REPORT REQUEST FOR EXPRESSIONS OF INTEREST

Trenton MOVES

AUTONOMOUS

ATAK electric

Automated by ADASTEC

in cooperation with BMW

Contents

A. Cover Letter

ADASTEC Corp.

Addresses:

HQ – Operational Office:

330 E Liberty St., Ann Arbor, MI 48104, USA

Point of Contact Information:

Atalay TAŞKOPARAN

atalay@adastec.com

+1 (415) 619-1051

B. Executive Summary

Congestion in traffic is a significant issue, mainly in all cities. Even with the advances of shared and automated passenger cars, this issue is not addressed. Public Transportation is an integral part of any Smart City and Urban infrastructure. In 2018, in the US alone, people took 9.9 billion trips on public transport services. Over the last 20 years, ridership has grown 21% - a higher growth rate than the population growth. Many transport systems in the US and worldwide are antiquated. It is proven that investment in public transportation systems drives economic growth. In the US, Public transport is also 10x safer than a car journey. Providing a clean, modern, socially inclusive 24x7 across a wider coverage area can increase demand, further improve safety, and drive broad economic returns to businesses and communities. This is only feasible with lowered labor costs and improvements in the bus and the infrastructure to deliver these economic advantages.

Automated buses radically reduce labor costs. Autonomy as a service platform flowride.ai for full-size buses enables full automation along a route. The platform can handle public transportation-specific use cases allowing the quick implementation of existing routes. The open platform enables integration of infotainment, payment, shared mobility services allowing a high-quality public transportation experience.

The first deployment of flowride.ai is Karsan Autonomous e-Atak, a state-of-the-art full-size, full-speed electric bus. Karsan Autonomous E-Atak is factory fitted and uses all the advantages of the base platform, which is already deployed and in service in many cities worldwide.

Autonomous E-Atak delivers safe, comfortable, cheap, clean mobility needed by modern cities of the future.

Bus Producer KARSAN

Karsan was established in 1961; with its business partnerships and game-changing innovations, Karsan today operates in 20 different countries worldwide. Karsan's focus on the satisfaction of businesses and societies has driven the company to develop innovative designs, which now embodies in 100% Electric Bus. Currently, Karsan manufactures the all-new H350 LCV for Hyundai Motor Company (HMC), 12-18m buses for Menarinibus, while also producing the immensely popular Karsan minibus JEST. Karsan also offers solutions to the changing needs of the cities in public transport systems with its 8m accessible Karsan branded ATAK and STAR buses. In addition to vehicle manufacturing, Karsan provides industrial services in its plant located in Bursa Organized Industrial Zone. KARSAN has ISO 9001, ISO 14001, ISO 18001, SA 8000 certificates. Karsan have last three years (2018 – 2019 – 2020) average revenue of 273.558.367 USD. You may check detailed financial information from below mentioned link.

https://www.karsan.com/en/investor-relations/financial-information/annual-reports

Automation Provider ADASTEC Corp.

ADASTEC Corp, established in 2018, is a US-based automation provider for full-size buses and commercial vehicles. ADASTEC delivers the most advanced Level 4 automation platform, flowride.ai, for full-size buses and coaches currently available. ADASTEC has offices in Ann Arbor, MI, San Francisco, CA, Istanbul, Turkey, and Ploiesti, Romania. ADASTEC has ISO 9001, ISO 27001, ISO14001, ISO45000, ISO26000 certificates. The company has completed seed funding stage in 2021 and raised over $4.5 Million USD.

Experience with Similar Projects

ADASTEC flowride.ai integrated Karsan Autonomous e-ATAK, is deployed in 5 countries in Europe & North America. (USA, France, Norway, Romania & Turkey).

C. Responses to the NJDOT Questions

1. Potential Project Description

1.1. In no more than 1500 words, describe your solution: How does it work?

As a solution, we offer KARSAN ATAK Electric Bus integrated with flowride.ai, which is a SAE Level-4 Automated Bus Driving Platform for the project. flowride.ai delivers the most advanced Level 4 automation platform for full-size commercial vehicles currently available. The flowride.ai is designed for large-scale public transport along predefined routes on public roads. The platform allows OEMs to build the best automated bus configurations for the needs of the operators.

The first deployment of flowride.ai is KARSAN Autonomous e-Atak, a state-of-the-art full-size, full-speed electric bus. KARSAN Autonomous e-Atak is factory fitted and uses all the advantages of the base platform, which is already deployed and in service in many cities worldwide.

- KARSAN Autonomous e-Atak Bus has a range of 185 miles (300 km) on a single charge with proven BMW Li-Ion batteries. Daily operations can be executed continuously. It is a perfect match for longer routes and public transportation.
- KARSAN Autonomous e-Atak Bus has an EU-homologation certificate and factory fitted, serial manufactured with autonomous features.
- KARSAN Autonomous e-Atak has a high capacity, up to 52 passengers (maximum 21 people seated). Therefore, compared with the small shuttles with low capacity, Autonomous e-Atak is more efficient and affordable.
- KARSAN Autonomous e-Atak is fully handicapped accessible, and it has a priority wheelchair area as a standard.
- KARSAN Autonomous e-Atak is 27.2 ft long. Thus, social distancing is possible, if necessary.
- KARSAN Autonomous e-Atak Bus is the first and only automated bus that has NHTSA approval and deployed. (https://www.nhtsa.gov/automated-vehicle-test-tracking-tool)
- SAE Level-4 Automated Bus Driving Software Platform flowride.ai is the only Automated Driving Software Platform used in Public Road (USA, Romania, Norway).
- KARSAN Autonomous e-Atak Bus Driving Software Platform is “Designed by Safety” in accordance with the related Safety Standards.
- KARSAN Autonomous e-Atak can speed up to 37.2 miles per hour.
- KARSAN Autonomous e-Atak can be operated at mixed traffic conditions.
- KARSAN Autonomous e-Atak can be operated fully autonomous in the route with day and night conditions.
- KARSAN Autonomous E-Atak can safely continue its operation in rainy, snowy, and slightly foggy weather conditions.

1.2. Is your potential project scalable in and beyond Trenton, NJ? If so, how?

After the area where the bus will be operated is determined and mapped in advance, it can be scalable to in and beyond Trenton, NJ within the scope of ODD, where public transportation is needed.

1.3. How soon will a minimally viable version of your solution be operational? How long does it take to scale to full operations (for proposed service scope, see 3.1 Operational Design Domain and Service Concept)?

Autonomous e-Atak can be produced and delivered in six months. 100 buses of Autonomous e-Atak can be produced and delivered in 12 months.

For the pilot phase, once the bus arrives at Trenton, three months are needed to deploy it on a fixed route with a fixed schedule. At the end of the first three months, additional three months are needed to operate dynamically (on-demand).

For full service, at least five buses can be operated to meet all expected ODD requirements 1.5 years after the first bus arrives (one year after the end of the pilot phase). Additional 1.5 years is required for the operation of 100 buses.

In total, 3 years are required to scale to full operations.

1.4. Describe geographically and narratively the anticipated Operational Design Domain and additional right of way impacts of your proposed potential project.

The main target and operation area of Autonomous e-Atak is urban transportation routes. The vehicle can drive fully automated in a pre-mapped environment along routes with multiple stops. There could be fixed or dynamic routes and schedules for the operation. Since the focus of the Autonomous e-Atak is urban and public transportation, it can be operated in city streets, suburban/rural roads, campus roads, and at the mixed traffic conditions. There are ongoing projects to support highways/freeways and maintenance yards. Currently, Autonomous e-Atak speeds up 25 mph, but with the highway project, it will be increased to 37.2 mph.

Autonomous e-Atak has equipped with multiple sensor modalities. Hence, it can be operated in both day and night conditions, in rainy, hazy, and light snow weather. At the end of 2022, heavy snow and foggy weather will also be supported.

Autonomous e-Atak can handle intersections, traffic lights, crosswalks, and traffic participants. Handling of uncontrolled intersections is in the development phase. It requires authorization at the uncontrolled intersections for now, but it will be handled in 2023 Q1. Traffic lights can be handled with or without V2X communications, but it is highly recommended to have V2X infrastructure. Autonomous e-Atak wouldn't make unnecessary brakes for pedestrians on the curbs or cyclists on the bike lanes.

1.5. Describe challenges regarding proposed Potential Project Summary and Parameters

The most challenging parts of proposed Potential Project Summary and Parameters are operating 100 autonomous buses and serving on-demand service. To cope with the challenges, we plan to be a partner with a multinational transportation company that operates public transportation systems.

2. Product Capabilities & Limitations

2.1. Describe the testing and safety research conducted for your AV(s).

ADASTEC's flowride.ai uses a modular approach structured as a pipeline of separate components linking sensory inputs to actuator outputs. flowride.ai platform fuses advantages of a deterministic system with deep learning methods, thus allowing safety certification of the platform for real deployments and serial production. Developing individual modules divides the challenging task of automated driving into an easier-to-solve set of problems. These sub-tasks have their corresponding literature in robotics, computer vision, and vehicle dynamics, making the accumulated know-how and expertise directly transferable. Functions and algorithms can be integrated or built upon each other in a modular design, e.g., a safety constraint can be implemented on top of a sophisticated planning module to force some hard-coded emergency rules without modifying the inner workings of the planner. This modular architecture enables designing redundant but reliable architectures.

As ADASTEC & Karsan, it is vital for us to measure the platform's safety, take measures according to these measurements, and prepare and continue the developments. Like every automotive product, electric and electrical components hold the most important place in autonomous vehicles. Accordingly, all sensors (including drive-by-wire sensors and actuators) used in the autonomous system are based on ISO 26262. Their backup systems are also designed following the same structure. In addition, ISO 26262 recommendations and guidelines are followed and developed in safe software and system designs with a holistic development approach. Safety plays a key role from the beginning of the development, including the concept phase, to the deployment of the product, and then to operation and maintenance.

Determining all components' ASIL (Automotive Safety Integrity Level) levels makes it easier to see the problems before the deployment. Hazard Analysis and Risk Assessment (HARA) methods are used for this process. In addition, studies such as Systems Theoretic Process Analysis (STPA), Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) are carried out to evaluate the system better, define Safety Goals correctly, and plan Safety Mechanism developments.

On the other hand, there are no clear and precise standards since automated vehicle technologies are a new and rapidly developing field. Therefore, the evaluation of standards such as ISO 21448 – "Safety of the intended functionality (SOTIF)" and ISO 22737 – "Intelligent transport systems – Low-speed automated driving (LSAD) systems for predefined routes" together with the existing ADASTEC procedures and standards play a significant role. SOTIF is handled together with FuSa in automated driving system design, ensuring the functional safety of the elements, as well as evaluating the effects of misuse, lack of capacity, environmental factors, and covering known, unknown use cases and non E/E technologies the Operational Safety is provided.

ISO 22737 is one of the most recently published related standards and directly covers Low-speed automated driving (LSAD), providing guidelines and test procedures. In this context, ADASTEC has added these directions to safety procedures and has established an inclusive test and development infrastructure by adding the specified cases to the test scenarios.

The fact that the Karsan E-Atak bus, the base vehicle of Autonomous E-Atak, has already completed its homologation processes and passed EMC tests and quality processes gives us a massive advantage for system safety. Autonomous E-Atak is a factory-fitted vehicle, not a retrofit like many automated vehicles available in the market. HARA (Hazard Analysis and Risk Assessment), FMEA (Failure Modes and Effects Analysis) and FTA (Fault Tree Analysis) studies were carried out by considering the vehicle as a whole together with the automation platform. The assessments are done in the production line and the facilities of the Karsan. In this way, all mechanical, electrical, network-based, and software-based risks are eliminated. We are constantly improving our platform with our Hazard Analysis and Risk Assessment studies, which we have prepared with reference to the SAE J2980 document. In addition to standard risk analysis studies, some agile analysis methods are used within ADASTEC. Based on the RPN

(Risk Priority Numbers) revealed by the studies carried out, the existing controls and redundant structure were checked. A flexible design has been developed to integrate software and hardware systems required for additional control in necessary matters.

The preparation of these studies is carried out in conjunction with the reference standards. The rules determined by the transport ministries, transport units, and transport companies of the countries are also considered. A superset of standards including these rules followed to enable wider geographic deployment of the vehicle.

Undoubtedly, essential parts of a safe system are the mechanical and electrical continuity of the equipment used. In this regard, it is possible to encounter some problems due to external factors or the equipment themselves. In this case, the performance of the overall system may be affected. To minimize the risk, backup systems, a redundant and fault-tolerant architecture is available in our design. Subsystems like localization, perception, control, etc. supported by a minimum of three different sensor modalities. (See chapter 5) The same redundant architecture also exists in the autonomous system's sensors, the communication between the vehicle and the autonomous platform, and in the vehicle's own electronic control unit (ECU). In this way, even with multiple errors system can continue its regular operation.

At the same time, the results of the tests performed in real-life conditions should be evaluated to create a safe system and make a risk analysis. For Autonomous E-Atak, the tests carried out on private roads were specifically designed to cover the promised ODD of the vehicle. According to ADASTEC & Karsan Test and Validation documents, the risk levels determined for the system are updated and improved with the experiences and contributions of the field engineers who perform the tests. Thanks to the data recorded during the tests, the probability of occurrence and the speed of understanding the risks are assessed according to realistic values. The test document prepared by NHTSA, in this sense, has made a significant contribution to the studies. Our engineers, who participate in field tests, also analyze the routes where the product will be operated, ensuring a safer and more efficient deployment process progression. All the routes the vehicle will be deployed are pre-simulated in simulation and with collected field data.

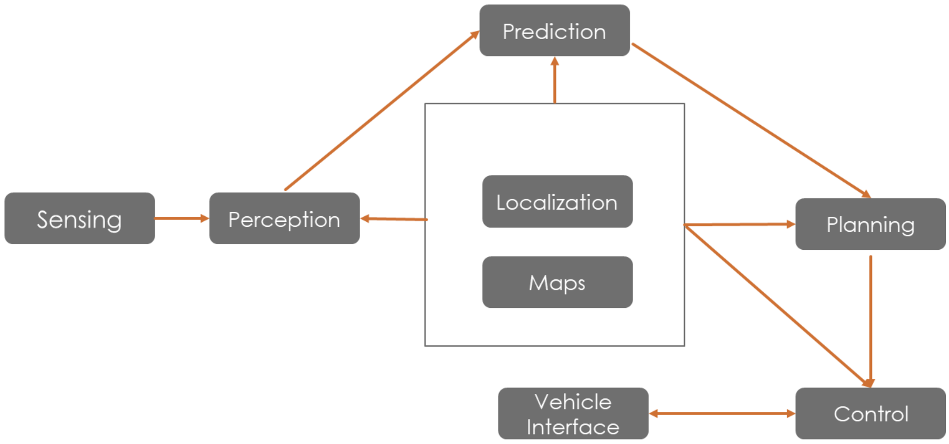
After deployment, operations are carried out by specially trained implementation engineers who have taken part in many software and safety tests of the vehicle.

An additional output of the risk analysis is the interfaces prepared for the safety of operations. The interfaces include safety driver precautions, error displays, and passenger warnings, making the vehicle's operation safe and straightforward.

2.2. Describe your safety technology, such as but not limited to, system technology, sensor technology, navigation, obstacle detection, and traffic signal interface, etc.

The main target and operation area of Autonomous E-Atak is urban transportation routes. The vehicle can drive fully automated along routes with multiple stops. The routes are pre-mapped and fully simulated. Before deployment, a detailed 3D simulation environment, HD-Maps, and 3D maps are prepared. If the vehicle is out of ODD, minimum risk maneuver is performed.

The autonomous driving stacks in flowride.ai and their relations with each other are shown in the diagram below.



Sensor Suite:

flowride.ai uses enhanced sensor fusion with map-based priors. Sensor fusion is a complex task; what to fuse, when to fuse, how to fuse questions should be answered according to the system design. flowride.ai uses maps as an additional sensor that increases the deterministic behavior of the system without ignoring generalization to adapt to different road conditions. Sensors are placed mainly targeting public transportation operations. Pedestrian and animal detection is enhanced with the fusion of thermal cameras. Bus stops handling is a significant challenge not covered by other L4 automation platforms. flowride.ai platform handles the interaction with passengers on the bus stops, automatically checks the safe zone after passengers enter the bus. Localization is also enhanced with map fusion based on novel algorithms created with the scientific research of ADASTEC.

In order to improve the effectiveness of the sensors and to avoid any miss-detection, multiple sensors have been used and their positioning has been optimally adjusted.

Sensor Type	Quantity	Property
LiDAR	4	32 Channels
LiDAR	1	128 Channels
GNSS/INS	1	High Precision GNSS receiver
RGB Camera	6 (Optional 8)	3 Front facing, 3 Backward facing, 2 T Junction (Optional)
Thermal Camera	2	Front Facing, Door
RADAR	1 (+2 optional)	Digital Scanning RADAR
Ultrasonic	16	360-degree coverage

Autonomous E-Atak camera configuration employs 6 RGB Cameras and 2 Thermal Cameras. Cameras can sense color and is passive, i.e., they do not emit any signal for measurements. Sensing color is extremely important for tasks such as traffic light recognition. 2D computer vision is an established field with unique state-of-the-art algorithms. Moreover, a passive sensor does not interfere with other systems since it does not emit any signals.

Our cameras target brightness provides dynamic calculation of gain and exposure, enabling improved perception regardless of the time-of-day and lighting conditions. The cameras allow a wide-angle field of view and high precision recognition in daytime and nighttime for Automated Driving.

Three RGB cameras are front-facing, two of them in the place of right and left mirrors, and one of them is placed at the back of the bus.

The system utilizes two thermal cameras. Thermal imaging through infrared sensors is also used for object detection in low light conditions, which is particularly effective for pedestrian detections. Thermal sensors create images from heat, not light, to detect pedestrians and oncoming vehicles regardless of lighting conditions. They provide the ability to reliably classify objects in the dark and through obscurants, including smoke, sun glare, and most fog – day or night. Because they detect heat, thermal cameras have the unique ability to reliably classify people and animals better than other sensor technologies. Including thermal cameras increases the situational awareness, reliability, and safety capabilities of the sensor suite.

Radar, LiDAR, and ultrasonic sensors are very useful in covering the shortcomings of cameras. Depth information, i.e., distance to objects, can be measured effectively to retrieve 3D information with these sensors. They are not affected by illumination conditions. They are active sensors. Radars emit radio waves that bounce back from objects and measure the time of each bounce. Emissions from active sensors can interfere with other systems. Radar is a well-established technology that is both lightweight and cost-effective.

Our Radar is fitted in front of the vehicle inside the bumper. Radars can detect objects at longer distances than other sensors. In our setup, Radar also works as an additional fault tolerance factor by providing emergency braking. Depth information, i.e., distance to objects, can be measured effectively to retrieve 3D data with the Radar.

LiDAR is used on all Level 4 or Level 5 prototype vehicles due to its ability to provide accurate depth and spatial information about the environment. LiDAR data, represented in a 3D point cloud, augments camera and radar data to classify objects around the vehicle more quickly and accurately. It provides highly accurate and precise depth information, works day and night, agnostic to lighting and most external conditions, mid-level resolution (much higher than Radar, lower than a camera).

We have five LiDARs that are mounted on the bus. We have 128-channel LiDAR at the top and 32-channel LiDARs at the corners.

Localization:

Localization stack is based on finding the vehicle's location in the world frame by using real-time sensor data and matching them with HD maps. Objects around the vehicle localized in the world after the vehicle locates itself. Our state-of-the-art localization system fuses data from:

- LiDAR: landmark localization
- HD-Maps
- High precision GNSS with IMU and satellite-based correction
- External IMU
- Vehicle CAN
- Odometry

In this way, our vehicle can localize in urban canyons, tunnels, and other challenging conditions. Also, the fusion of multiple sensors for localization provides redundancy. Even with an HW failure in the localization subsystem vehicle can continue its operation.

Perception:

For complex urban scenarios, our systems employ sensor fusion for perception. The automated driving system uses multi-modal signals for perception, RGB & thermal camera images, LiDAR points, Radar points, ultrasonic sensors, and map information. As a result, it perceives all relevant traffic participants and objects accurately, robustly, and in real-time.

Classifying vehicles, pedestrians, bicyclists, animals, and objects that could affect the vehicle's safe operation is challenging, and the perception stack's mission is to detect and classify them. The sensing and perception system is designed as one object could have been seen and detected by at least two sensor modalities. Using five different sensor modalities aims to create a fault-tolerant, redundant, and robust system.

The system can detect and classify objects around the vehicle at a 360-degree view. It determines objects' positions, estimates their speeds and directions. We fuse outputs from multiple sensors (LiDAR, RGB Camera, Thermal Camera) for increased precision in detecting objects and scene perception. Besides, the perception system can detect traffic lights and traffic signs. Since the system vehicle is a bus, the perception software's other responsibility is to check around the vehicle for the safety of passengers.

Prediction:

Prediction software module predicts objects' next states such as position, speed, and direction according to objects' classes. For example, static objects cannot move suddenly, but dynamic objects can. The behavior of a dynamic object changes according to its class. For example, even though most traffic participants' behavior is similar, pedestrians can change their directions suddenly compared to others.

Since the bus moves among other dynamic objects on the road, such as cars, bicycles, and pedestrians, our system needs to predict the behavior of these objects to make the best decisions about what the vehicle should do. The behavior of an object is predicted by generating a trajectory for it. Prediction is real-time, which means the latency is less than 40ms.

Planning:

Since the bus moves among other objects on the road, many of them are moving objects, such as cars, bicycles, and pedestrians, our system needs to predict the behavior of these objects. So that we are able to make the best decisions about what our own vehicles should do. We predict the behavior of an object by generating a trajectory for it. Prediction is real-time, which means the latency is smaller than 40ms.

The planning software plans multiple routes for the vehicle to drive from the start to the end, including bus stops. It uses HD maps to define the drivable areas and selects the best trajectory for the trip considering vehicle limitations. If there is an object on the road which can affect safe drive, planning decides to swerve or lane change according to other routes' availability.

While the planning module plans trajectory, it obeys traffic rules defined in HD maps. Planning decides movement according to the other vehicles' locations in the intersections.

Control:

The control module generates control signals for actuators and communicates with the vehicle. It gets commands from the Planning Module and calculates necessary throttle, brake, and steering angle commands to send the bus as inputs, considering predefined jerk and acceleration limits.

V2X:

Our vehicle can communicate with the interface and other vehicles around itself with On-Board Unit (OBU). With this communication, our bus can move more safely and more comfortably for passengers. A critical use case for V2X communication is the traffic light communication (with the Roadside Units – RSU). Traffic light detection and handling is much safer with V2X communication. Receiving time-to-green information (SpaT: signal phase and timing) enables smoother moving and safer passage along the intersections.

HD Maps:

flowride.ai uses High-Definition (HD) Maps to understand the environment in real-time. The maps include a 3D point cloud map of the environment, the geometry of the road and curbs, drivable area, lane boundaries, traffic signs, crosswalks, stop lines, yielding points, speed bumps, traffic lights, and traffic rules. HD maps are created with the help of LiDAR, IMU, GNSS sensors, and Cameras.

FALLBACK (Minimal Risk Condition):

Our flowride.ai ADS is capable of performing the fallback and achieving a minimal risk condition automatically after the occurrence of a system failure in the ADS or vehicle that prevents continued driving task performance or upon operational design domain (ODD) exit to reduce the risk of a crash when a given trip cannot or should not be continued.

Our automated driving system constantly monitors the vehicle's performance to detect any system failures and changes in operating conditions and evaluates the risks involved.

The characteristics of automated achievement of minimal risk condition vary according to the type and extent of the system failure and the particular operating conditions when the system failure or ODD exit occurs.

The ADS performs one of the following fallback responses based on the risk assessment:

• bringing the vehicle to a stop within its current travel path, turning on the hazard flashers, summoning road-side assistance

• removing the vehicle from an active lane of traffic, maneuvering the vehicle to the road shoulder and parking it, turning on the hazard flashers, summoning road-side assistance

• automatically returning the vehicle to a dispatching facility or to a predefined stop designated in the map in degraded mode ("limp-home mode")

Our buses additionally have a failure mitigation strategy which is designed to automatically bring the vehicle to a controlled stop in path following the occurrence of a system failure (e.g., connection to ADS is lost, ADS is not responding, loss of backup power after initial power failure or incapacitation of the ADS' computing capability) or external event so catastrophic that it incapacitates the ADS, which can no longer perform vehicle motion control to perform the fallback and achieve a minimal risk condition.

The ADS has a fault-tolerant design which provides high availability. Two identical physical computing units in the system are configured as a failover cluster (i.e., primary, and secondary computing units with a redundant set of base vehicle connections). Failover occurs in the cluster, and the system automatically switches to the secondary computing unit when the primary computing unit fails. The system transitions to a degraded mode (the "limp-home mode") after the failover. The ADS utilizes the backup system in order to achieve a minimal risk condition.

The next version of the bus will also be equipped with a redundant electrical power system and redundant actuators (steering and braking).

Our buses are also capable of requesting remote assistance in order to facilitate trip continuation when the ADS encounters a situation it cannot manage. A remote assistant in the control center uses the vehicle's onboard cameras to identify the situation and instruct the ADS to proceed or provide the ADS with revised goals and/or tasks that allow the vehicle to automatically proceed and complete its trip.

2.3. Does your AV(s) use Vehicle-to-Infrastructure (V2I). If yes, please describe its impact on safety and the extent to which V2I systems are required.

Yes, our buses use Vehicle-to-Infrastructure. Our vehicle can communicate with the interface and other vehicles around itself with On-Board Unit (OBU). With this communication, our bus can move more safely and more comfortably for passengers. A critical use case for V2X communication is the traffic light communication (with the Roadside Units – RSU). Traffic light detection and handling is much safer with V2X communication. Receiving time-to-green information (SpaT: signal phase and timing) enables smoother moving and safer passage along the intersections.

2.4. Describe any physical infrastructural requirements for the successful operations of your service.

In case the V2X system cannot be used, there is no need for any physical infrastructure.

2.5. Describe the process by which improvements to the vehicle/sensors/automated driver would be made.

ADASTEC's Long-term roadmap will be established based on the topics below.

1- No Safety Driver in the route: To provide the safest operation by minimizing human-induced errors of automated vehicles, developments will be done to ensure safe and comfortable operation without the need for an automated vehicle safety driver. Currently, flowride.ai can operate without a driver, but a completely driverless system will be designed by making improvements and tests, considering all the variables (environment, traffic, etc.).

2- Adverse weather conditions: Autonomous E-Atak can safely continue its operation in rainy, snowy, and slightly foggy weather conditions. However, to provide the safest operation in different parts of the world, the system is being improved against various harsh weather conditions. In addition, the impact of existing deployments and projects on this development aim is also beneficial. For example, sensor fusion methods are being developed for adverse weather conditions within the scope of the ongoing project at Michigan State University, USA. This project is funded by The Scientific and Technological Research Council of Turkey (TUBITAK).

3- Highway / Freeway Operation: Operational routes and road types are important factors in developing the safest automated public transportation system for cities. In the current situation, while providing operations on city streets, suburban/rural roads, and campuses, improvements will be made to provide Highway/Freeway operations to reach longer distances and ensure safe operation on different routes.

4- Road Works: Road works may change the route. These maintenance works can take place on the roads at regular intervals. Despite this change, the road work handling function will be developed to continue the operation. A fast update of HD-Maps will be developed to overcome this challenge.

5- Maximum speed limit: The current maximum operational speed of Autonomous E-Atak is 18.6 mph. With ongoing developments, this speed will gradually become 25 mph and 37.2 mph. Since this development also depends on the operation environment, holistic development studies will be carried out. The current project, which provides high-speed operation capability, is funded by The Scientific and Technological Research Council of Turkey (TUBITAK).

6- Overtaking: When the system detects an object on the operating route, it brakes, decelerates, and stops at a safe distance. Then, the safety driver must manually drive the vehicle and pass the relevant object for the automated driving system continues operation again. With the related developments, the system will be capable to carry out this process autonomously. In addition, when a sudden object encounters, the safest maneuver will be calculated according to the TTC (Time to Collision) calculation, with the developments, swerving maneuver will be possible when necessary.

7- Emergency Vehicles: Emergency vehicles constitute a common scenario in traffic. While it is necessary to yield to the emergency vehicles coming from behind in traffic, it is essential to prioritize coming from the dual carriageways. These vehicles will be recognized with the developments, and the most appropriate maneuver will be done.

8- V2X: Within the scope of the V2X studies, which is under development, it is aimed that the system will communicate with the traffic light, share the relevant information and provide the safest and most efficient passage. This ongoing project is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) and supported by U.S. Department of Transportation (USDOT), University of Michigan-TechLab. Currently, traffic light recognition from V2X is under test in our Michigan State University deployment. In addition, an infrastructure for platooning will be designed with better capacity optimization. The ongoing developments aim to ensure a safer and more efficient operation by establishing communication with other infrastructures and vehicles via V2X technologies.

9- Full compliance of safety standards: In order to develop a safe automated vehicle driving system with current developments, existing standards are followed. In the ongoing process, full compliance with these standards will be achieved with a holistic approach. Also, contributing to the conversion of standards related to systems integrated into existing automotive and automated vehicles directly into standards related to the development of safe and comfortable automated vehicle systems. While following the recommendations of the standards, we will also contribute to new standards with our experiences.

The next version of the bus will also be equipped with a redundant electrical power system and redundant actuators (steering and braking).

2.6. Describe how your solution achieves the following potential project goals:

2.6.1. Safety

As mentioned in Chapter 2.2, although there are many standards related to autonomous driving system development, testing and operation processes, evaluating and following only one of the standards is not sufficient to develop a safe and efficient system. For this reason, we adopt a holistic approach and apply it to all our departments (for ISO 26262, ISO/PAS 21448, ISO 22737, UL 4600 and others). Our development processes are planned to cover this holistic approach from concept phase to operation and maintenance. In addition, it is very important to plan, perform and report the tests in parallel. We have Safety and Testing Team that works with other teams to achieve these goals.

At ADASTEC, the development and test processes are followed with the V-Model principles also recommended by the standards. In the planning of each development process, from the first step, the requirements of the tests are determined and designed in parallel with the development plans.

In the general construction, holistic and procedural tests and simulations are carried out under the headings of software tests, simulation tests, x-in-the-loop tests, and real road tests. In addition, ODD tests, tests for standards, scenario tests, deployment tests are included in the process plans of the products, and they are continued with the principles of continuous development and improvement.

Each software module starts its validation process through a virtual world. Our photorealistic simulation, in combination with various driving scenarios, provides a solid base to analyze and pinpoint flaws before real-world testing. Based on simulation results, if the software module fulfills the defined pass/fail criterion, then the validation process continues with testing the actual vehicle at the test track. Simulation and real-world testing form a cycle that iteratively enhances software capability in terms of functionality and safety.

This modular software development approach combined with hardware and real-world vehicle testing provides comprehensive validation and verification methodology.

During the ADASTEC development studies, Safety and Test are included in all processes. In parallel with the developments made in this project, tests will be designed according to the safety and technical requirements. It is crucial to build-up the Safety Case in the whole process. Test records and logs, reports, development tests and notes, simulation results and reports, and all kinds of data that will be evidence will be included in the safety case. In this way, new inputs to the development processes will be created, the safest and efficient system design will be provided, and the stakeholder, standard institutes, and partners will be able to follow all the processes. This process will be continued to implementation routes. The operation will continue in the new route by optimizing the system in the pilot phase and integrating all environmental variables within the scope of perception, prediction, and control. In the whole process, the safety case will continue to be fed with camera recordings, data logging, and related system records, and regular reports.

2.6.2. Equity

With the public transportation ecosystem to be developed within the scope of the project, all residents of the neighborhood (elderly, child, adult, disabled) will be able to summon the autonomous bus by going to the nearest kiosk and travel safely and comfortably to any other kiosk point they want.

Calling the vehicles will be achieved from the mobile phone application, as well as via the devices at the kiosk points for those who do not have access to the mobile phone. In addition, thanks to Autonomous e-Atak, which has a maximum capacity of 50 passengers, they will be able to receive service without experiencing capacity problems and with very short waiting times. Thus, equal, safe and comfortable travel services will be provided for all neighborhoods planned within the scope of the project.

2.6.3. Affordability

In order to carry out the operation, we will work with a bus transit agency. Compared with the small shuttles, a full-size bus will be more affordable in terms of the operational cost and service per passenger mile, since it has a higher passenger capacity.

2.6.4. Sustainability

Autonomous e-Atak is a fully electric, zero-emission M3 category public transportation bus, includes TM4 Electric Motor and BMW Li-Ion 360V battery. With this equipment, it can reach a range of up to 185 miles on a full charge. For this reason, it is able to achieve all the sustainability targets of the project with high efficiency.

2.6.5. Efficiency

For active fleet management, dynamic repositioning and optimum routing, a partnership will be made with a professional and international public transport agency experienced in the operation of autonomous vehicles.

2.6.6. Desired Features

- Autonomy

  flowride.ai delivers the most advanced Level 4 automation platform for full-size commercial vehicles currently available. The main target of flowride.ai is its implementation and operation on public transportation buses and the automation of urban transportation routes.

flowride.ai platform consists of a modular automated driving software in the bus and a cloud-based back-office platform. The bus module handles all aspects of the automated operation of the vehicle through an integrated, fault-tolerant set of sensors and HD-Maps, where enhanced sensor fusion and deep learning techniques are utilized. The cloud-based platform supports mission control, data sharing, and fleet management operations.

flowride Drive

- Level-4 Automation Stack
- HMI
- Connector

flowride Cloud

- Open API
- Data Storage
- Data Sharing

flowride APPs

- Remote Management
- Command & Control
- Passenger Application
- Analytics

Current key features of the autonomous driving stack are represented below:

	In-city Bus Routes Predetermined/ Pre-mapped Campuses / Dedicated Mixed Traffic Conditions
	Fully Automated in the route Day/Night working capability Operation in Rain / Hazy conditions No Safety Driver in the route (2022 Q4)
	Operation Management Mission Management Communication Data sharing
	Bus stop handling Controlled Intersection handling Yielding function for uncontrolled intersections Traffic light Crosswalk handling Traffic participants handling

The main target and operation area of Autonomous E-Atak is urban transportation routes. The vehicle can drive fully automated along routes with multiple stops. The routes are pre-mapped and fully simulated. Before deployment, a detailed 3D simulation environment, HD-Maps, and 3D maps are prepared.

The following table defines the operational design domain. The minimal risk maneuver is performed if the vehicle is out of ODD.

Attribute	Capability
Routes	• Dedicated/Non-Dedicated Bus Routes • Predetermined/Premapped • Mixed Traffic Conditions • Multiple Bus Stops • Multiple Routes/Timetables
Road Types	• City Streets • Suburban/Rural roads • Campus roads • Highway/Freeway (2022 Q4) • Maintenance Yard (2023 Q1)
Speed	• 18.6 mph • 25 mph (2022 Q1) • 37.2 mph (2023)
Lighting & Hours	• 24 Hours • Day & Night
Weather	• Rain • Hazy • Light Snow • Foggy and heavy snow (2022 Q4) • Hail, Extreme environmental conditions (including but not limited to hurricanes, earthquakes, landslides, etc.) are not supported
Hills	• 24% climbing capability
Driving	• Intersection handling • Traffic lights • Crosswalk handling • Traffic participants handling • Overtaking (Requires authorization)
Tunnels/Urban Canyon	• Supported
Changes in Map	• HD-Maps should be updated to cover any changes in the route
Min Curvature	• 23 Ft (7 Meters)
V2X Support	• Traffic light

- ### Safety and Communication

Autonomous E-Atak has physical emergency stop buttons for safety drivers. Also, the safety operator can stop the vehicle immediately by hitting the "EMERGENCY BRAKE" button from the Operator HMI. Emergency stop buttons could be also added to the inside and outside of the buses for passengers as an option as well as smoke and fire detectors. Once any passenger pushes the emergency buttons, the bus will brake and doors will be opened immediately. It has also software-defined emergency evacuation capability. Our buses have a failure mitigation strategy which is designed to automatically bring the vehicle to a controlled stop in path following the occurrence of a system failure (e.g., connection to ADS is lost, ADS is not responding, loss of backup power after initial power failure or incapacitation of the ADS' computing capability) or external event so catastrophic that it incapacitates the ADS, which can no longer perform vehicle motion control to perform the fallback and achieve a minimal risk condition.

flowride.ai doesn't feed the GPS data into the police and fire department and 911 dispatch center. However, this function could be integrated according to developments in the Pilot Phase, easily.

Autonomous E-Atak has internal live cameras with recording capability. Internal and external cameras could be monitored form a centralized operations center.

Flowride Cloud enables information access for the status and the planned operations of automated transit systems from a control center through managed APIs (Application Programming Interface) and APPs (Applications).

Open API platform for the automated fleet includes all the required interfaces for automated fleet management from a control center. flowride Cloud handles all the requirements for secure and high-performance data sharing, analysis, and integration. It provides seamless integration to all stakeholders for automated and modern transportation.

Operators, automated fleet owners can develop their flowride APPs for the automated fleet using flowride API. flowride APPs support remote management of the fleet operations.

Autonomous E-Atak secure data transmission to the cloud provider, such as telemetry, status, events, and logs, are done with the MQTT (MQ Telemetry Transport) network messaging protocol. This protocol can create lossless, bi-directional connections with the remote-control center and the vehicle with minimal latency. Since flowride.ai uses AWS IoT (Amazon Web Service – Internet of Things) Core as a service, there is no overhead on managing and scaling the MQTT broker infrastructure. This big data coming from the vehicles are stored within the cloud data lake for further real-time monitoring and analysis. Upon any suspicious activity or disengagements from the vehicle, a set of telemetry and diagnostic logs are also uploaded to the remote serverless data store to be reviewed by the developers.

An MQTT connection is always open between the vehicle and the remote-control center. It can publish messages to the vehicle with very low latency. Our set of APIs opens a way to interact with the vehicle in a modeled and secure manner. Flowride API is documented in OpenAPI Specification, allows interacting with the vehicles HMIs for remote information, such as possible traffic events or a way to interact with the vehicle in a forced disengagement scenario. Flowride API also enables company applications to overview analytic data generated by the vehicles by querying the data stores. For partners that require more observability on the vehicles, we offer one-way direct communication with the MQTT network for real-time monitoring of the raw data.

Since this is a full-size bus, child safety seats could be added to all vehicles as a standard.

- Rider Experience

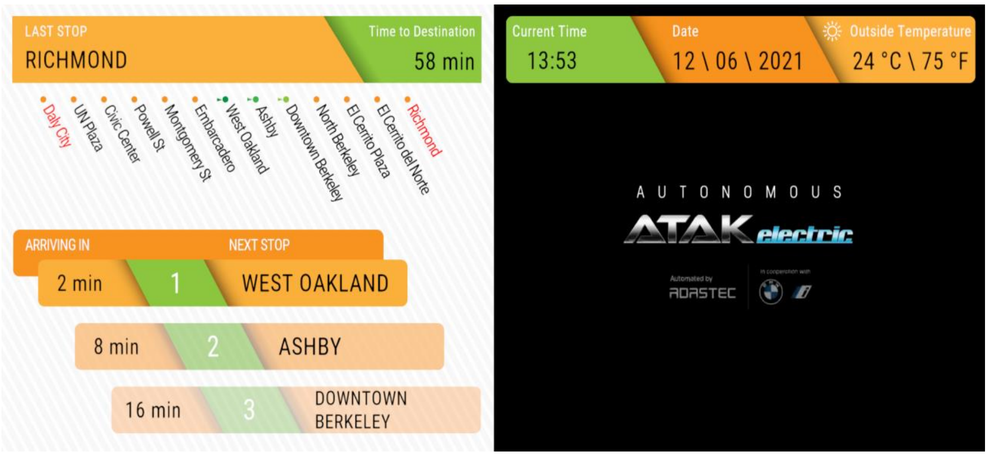
Autonomous E-Atak has passenger A/C with heating function, driver A/C with heating function, passenger area heater, and passenger sidewall heater as a standard. It is fully handicapped accessible, and it has an area for wheelchairs. There are six different passenger capacity alternatives for the bus. Up to 52 passengers can get on it, and up to 21 passengers could be seated with seat belts. The passenger capacity alternatives are below.

PASSENGER CAPACITY ALTERNATIVES

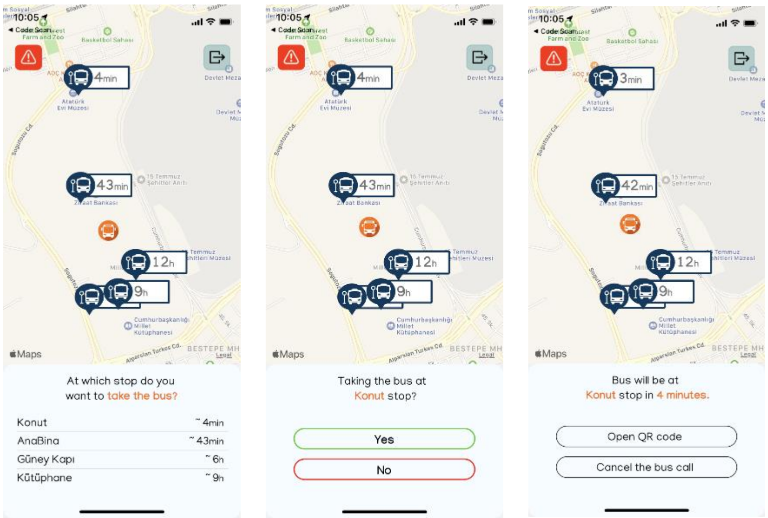
	Seated	Max. Standing	Foldable	WheelChair	Max. Total Passenger***
18+4	18	34	-	-	52
	18	28	-	1	47
	18	29	4	-	51
21+2	21	31	-	-	52
	21	25	-	1	47
	21	25	2	-	48

***Passenger capacity depends on selected optional features & wheelchair area utilization.
Wheelchair is valid only when foldable seats are not being used.

There are two sources to inform the passengers: a large screen inside the bus and the mobile application. The list of destinations, time of arrival of the stops, and the progress between them are displayed on the screen inside the bus. In addition, weather conditions and location-based information are also provided to the passengers. Also, the state information of the vehicle such as "Waiting," "Approaching to the bus stop," and other announcements are provided to inform the passengers.



Passengers can see the vehicle's location and the specified route on a map showing the arrival time at each bus stop via the mobile application. Passengers can summon the vehicle to the target bus stop by choosing from the list in the app. When the vehicle approaches the selected bus stop, the application notifies the passenger. There is also a clearly labeled emergency button on the main screen of the mobile application for passengers to immediately inform the central authority in case of any emergency.



In the pilot phase, the bus stop intercom device will be placed at the bus stops on the route, where the passengers can make calls for the bus and access information about the operation. Also, the centralized operations center can make announcements to passengers waiting in the bus stop via this equipment. The device is used to create a live communication link between passengers and traffic control Centre via a cellular link. A 4G/LTE live connection is established from device to system control computer and this link is used to make a bus request, receive status messages and create a live conversation with dispatch offices if available. The device has two user buttons; one is to request for a bus ride and creates a call to the next available bus for a passenger pick up. Call status is displayed on screen and an audible signal is created if the screen message changes. Second button is to request an audio call with the dispatch officer if available. Call status can be observed on screen and if the call is responded, the passenger is informed to talk to the officer on duty.

All kinds of payment options can be applied according to demand.

3. Driverless Operations

3.1. Can your AV drive fully autonomously without any human input or on-board customer hosts? Please describe the extent of autonomy and its ODD.

With the goal of providing the safest operation by minimizing human-induced errors of autonomous vehicles, developments will be done to ensure safe and comfortable operation without the need for an autonomous vehicle safety driver. Currently, flowride.ai can operate without a driver, but a completely driverless system will be designed by making improvements and tests, considering all the variables.

3.2. If driverless operation has been achieved, describe its extent and limitations.

We had several demos without the driver. The most important ones are demos for Norwegian authorities and for the President of Turkish Republic. The routes for demos were completely closed off other pedestrians and vehicles to ensure safe and comfortable operation.

https://www.youtube.com/watch?v=mVCiVCukUGY&ab_channel=AdastecCorp.

https://www.youtube.com/watch?v=m56f4LOYaBs&ab_channel=AdastecCorp.

3.3. Describe the process by which decision to remove the on-board customer host would be made.

Ensuring the safety of the fleets is one of the most critical functions of the traffic control center. Intervention to the vehicle, like removing it from a problem area and pulling it over to a safe place, may be required in some specific cases which cannot be resolved instantly by the automation system. Ottopia platform will be integrated into the flowride.ai system to strengthen the functionality of the existing traffic control center. This integration will be accomplished after the pilot phase of the project.

Ottopia provides a teleoperation system for automated vehicles. When a driverless vehicle encounters a situation it cannot handle, the operator, located in a distant control center, can assist remotely and drive the vehicle at low speed.

The operator's station enables remote control over connected vehicles as well as driving and monitoring using high-quality video streaming. The station is located at the fleet's operation center and connected to the vehicle over cellular networks.

4. Prior Experience

4.1. Please provide no more than three (3) examples of existing customers using your proposed solution or a similar solution.

- One of the deployments is in Norway. Vy Buss is one of the companies who participate in the project. Vy is the largest bus company in Norway and second largest bus company in Scandinavia, operating in Norway and Sweden. Currently, the product we provide is in the city of Stavanger. With the inclusion of systems such as fleet management, vehicle to everything, remote control, we are on our way to becoming city-integrated product. It will also soon begin testing for use in Bus Rapid Transits. There are other deployments planned in the northern region and it is expected to be completed in 2022.
- Another deployment is in Romania. The customer, Invoker Trans IT, is part of the telecommunication industry in the city of Ploiesti. The project was completed in 2021 and is used autonomously in the techno park area where the company is located.
- One more deployment has been carried out by us in the USA. Operation still goes on in the campus area, which is a public road, to carry students from the parking lot to the Auditorium in Michigan State University. The project partners are Michigan Economic Development Corporation and Michigan State University. With this project, Autonomous e-Atak Bus has become the first and only automated bus that has NHTSA approval and deployed.

4.2. If applicable, please provide details of any other transportation agencies or governmental entities who are customers.

- One of our customers is in France. Project partner Keolis Group is one of the biggest shared mobility solutions providers in the world. They are also one of the biggest transportation agencies in Europe. Currently, the product we provide is in the city of Châteauroux. The customer is currently planning to expand its usage area by integrating the services it provides into the bus. Further deployments planned with this partner will be completed in 2022.
- And the other customer we work with is Kolumbus. They are a governmental entity in Rogaland Region in Norway. Mostly they operate buses and boats but other than that they have car sharing solutions, electric bikes and connecting trains to reduce private vehicle usage in Rogaland.

4.3. Please provide details of any previous, ongoing, or scheduled sales discussions that you are having with NJDOT (if any)

We don't have any previous, ongoing, or scheduled sales discussion with NJDOT.

4.4. Please provide details of any previous, ongoing, or scheduled sales discussions that you are having with NJDOT contractors (if any).

We don't have any previous, ongoing, or scheduled sales discussion with NJDOT.

5. Company Information

5.1. Is your company Disadvantaged Business Enterprise (DBE) or Small Business Enterprise (SBE) certified?

No, it is not Disadvantaged Business Enterprise (DBE) or Small Business Enterprise (SBE) certified.

5.2. Is your company registered to do business in the state of New Jersey?

No, it not registered to do business in the state of New Jersey.

5.3. What is your business incorporation number, Tax Identification Number or Employer Identification Number?

ADASTEC CORP.

EIN # : 36-4860443

6. Partnership Information

6.1. Please list requirements your firm would have of State of New Jersey and City of Trenton as a partner on this potential project.

Indoor and outdoor parking lots with charging stations, offices for the traffic control center and for engineers who are responsible for the deployment of the buses are required. Also, investment in V2X infrastructure is highly recommended.

6.2. What is your proposed commercial model and/or proposed approach to financing?

We propose commercial model is to request a confirmed and irrevocable letter of credit to confirm orders.

6.3. Please list your proposed core team members and their roles, as well as any sub-contractors.

There will be three core members existing. KARSAN is the bus producer, ADASTEC is the automation provider and a bus transit agency will be the operator of the buses.

7. Competition Information

7.1. Please list any existing non-compete arrangements or intellectual property agreements that overlap with the potential project.

7.2. How did you hear about the program?

We heard the program from the Mass Transit website.

7.3. Please share any additional links or comments related to this application.

https://www.nrk.no/rogaland/na-skal-denne-autonome-bussen-sleppast-laus-i-bytrafikken-i-stavanger-1.15819751

https://www.forbes.com/sites/davidnikel/2022/01/21/driverless-bus-test-announced-in-downtown-stavanger-norway/?sh=59921d7e6552

https://www.raillynews.com/2022/01/Autonomous-e-Attack-hits-Norwegian-roads/

https://mobility.msu.edu/events/MSU%20Autonomous%20Bus.html

https://msutoday.msu.edu/news/2021/msu-unveils-new-electric-autonomous-bus

https://www.egr.msu.edu/news/2021/11/09/msu-introduces-electric-autonomous-bus

https://www.autonews.com/shift/michigan-state-will-launch-electric-self-driving-bus-early-2022

https://www.dbusiness.com/daily-news/msus-new-electric-autonomous-bus-launches-in-january/

https://www.sustainable-bus.com/electric-bus/autonomous-bus-michigan-university/

https://www.lansingstatejournal.com/story/news/2021/11/05/self-driving-bus-msu-michigan-state-university/6287717001/

https://cbwmagazine.com/turkish-president-travels-in-autonomous-e-bus/

https://www.sustainable-bus.com/electric-bus/turkish-president-erdogan-is-the-first-passenger-of-the-autonomous-atak-electric/

http://carrilbus.com/el-presidente-turco-erdogan-se-convierte-en-el-primer-pasajero-de-karsan-autonomous-atak-electric

https://www.karsan.com/en-se/autonomous-atak-electric-highlights