U.S. Department of Transportation

ITS4US

IT'S TRANSPORTATION FOR ALL OF US

BuffALLo All Access Low-Speed Self-Driving Shuttles:

State of the Technology and Sustainability & Equity Implications

Niagara Frontier Transportation Authority

May 16, 2023

Agenda

- **Purpose of this Webinar**
  - To share NFTA's experience, and lessons learned, in planning for and procuring a Self-Driving Shuttle (SDS) to provide integrated, flexible, demand-responsive, end-to-end transit options for the community.

- **Webinar Content**
  - ITS4US Deployment Program Overview
    - Elina Zlotchenko, ITS-JPO
  - BuffALLo All Access Program Overview & SDS State of Technology
    - Robert Jones, Niagara Frontier Transportation Authority
    - Adel W. Sadek, University at Buffalo
    - Stephen E. Still, University at Buffalo
  - Stakeholder Q&A
  - How to Stay Connected

Webinar Protocol

- **Webinar Protocol**
  - Please mute your phone during the entire webinar
  - You are welcome to ask questions via chatbox at the Q&A Section
  - The webinar recording and the presentation material will be posted on the ITS4US website

Elina Zlotchenko

ITS4US Program Manager

ITS Joint Program Office

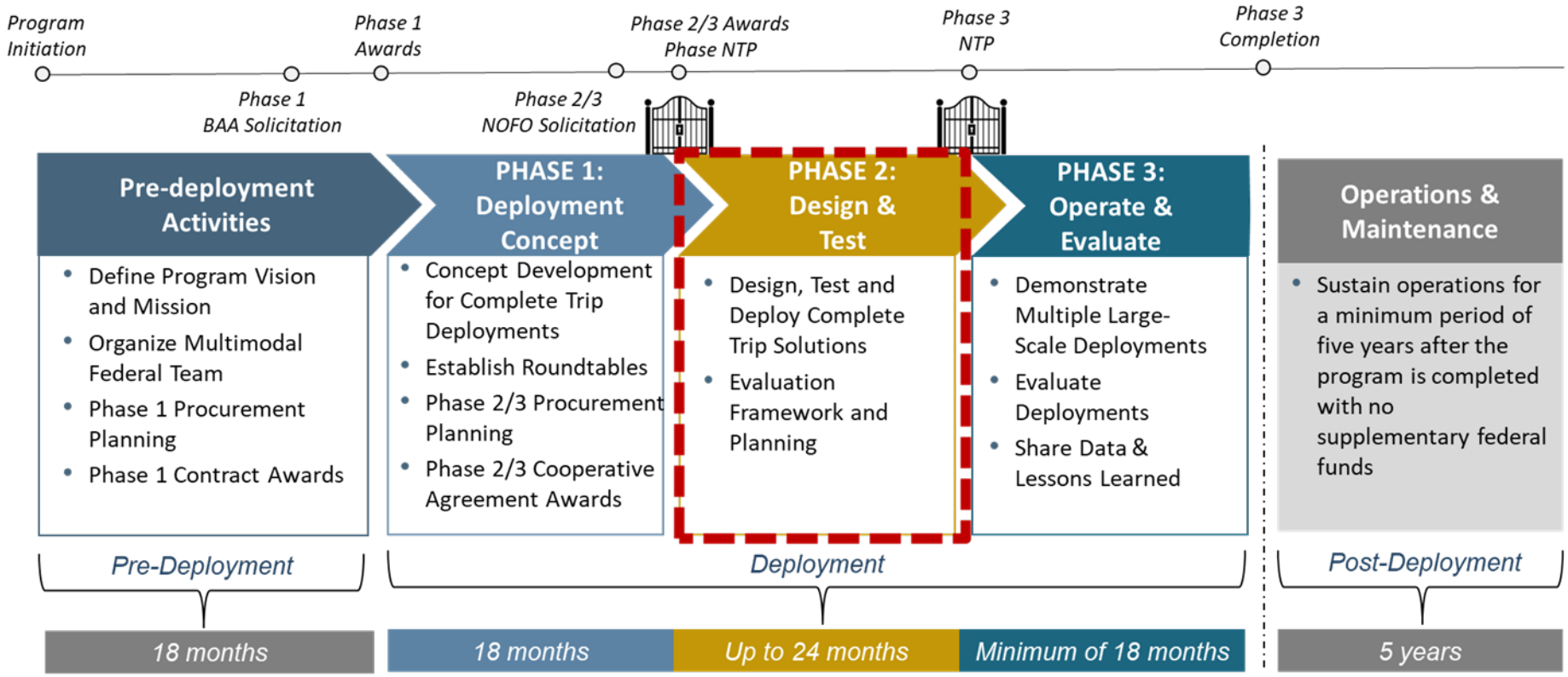
ITS4US Program Overview

- A USDOT Multimodal Deployment effort, led by ITS JPO and supported by OST, FHWA and FTA
- Supports multiple large-scale replicable deployments to address the challenges of planning and executing all segments of a complete trip

ITS4US
IT'S TRANSPORTATION FOR ALL OF US

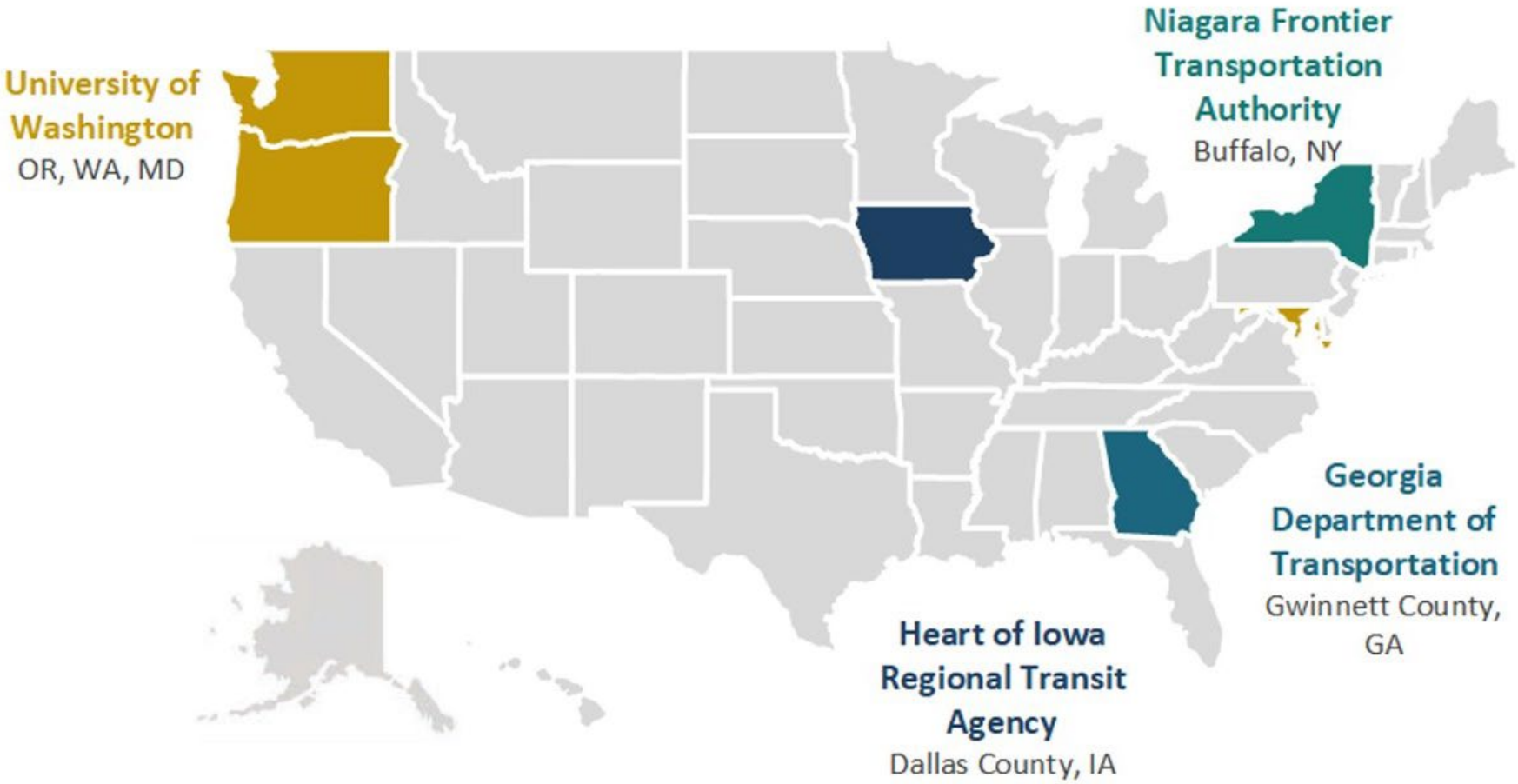
Vision: Innovative and integrated complete trip deployments to support seamless travel for all users across all modes, regardless of location, income, or disability

Deployment Phases



Source: USDOT

ITS4US Deployment Sites



Source: USDOT

ITS4US Team Photo Collage

ITS4US

Source: USDOT

U.S. Department of Transportation
ITS Joint Program Office

Robert Jones, AICP

BuffALLo All Access

Concept Deployment Lead

Deputy Director, Public Transit, NFTA

Deployment Objectives

Consistent, continuous trips to, from, and within the BNMC area.

Online and offline ways to receive real time information on services, and infrastructure usability and accessibility.

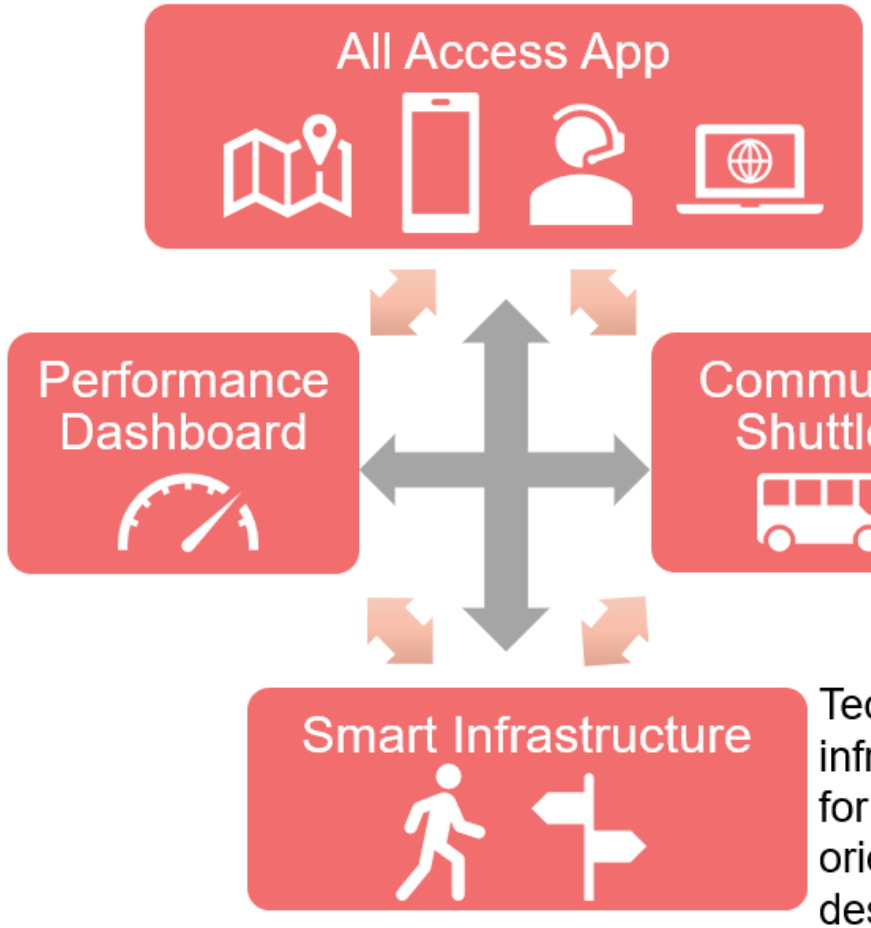
Trip paths that are **safe, accessible, and compatible** with user-defined preferences and capabilities.

Integrated, flexible, demand-responsive, end-to-end transit options for the community.

BuffALLo All Access

- Deployment area: Buffalo Niagara Medical Campus
- Deploys new and advanced technologies to address existing mobility and accessibility challenges
- Integrates accessible trip planning tool with:
  - Current transit services
  - Indoor/outdoor wayfinding
  - On-demand shuttle service
  - Intersection pedestrian safety technologies
- Factors in travelers' preferences and accessibility-related needs for comprehensive trip planning

System Overview



Mobile app, website, and call center for travelers to plan and take trips.

Measures and presents the performance of the system.

Shuttle system providing scheduled and on-demand connections to Metro Rail, BNMC, and surrounding neighborhoods.

Technology and supporting infrastructure for wayfinding for indoor and outdoor orientation, navigation and destination confirmation.

Deployment Concept Summary

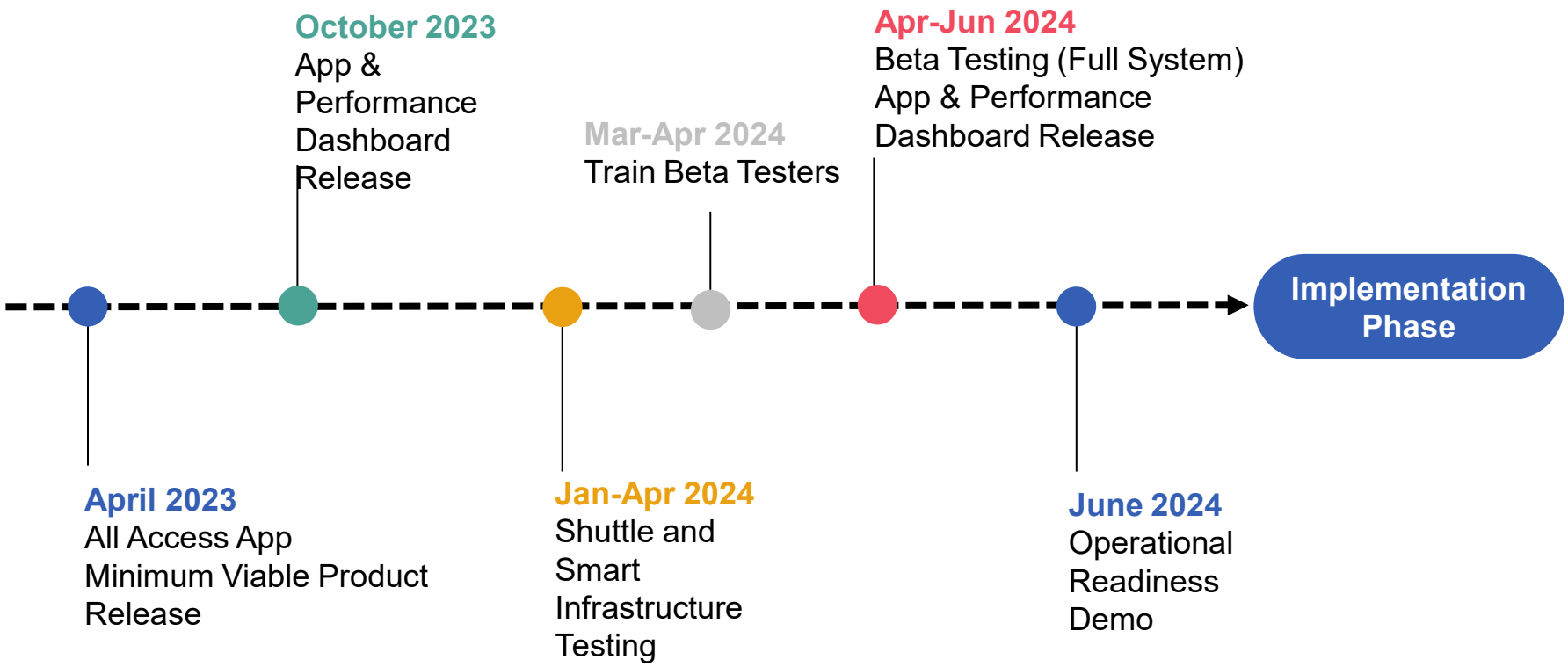
Pre-Trip Planning	Transit to Campus	Within and Around Campus	Inside Building
• Turn by turn guidance to and from bus and rail stops • Availability of various transportation services — Bus, Rail, Paratransit	• App-enabled location tracking, alerts, access preferences (voice, text, haptic alerts) and real-time arrival information • App includes paths through stations, stops and buildings (elevators, stairs, walkways, escalators)	• Hail accessible human or self-driving shuttle (through app) • Universal design & pedestrian safety applications at high-traffic intersections around campus • Outdoor wayfinding, sidewalk improvement for pedestrians with and without disabilities	• Paths through partner buildings for all

NFTA-METRO
nfta.com

At-Scale Deployment Summary

Deployment Element	Estimated Number
Participants	100 participants during Phase 2 to support development and testing of the system and its components. 300-500 participants total in Phase 3 (including Phase 2 participants). Final number will be dependent on the number of people interested in participating. Outreach and recruitment efforts will focus on obtaining the highest and most diverse number of participants possible.
Beacons/Smart Signs	Under 100 devices. The final number is unknown at the time and will be determined once the facilities are measured.
Touch Models	1 model as part of this pilot (location to be determined in Phase 2). Note that pilot will leverage the efforts of an external study that is placing another model at the Innovation Center on the BNMC.
TIH	2 hubs, with location to be determined in Phase 2.
PED-X Intersections	2 intersections, Main St. & Best St. and Ellicott St. & High St. 2 National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) Supported MioVision platform to serve as a communications broker / gateway (one per intersection, total number: 2).
Vehicles	A maximum of 4 shuttles , a combination of SDS and HDS. Phase 2 will start with 2 shuttles for testing and integration efforts, and 2 additional shuttles will be added in Phase 3. SDS Vehicles: 1-2 (note: the number will depend on the procurement) HDS Vehicles: 2-3 depending on the service plan and demand.
Online/Offline Platforms	1 CTP website and mobile application. 1 Performance Dashboard.

BuffALLo All Access Phase 2 Timeline



Stephen E. Still

University at Buffalo

Professor of Practice, Department of Civil, Structural & Environmental Engineering

The Stephen Still Institute for Sustainable Transportation & Logistics

GOALS of Automated "Driverless" Vehicles

- Safety – superior to human drivers
- Equitable and accessible mobility
- Affordability

Human Drivers Have a Poor Safety Record

- **Vehicle fatalities are at unacceptable levels**
  - In 2021, 42,915 people lost lives on USA roads, a 15 year high, despite advancements in vehicle safety (1)
  - Worldwide, fatalities are near 1.3 million per year (2)
- **$340 Billion was the economic cost of crashes in 2019 according to the US DOT NHTSA** (3)

3Ds: Drunk Drowsy Distracted

Sources:

1) *National Highway Traffic Safety Administration. "Traffic Safety Facts Annual Report Table" National Statistics June 2022.*
2) *World Health Organisation: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries*
3) *https://www.nhtsa.gov/press-releases/traffic-crashes-cost-america-billions-2019*

Automated "Driverless" Safety

- **Safe operation of AVs is an absolute requirement**
  - In these "early" days, the bar will be set very high
  - Any frequency of serious accidents or fatalities will be "game over"

We Will Have Trained Safety Attendants Behind the Wheel for the ITS4US Project

- **The "Driverless" track record has been impressive**
  - Waymo, an industry leader, just published safety results from 1 million miles of "rider-only" experience (1)
  - No injuries, 2 reportable accidents, 18 minor contact events
  - Another leader, GM's Cruise, recently published results – claiming 73% less risk of injury compared to human drivers (2)

Sources:

1) *Victor, Kusano et al, "Safety Performance of the Waymo Rider-Only Automated Driving System at One Million Miles". Waymo LLC*
2) https://getcruise.com/news/blog/2023/cruises-safety-record-over-one-million-driverless-miles

Medical and Food Access – Why Automate

WHAT ARE TRANSPORTATION ISSUES THAT AFFECT PATIENTS?

Each year, 3.6 million people in the United States do not obtain medical care due to transportation issues. Transportation issues include lack of vehicle access, inadequate infrastructure, long distances and lengthy times to reach needed services, transportation costs and adverse policies that affect travel. Transportation challenges affect rural and urban communities.

Source: American Hospital Association

A Focus of Buffalo ITS4US is the BNMC

Grocery shopping in Buffalo's food desert

Posted at 3:29 PM, Aug 04, 2020 and last updated 5:35 PM, Aug 04, 2020

BUFFALO, N.Y. (WKBW) — Buffalo's East Side is considered a food desert. It is a problem for people who live there because they don't have access to affordable and nutritious food.

"We are considered a food desert on Federal standards. They have to go over three miles to the east, north, south or west to get to a supermarket. And I believe in the 21st century that we shouldn't have to have that going on," said Pastor Dwyane Jones. *Source: WKBW Buffalo*

Large Elderly Population Lacks Mobility

- **The elderly represent the fastest growing population segment in the USA**
  - Between 2020 and 2050 the 65+ population will grow from 56 to 86 million, and from 17% to 22% of the population (1)
- **The elderly population is challenged with low levels of mobility**
  - High incident of low-income limiting mode options
  - Physical impediments to using transit
  - Restrictions (voluntary or otherwise) from driving privileges

Automated Vehicles Have the Potential to Offer High Quality Door-to-Door Mobility at Affordable Prices

Source:

1) *US Census Bureau "Demographic Turning Points for the US: Population Projections". Revised February 2020*

East Buffalo “Hits All the Boxes” for Need

Zero Car Households: 47%
Income less than $25k: 40%
Elderly Population (65+): 22%

Source: US Census, Photos taken by the speaker, S. Still

Economic Baseline – "Scenario Estimate"

- **Baseline economics of human-driven shared service**

Assumptions:

Labor expectation: $30 / hour
Purchase Cost: $37,000
Fuel Economy: 30 mpg, $3.70/gallon
Standard Maintenance, Insurance, Registration

Cost / Per Mile: $2.10
72% is labor

Notes:
1) *Fuel cost, AAA, Buffalo, May 2023*
2) *Maintenance, Insurance, Registration: AAA "2022 – Your Driving Cost Brochure"*

"Driverless" – Comparable Scenario

Assumptions:

Labor expectation: $0 / hour
Purchase Cost: $37,000
Automation Kit: $50,000
Fuel Economy: 30 mpg, $3.70/gallon
Standard Maintenance, Insurance, Registration

Cost / Per Mile: $0.56
0% is labor

And if we dare share rides?:
Cost / Per Mile: $.25 ??

What AV Models Will Predominate ?

- **Option 1: Private Household Ownership**
  - Expensive vehicles – likely for the wealthy who have mobility
  - Assumes SAE Level 5 (everywhere all the time) - unlikely
  - Perhaps Level 2-3 (shared automation) is what they really want

- **Option 2: Privately Owned Shared Fleets**
  - So far the predominant model e.g. Waymo, Cruise, etc.
  - Limited to Level 4 Operational Design Domains (for safety)
  - Will these be profitable enterprises ?
  - Large initial $ outlays – so supported by large companies

- **Option 3: Publicly Supported Shared Fleets**
  - Justified in terms of enhanced public mobility
  - Provides access to trips for work, social, medical…purposes

Adel W. Sadek

University at Buffalo

Professor, Department of Civil, Structural & Environmental Engineering

The Stephen Still Institute for Sustainable Transportation & Logistics

Community Shuttle (CS) Subsystem

- Select CS-related User Needs:

UN-E-TP-1. Spontaneous Trip: The system needs to provide *the ability to execute spontaneous trips using public transit travel options*….

UN-E-TP-3. Increased Access. The system needs to *increase access of surrounding community to BNMC ..without the use of personal auto*……

UN-E-TP-4. Independence. The system needs to *support independent travel by travelers with disabilities* as much as possible…

UN-E-TP-6. Integrated Multimodal Service: The system needs to be able to *generate and execute multimodal trip plans*…..

UN-E-TP-12. Shuttle Trip Booking and Reservation. The system needs to allow users to *book/reserve a ride on a shuttle based on their preferences, location and origins/destination….*

Community Shuttle (CS) Subsystem

- Select CS-related User Needs:

UN-E-TE-2. Mobility Devices Access: Vehicles in the system *need to include lifts, ramps and securement systems necessary for travelers using mobility devices*

UN-E-TE-13. Adverse Weather Operations. The system needs to *support operations of services in adverse weather*.

UN-S-SO-13. Open Architecture and Interoperability – The system needs to have *an open architecture and be interoperable…..*.

UN-S-BO-4. Shared Use: The system needs to provide as much *shared use of services as possible and not function like an extended taxi service*.

UN-S-BO-5. Filling Transit Gaps: The system needs to act *as a first mile and last-mile (FMLM) service……*

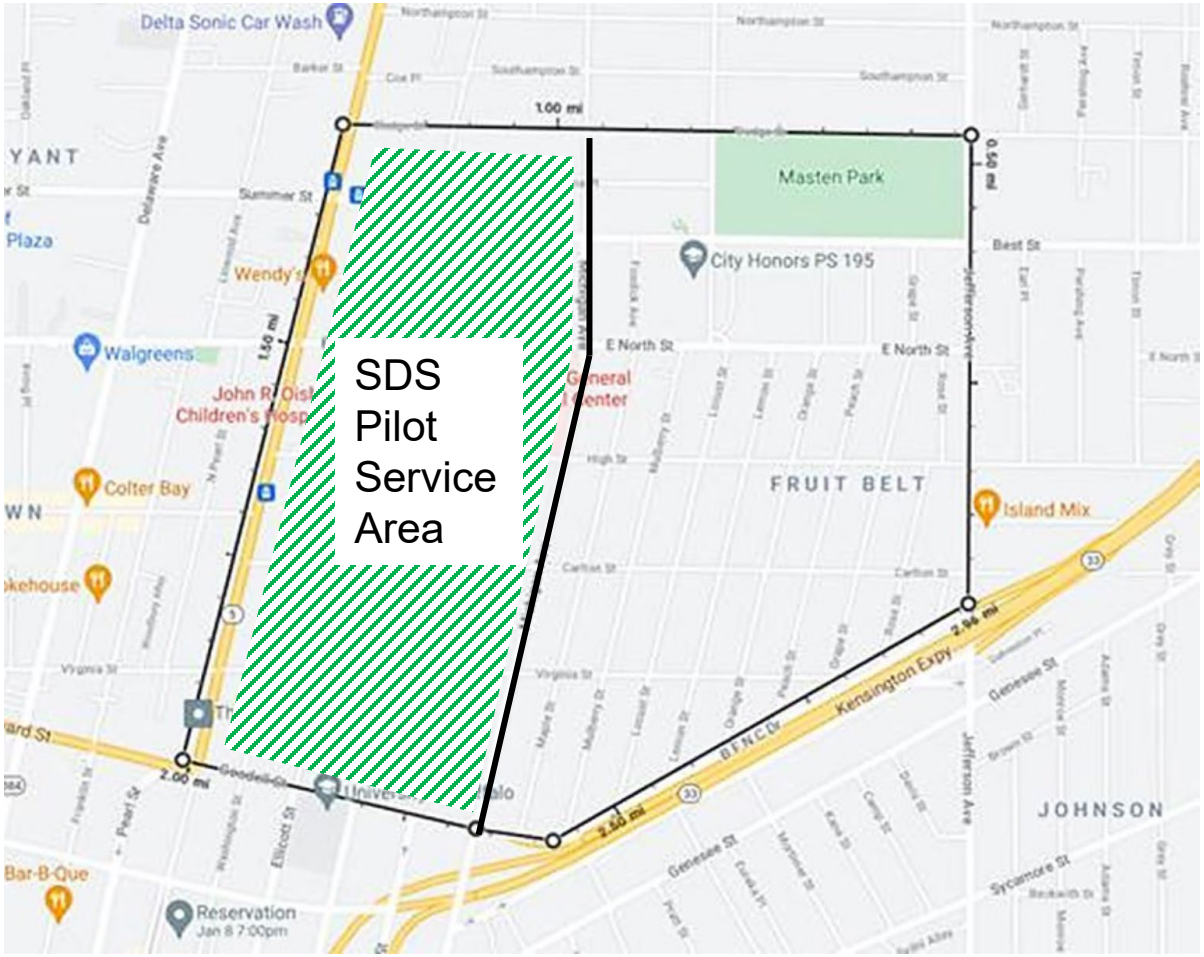
Community Shuttle ConOps

- Operate as a demand-responsive micro-transit fleet consisting of:
  - Human-driven Shuttles (HDS)
  - ***Self-Driving Shuttles (SDS)***
  - Shuttle Operations Center (SOC)

- SDS will be demand-responsive, but operations will be constrained to a pre-defined route of pre-selected streets that satisfy the SDS ODD

- Why a mixed fleet of HDS and SDS?
  - HDS provide alternate mode when conditions go beyond SDS ODD, to travelers who cannot get to SDS pick-up & drop-off locations
  - Contrast the pros and cons of AVs vis-à-vis human-driven vehicles.
  - Insight into the business case for using Avs
  - Offer an educational opportunity for the community to learn about AVs
  - Lower the risk of this subcomponent of our project

CS Service Area



Source : Gopalakrishna, D. et al. (2021). Phase 1 Concept of Operations (ConOps) – Buffalo NY ITS4US Deployment Project, Report No: FHWA-JPO-21-860

SDS Functions (a few examples)

- Autonomous Driving Functions:
  - Sensing & Perception
  - Path & Motion planning
  - Vehicle Control
- Pickup & Drop-off Monitoring
- Passenger Monitoring
- Vehicle Health Status Monitoring
- V2X Communications
- Passenger Information System
- Accessibility Support
- Wheel-chair securement

Photo taken by Douglas K. Levere, UB Image Specialist. Permission granted to authors for use.

SDS Operations Center (SOC) Functions

- Operational Design Domain
- Routing/Scheduling
- Incident Management
- Remote Monitoring
- Reservation Management
- Trip Reporting

Photo taken by Douglas K. Levere, UB Image Specialist. Permission granted to authors for use.

SDS-Related Functional Requirements

Req ID	Title	Description	Need ID
Req-CS-001	Manual and Autonomous Driving	The SDS shall allow for both manual and autonomous driving.	UN-S-SO-14
Req-CS-002	Motor Technology	The SDS shall be powered by either electric motor(s), an Internal Combustion Engine (ICE) or a hybrid engine. If electric, the SDS battery shall allow the SDS to operate for between 4 - 6 hours on a single charge. Accepted charge rate should be in excess of 6 kwh.	UN-S-SO-14
Req-CS-003	HVAC System	The SDS shall be equipped with an HVAC system, providing for adequate cooling and heating consistent with passenger comfort in the Buffalo environment, while ensuring that an electric SDS could operate between 4 - 6 hours before needing to be recharged.	UN-S-SO-14
Req-CS-004	SDS Capacity	The SDS shall have a capacity for transporting 4 or more passengers, plus a safety steward.	UN-S-SO-14
Req-CS-008	Ramp / Lift	The SDS shall be equipped with either a lift or an automated wheelchair ramp that deploys automatically when needed for loading/unloading. If equipped with a ramp, the slope of the ramp shall not exceed 1:6.	UN-E-TE-2
Req-CS-009	Wheelchair Securement	The SDS shall be equipped with an automated or semi-automated wheelchair securement mechanism for securing/unsecuring passengers with mobility devices (e.g., wheelchair, manual or motorized scooter).	UN-E-TE-2

SDS-Related Functional Requirements

Req ID	Title	Description	Need ID
Req-CS-014	Multiple and Redundant Sensor Systems for Perception and Localization	The SDS shall be equipped with multiple and redundant sensor systems for perception, and localization	UN-S-SO-14
Req-CS-014.1	LIDAR Sensor	The SDS shall be equipped with at least one LIDAR sensor	UN-S-SO-14
Req-CS-014.2	RADAR Sensor	The SDS shall be equipped with at least one RADAR sensor	UN-S-SO-14
Req-CS-014.3	Camera-Centric Computer Vision	The SDS shall be equipped with a camera-centric computer vision system	UN-S-SO-14
Req-CS-014.4	Inertial Measurement Unit	The SDS shall be equipped with an inertial measurement unit	UN-S-SO-14
Req-CS-014.5	Localization	For localization, the SDS shall use GPS (with Real-time Kinematic (RTK) positioning for correction), along with a 3D high-definition map.	UN-S-SO-14

SDS-Related Functional Requirements

Req ID	Title	Description	Need ID
Req-CS-024	Detect, classify, measure and Interpret Objects	The SDS perception module shall detect, classify, measure objects and vehicle motion, and interpret surrounding environment across 360 degrees, based on input from multiple and redundant sensors as listed in Req CS-014. This shall take place in such a manner to allow the SDS sufficient time to take appropriate action as described in Req-CS-026.	UN-S-SO-14
Req-CS-024.1	Detect Vehicles	The SDS shall detect oncoming and stationary vehicles at a specified distance (relative to their speed) to allow the SDS to take appropriate actions to ensure safe and efficient operations.	UN-S-SO-14
Req-CS-024.2	Detect Pedestrians	The SDS shall detect pedestrians standing and crossing an intersection. Detection will be based on detecting the pedestrian at a specified distance (relative to their speed) to allow the vehicle to take appropriate actions regarding moving pedestrians.	UN-S-SO-14
Req-CS-024.3	Classify Objects	The SDS shall be able to classify and interpret detected objects, including the ability to distinguish between static objects to the side of the road (e.g., snow banks) and pedestrians.	UN-S-SO-14

SDS Vendors

- Early engagement with SDS Vendors
- Gauge interest, capabilities, and likely cost
- SDS vendors researched and contacted are listed on the following slides in alphabetical order

ADASTEC, Corp

- Adapted Open-source Autonomous Driving software, Autoware, for their use
- Based in Turkey, with US Headquarters Office in Ann Arbor, Michigan
- Prior Deployments
  - Michigan State University
  - Norway
  - Romania
  - Istanbul, Turkey

Autoware Foundation & Autoware CoE at UPenn

- The Autoware Foundation is non-profit organization supporting open-source projects enabling self-driving mobility
- Autoware is an open-source software for Autonomous Driving, built on Robot Operating System (ROS)
- Road map shows prior applications in valet parking, racing, cargo delivery, and current focus on bus/shuttle on public roads and robo-taxi applications
- A traditional shuttle could be outfitted for Autonomous Driving and controlled by Autoware

Beep, Inc.

- An Autonomous mobility-as-service company and not a SDS manufacturer

- Worked with a couple of SDS vehicles:
  - Navya
  - Olli

- Prior and On-going deployments:
  - Several locations in FL
  - Other locations in GA and AZ

Photo taken by Douglas K. Levere, UB Image Specialist. Permission granted to authors for use.

COAST Autonomous

- A self-driving technology company out of California
- COAST P-1 Shuttle designed to operate on pedestrian paths, and in mixed traffic. Prior Demo in Times Square
- Deployment on the University of South Florida Campus

EZ Mile

- A French SDS company, with an office in Denver, CO.
- E-Z 10 SDS with a capacity of about 12 people - is fully electric with a built-in automated electric ramp for accessibility
- Operated as a scheduled, and as an on-demand service.
- The company has its own Fleet management and supervision system: EZFleet, and a test-bed and demo site in Golden, CO.
- EasyMile's new strategy is to move into larger traditional looking shuttles

May Mobility

- Ann, Arbor, Michigan
- Began as a start-up led by Prof. Edwin Olson, U-M
- Toyota is the largest sponsor
- Prior and On-going Deployments in:
  - Arlington, TX
  - Ann Arbor, MI
  - Fishers, IN
  - Grand Rapids, MI
  - Japan

NAVYA

- A French company with several prior deployments around the globe, including locations in the US (Florida and the University of Michigan).

- Navya's SDS, Autonom®, was first launched in 2015 as a first and last mile transportation solution

Ohmio

- Developed by HMI Technologies, a New Zealand-based company
- An electric driverless car, communicating with road signs and other autonomous vehicles.
- Successfully developed and piloted in New Zealand, Australia, China and South Korea.
- Claims to be the first 5G CAV, thanks to a partnership between Ohmio and Spark in Auckland.

Sensible 4

- A Finnish company whose full-stack AD software is designed to operate under all weather conditions

- Several demonstrations including one in Helsinki, with 3 Sensible 4 vehicles operating in regular traffic

RFP Development Process

- Worked with UB Purchasing to develop the RFP, based on the Functional Requirements & market research performed
- RFP went through several rounds of iteration between project team and UB Purchasing
- RFP Released on December 28, 2022

Key Events	
Questions and requests for RFP clarification due:	January 11th, 2023
Answers to questions and requests for clarification issued:	January 18th, 2023
Proposal Due Date and Time:	February 1st, 2023, at 2:30 pm (EST)
Projected Award Date:	February 2023
Projected Contract Start Date:	March 2023
University reserves the right, in its sole discretion, to modify the above schedule. Bidders will be notified via email of any changes in a timely manner.	
RFP #: **22DBM0071**	**RFP Title/Issue Date:** BUFFALO ITS4US Issued: December 28, 2022

RFP Sections

SECTION 1. INTRODUCTION

- SUMMARY OF SCOPE
- BACKGROUND
- METHOD OF AWARD
  - Technical 70 %
  - Price 20 %
  - Presentation 10%

SECTION 2. SCOPE OF WORK AND SPECIFICATIONS

SECTION 3. SUBMISSION REQUIREMENTS AND GUIDELINES

SECTION 4. BIDDER QUALIFICATIONS & REQUIREMENTS

2. Scope of Work & Specifications

- SDS Vehicles
  - Low-speed, preferably electric, SDS designed from the ground-up as an AV
  - A traditional shuttle and or van and outfit for autonomous driving

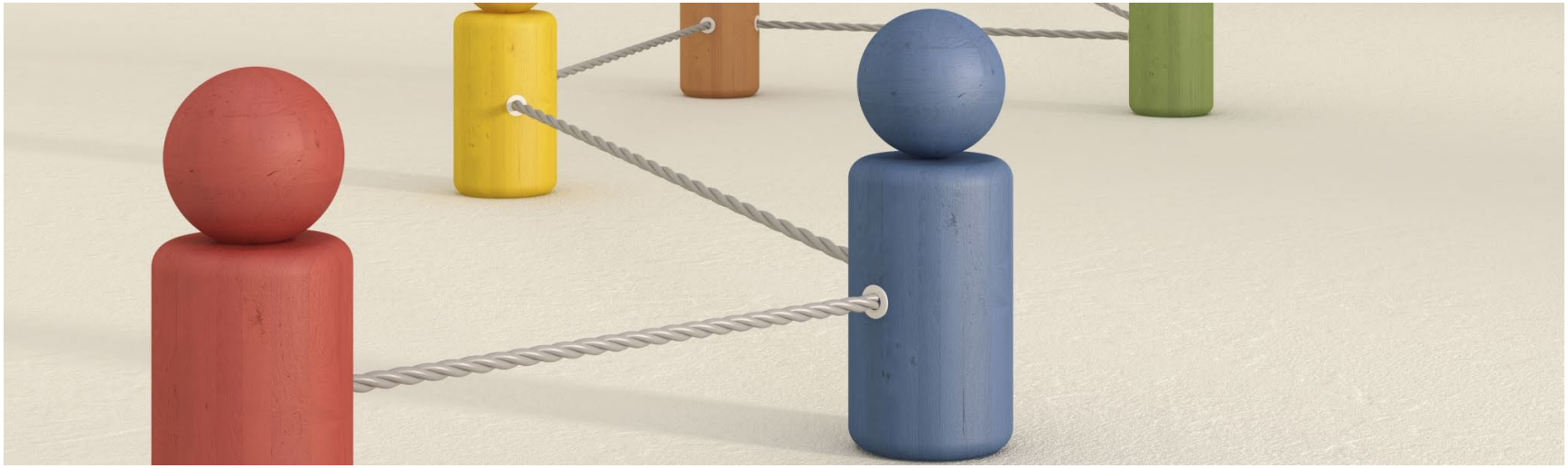
- SOC:
  - Interface with reservation component of CTP
  - Track location of SDS to estimate ETA

- High-level specifications:
  - Operational Design Domain
  - Integration with CTP
  - Safety stewards
  - Personnel requirements
  - Maintenance and Graphics

3. Submission Requirements & Guidelines

- Technical Submission
  - Hardware
  - Software
  - Interface with Infrastructure
  - Testing & Evaluation
    - A set of “must-have” requirements & how to test or validate
    - Data to be collected
    - Evaluation criteria to measure reliability and safety
  - Vehicle Models
  - Accessibility Features
  - Scheduling and Routing Approach
  - Passenger Information System
  - A set of “Desirable” requirements
- Cost Proposal

RFP Evaluation Process



- Selection Committee
  - 5 official members, with several advisory members
- Evaluation Matrix
- Cost Proposal Evaluation
- Presentation Evaluation

Testing of SDS

- Tactical or maneuvering behavior
- Operational Design Domain
- Object Detection & collision avoidance
- Fail mode behavior

Photo taken by Douglas K. Levere, UB Image Specialist. Permission granted to authors for use.

Twelve Testing Scenarios

- Left Turn Test
- Right Turn Test
- Four-way stop (with and without conflict)
- Shuttle Stop
- Stationary/Moving pedestrian Identification
- Following & Leading vehicle
- Passing vehicle
- Object Detection
- Static Vehicle Obstruction

Photos taken by Douglas K. Levere, UB Image Specialist. Permission granted to authors for use.

Data Needed for Testing & Evaluation

- Driving mode (Autonomous/Manual)
- Causes behind disengagement
- Vehicle's position
- Vehicle's velocity, acceleration
- Object detection and sensing status
- Vehicle's lights and signal status
- Vehicle's 360 degrees camera feed
- Vehicle's inner safety camera and audio surveillance
- Any Remote control commands
- Vehicle's failure status

Photo taken by Douglas K. Levere, UB Image Specialist. Permission granted to authors for use.

Addressing Sustainability & Equity Goals of BuffALLo All Access Project

Source: ICF. (2023). Buffalo All Access in and around BNMC Flyer.

- Integrated, flexible, demand-responsive and end-to-end Transit
- Addressing the First- and Last- mile challenge & Transit Service Gaps
- Preference to Electric Shuttles
- Accessibility Requirements
- Support Independent Travel
- Serving under-served Neighborhoods

Lessons Learned

- Engage with vendors early
- Develop RFP after a good understanding of the market
- Be ready to be flexible
- Plan for enough funds

Stakeholder Q & A

Stay Connected

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Visit the ITS4US Deployment Program Website:
https://its.dot.gov/its4us/

ITS4US Deployment Program Video
https://youtu.be/pztI1lRyXAc