283**

Table 7. Resolutions Approved by RTA Board of Trustees for Project Task Completion.

Project Task	**Notes**
CDW Router Procurement	Board approved in September 2018 Resolution #2018-102 $1,454,825
Motorola Radio Procurement	Board approved in September 2018 Resolution #2018-101 $4,017,252.80
Trapeze ITS On-board Equipment	Board approved in December 2018 Resolution #2018- 113 Estimated - $7,719,263
MARCS Agreement Revision (5-years)	Board approval in February 2019 Resolution #2019-015 $1,200,000
Agile Networks	Board Approval in April 2019 Resolution #2019-40 $153,120
CDW Passenger Wi-Fi equipment	Board Approval in May 2019 Resolution #2019-54 $203,666
Cellular RFP	Board approval in June 2019

Appendix B: Roles and Responsibilities

At the beginning of the project, RTA established roles and responsibilities for key team members. The ITS and Electronic Repair departments managed the project. The ITS and Electronic Repair departments work closely together to manage the software and hardware. The Electronic Repair department oversees and maintains the on-board equipment; Electronic Repair is part of our Fleet Management team that performs quality assurance and equipment engineering as well.

Table 8. RTA Team Members and ATCMTD Project Roles.

Team Member	Department	Role
Dr. Caver	Operations	Champion
Michael Schipper	Engineering and Project Management	Co-Champion
Michael Lively	ITS	Project Manager
Tony Garofoli	Internal Audit	Steering Committee
Tony Richardson	Service Quality	Steering Committee
Pete Anderson	Information Technology	Steering Committee
Dan Dietrich	Fleet Management	Steering Committee
Raj Gautum	Finance and Administration	Steering Committee
Sean Thompson	Rail Management	Steering Committee
Sandy Strack	Training	Steering Committee
Julie Schultz	ITS	Project Team
Bonson Yee	Internal Audit	Project Team
Robert Mercer	Service Quality	Project Team
Chris Orlando	Information Technology	Project Team
Michelle Berry	Fleet Management – Inventory	Project Team
Chris Weil	Fleet Management – Electronic Repair	Project Team
Craig Wiehe	Finance and Administration	Project Team
Kay Satula	Office of Management and Budget	Project Team
Casey Blaze	Rail Management	Project Team

Appendix C: Developing the System

RTA worked with six different vendors to design, develop, and execute the project. Each vendor provided equipment and/or resources to create a comprehensive radio communications system for RTA. The system was comprised of hardware, software, and integrations between each system.

RTA created a design that would later be tested during the pilot program. The team had to ensure that each of the systems were compatible and would function as designed. Each of the vendors below provided a key function/service for the project. Prior to the purchase of each of the services, RTA gained approval from the board of trustees. Table 9 outlines the services provided by each vendor.

Table 9. ATCMTD Project Vendors and Services.

Vendor	**Services**
Trapeze	1. Installation and Programming of Trapeze equipment 2. Installation of Motorola radios 3. Installation of mobile routers 4. Annual Maintenance and Support
Motorola	1. Installation/Programming of consoles and portables 2. Programming of mobile radios (Trapeze performing install) 3. Annual Maintenance and Support
Sierra Wireless	1. Program the router to RTA specifications 2. Annual Maintenance and Support 3. Management software
MARCS	1. Provide radio backbone (13 towers) 2. Annual Maintenance and Support
Agile	1. Provide network connectivity to RTA facilities and MARCS controllers (Paratransit and Main Office) 2. Annual Maintenance and Support
AT&T Cellular	1. Unlimited Data for each vehicle 2. Annual Maintenance and Support