YARD AUTOMATION RESEARCH AND DEPLOYMENT: PHASE ONE

DATA MANAGEMENT PLAN

PREPARED BY: WSP

CapMetro

Contents

1. CAPMETRO YARD AUTOMATION RESEARCH & DEPLOYMENT (YARD) PROGRAM OVERVIEW

1.1. GOALS & OBJECTIVES

The CapMetro Yard Automation Research & Deployment (YARD) Program aims to assess feasibility, effects, benefits, and costs of automated transit fleets. The YARD program has the following goals:

1. Test and assess the potential future benefits and challenges of automated battery-electric buses (BEBs) through routine bus yard maneuvers.
2. Share lessons-learned from the automated vehicle demonstrations with CapMetro stakeholders and industry partners to improve the capabilities of the technology.
3. Collaborate with CapMetro workforce and Texas A&M Transportation Institute (TTI) to better understand the potential impacts to current positions supporting yard operations and identify what potential new positions may be required to operate and maintain automated BEBs.
4. Determine the long-term viability of fleet-wide bus yard automation for current and future CapMetro bus depots.

1.2. PROJECT DESCRIPTION

The project is funded through the FTA Automated Transit Bus Maintenance and Yard Operations Demonstration Program, one of several research initiatives under the multi-year FTA Strategic Transit Automation Research (STAR) program. The YARD pilot demonstration that will include autonomous BEB charging, will be a market-first in North America and will deliver insights that will help not only transit agencies understand the potential benefits but also help bus OEMs assess the interest and viability of the technology. The YARD program includes multiple partners, several of which will be producing deliverables described in the following sections. The YARD program stakeholders, partners, and their roles are as follows:

1. Federal Transit Administration (FTA): Program Sponsor
2. Capital Metropolitan Transportation Authority (CapMetro): Lead Agency
3. WSP: Program Lead, Implementation Lead
4. Perrone Robotics, Inc. (PRI): Lead Automation Engineer
5. Texas A&M Transportation Institute (TTI): Workforce Development Lead
6. Clever Devices: Automated Fleet Dispatch Software Developer

The FTA grant funds support the first phase of a two-phase programmatic effort to successfully demonstrate the first automated bus yard in North America. *Table 1* shows a breakdown between the two phases. This first phase will include two demonstrations, one held using a cutaway shuttle at the beginning of the project to educate the CapMetro workforce, and a second demonstration of automated heavy-duty BEB at the conclusion of the project.

Table 1. Project Overview by Phase

Project Category	Phase 1 First yard Automation Pilot (this project)	Phase 2 Fleet Automation pilot

Vehicle Automation	Two automated vehicle demonstrations – one with a cutaway shuttle, the other demonstration with a heavy-duty BEB.	Deploy multiple automated BEBs to test fleet-wide capabilities and challenges
Automated fleet dispatch	Develop software architecture diagram that illustrates how to eventually create an automated fleet dispatch system	Develop and deploy proof of concept software
Workforce	A workforce analysis to help inform TRB's transit automation tool with data from CapMetro.	Develop EV/AV workforce training curriculum
Other	1. Model automation's benefits and costs 2. Reporting requirements as instructed by the FTA.	Strategize long-term capital plan for fleet facilities

The second demonstration will utilize a retrofitted BEB with a level four, Automated Driving System (ADS) to showcase the technology and collect data on efficiencies gained in yard operation. While the focus of the program is yard automation, the retrofit will also show that it can provide benefits to revenue operations, such as an increase in safety due to Advanced Driver Assistance Systems (ADAS) which can assist drivers' awareness in difficult situations. Both goals, yard automation and driver assistance, align with the objectives outlined in the FTA STAR plan.

1.3. PERFORMANCE MEASUREMENTS

Table 2 – KPIs (Key Performance Indicators) by Use Case, illustrates how CapMetro will track and evaluate performance measures for the YARD program. Most importantly, these KPIs aligned closely with the goals and research included in the FTA STAR program which will validate the continued investments in transit automation research.

Table 2. KPIs by Use Case

	Use Case	KPIs for Automation	Supporting Data
1	Remote Start and Stop	Reduction in pull-in/out times	*Base case (manual operations)*: Average operator walk time for pull-in and pull-out relative to staging area. *Automation case*: Bus movement time to staging area
2	Automated Precision Parking	Increased parking capacity; reduced operator burden positioning under overhead pantograph charger	*Base case*: Capacity for 40' buses at North Ops today. *Automation case*: Capacity through precision parking within a safety tolerance
3	Automated Charging	Reduced charging dispenser cost	*Base case:* (a) Operator time & experience positioning below pantograph charger; (b) number of

	Use Case	KPIs for Automation	Supporting Data
			vehicles sharing a charger; (c) instantaneous peak load on grid. *Automation case*: (a) Time for vehicle to dock and begin charging; (b) increase in shared use of charger through automated parking on charge completion for next block (Phase 2); (c) reduced peak load (Phase 2)
4	Automated Bus Wash Navigation	Increased service reliability through yard operational efficiency	*Base case:* Total hostler time per bus for servicing (coordinating for next vehicle, walking to bus, driving, waiting for bay availability, etc.); *Automation case*: Staff time required to initiate autonomous state and transition back to manual.
5	Autonomous Yard Operations	Reduction in safety incidents by investment in technology for personnel and infrastructure safety	*Base case*: (A) total repair & insurance cost for yard incidents; (B) total cost for in-revenue incidents by incident type. *Automated case*: (A) reduction in total cost for yard incidents through autonomous yard operations; (B) incidents in revenue for ADAS-equipped vehicles (Phase 2)

2. OVERVIEW OF DIGITAL DATASETS

The FTA grant supports the first phase of a two-phase programmatic effort to successfully demonstrate the first automated bus yard in the U.S. Table 1 shows a breakdown between the two phases including the deliverables for phase 1, spanning automated vehicle demonstrations, modeling benefits and affects to the workforce, and laying the foundation for an automated fleet dispatch system.

This section describes the data that will be available from each, in turn:
- Section 2.1 – New data stream produced by the automated vehicle.
- Section 2.2 – Inputs and outputs for the technical deliverables.
- Section 2.3 – introduce additional streams that are expected to come online in phase two.

The lifecycle of this project uncovered additional information relevant for this DMP from initial stakeholder workshops through to data collection from an automated BEB. As a result, this document will be updated as the project team identifies pertinent information.

The FTA STAR plan describes automation providers using "proprietary software [that] converts raw sensor data into compressed, formal digital maps." While these algorithms are confidential, the sections below describe the information partners will provide publicly to support broader industry understanding of the challenges and benefits of bus yard automation.

2.1.   NEW DATA STREAMS (PHASE 1)

2.1.1.   AUTOMATED VEHICLE MOVEMENT

The first grouping, new data streams produced by the automated vehicle, captures everything generated directly by Perrone Robotics, Inc. (PRI) based on the outputs from the automated-vehicle platform during the two Phase One demonstrations. Perrone Robotics Inc (PRI) will supply interpreted and visualized data from the lidar, radar and cameras, pulled from the vehicle's on-board systems in the form of "event summaries." These event summaries will include interpreted data and expert analysis that will explain why test cases resulted in failures or otherwise interesting scenarios. In addition, WSP will provide the full test case spreadsheets including planned testing, results, and test engineer comments.

In total, PRI and WSP will provide:
- All test cases, results, and test engineer comments collected during the validation stage of YARD.
- Quantified precision docking capabilities – the vehicle's ability to repeatedly stop at a point within a given lateral and longitudinal offset (as part of the test results mentioned above).
- Quantified precision charging capabilities – the vehicle's ability to repeatedly stop underneath the charger within the dispensers lateral and longitudinal tolerances (as part of the test results mentioned above).
- Event summaries of vehicle data including expert analysis that will explain why test cases resulted in failures or otherwise interesting scenarios

The automated vehicle movement data from PRI will help to validate FTA assumptions around the benefits of yard automation. Specifically, KPIs will be informed based on data on the time for the bus to complete the pull-in/pull-out maneuver, reliability in parking in close proximity to another vehicle, time to precision dock under a pantograph charger and begin receiving charge. The next section introduces data-driven deliverables, a benefit-cost and workforce affect analysis, that will help define the value and impact of yard automation. At the end of the project, the FTA will be the Data Owner and WSP and PRI the Data Producer(s)/Steward(s).

2.2.   DATA-DRIVEN MODELS (PHASE 1)

The benefit-cost analysis and workforce affect calculator will produce .csv outputs with a generalizable methodology based on agencies of a given size, in a particular region, performing certain automated maneuvers. These models are described here given their overlap with other data systems but will have separate final deliverables.

2.2.1.   BENEFIT-COST ANALYSIS

One project deliverable of the YARD Program is the Benefit-Cost Analysis (BCA) to help transit agencies and the industry in general, quantify the return on investments in retrofitting buses with automation equipment. We recognize that project costs can often be one of the biggest challenges for updating transit technology. To increase the affordability of bus automation, the BCA model and demand signals through the project aims to help encourage bus OEMs to invest in altering their future production plans to include ADAS and ADS capabilities.

WSP has previously developed a similar model by closely applying and refining the use-case specific BCAs described in the FTA star plan which showed a potential 250%-yard capacity savings. WSP's BCA will pull in facility design and automation expertise that builds on FTA guidance, which WSP believes to be a more conservative 30% capacity increase through autonomous precision parking. We apply use cases relevant for CapMetro based on their specific operations, infrastructure, and safety characteristics.

Following USDOT guidance on BCAs, the model will take input from CapMetro, the FTA, and the National Transit Database (NTD). These inputs include average land value, average operator pull-in/out time within the yard, charging dispenser cost, retrofit cost, and operational cost. The model will then provide the monetized, annual savings based on the benefit categories applicable for an agency's yard (e.g., capacity savings, charging infrastructure cost savings, bus wash maneuver efficiencies, etc.). This model is built in Excel for transparency and adaptability during the pilot. Importantly, the YARD Program seeks to validate the assumptions in the model, providing performance based KPIs that build on the FTA STAR plan, as referenced above in Table 2. KPIs by Use Case. The final report will include a chapter detailing the BCA methodology and findings. Table 3 Captures the representative inputs for the BCA based on whether received from a specific project stakeholder or collected directly during the autonomous maneuvers.

Table 3. Representative inputs by input category.

Input Category	Num	Description	Units
1. CapMetro	a	Operator and yard hostler staff rates	$/hr
	b	Average real estate value	$/Sq Ft
	c	Average number of blocks per day	Qty
	d	Safety incident cost and type within the yard and in-revenue service	$/incident
2. PRI (Retrofit Costs)	a	CapEx cost for kit hardware, retrofit labor	$, one-time
	b	OpEx cost per bus (including training & support)	$/yr.
	c	Cost reduction due to efficiencies of retrofitting multiple buses of the same make and model	Factor/yr
3. WSP Facility Design	a	Average staff time to perform yard maneuvers	Mins
	b	Charging dispenser cost (e.g., equipment, install, O&M)	$
	c	Dispenser to bus ratio	%
4. Phase 1 Pilot	a	Precision docking ability, longitudinal and lateral deviation from target stopping location for each test.	Cm
	b	Staff time savings due to yard maneuvers (automated parking & recall, bus wash, charging, and maintenance)	Mins

As the project progresses, each input will be updated based on what information is practically available from the project stakeholders and during the pilot. These changes will accordingly be reflected in this plan. The data owner is the FTA and producer/steward will vary by specific input, including CapMetro, PRI, and WSP.

2.2.2. JOB IMPACT CALCULATOR

TTI's Job Impact Calculator estimates the number of front-line transit employees that may be affected by the implementation of the automated yard movements. Using inputs from CapMetro for the North Ops facility, the Project Team is estimating changes in work hours, job gains or losses, as well as the number of employees whose essential duties will now require additional training.

Inputs to the calculator are at the job-level. For each affected job, the calculator requires:
- Current Condition:
    o A list of current tasks performed by the job.
    o Estimated daily hours needed to perform each current task.
    o knowledge, skills, and abilities (KSAs) needed for each task.
- Projected Condition (after yard movements are automated):
    o A list of tasks performed by the job.
    o An estimate of the daily hours needed to perform each task.
    o KSAs needed for each task.

The calculator will produce outputs for each job based on the delta between the current and projected task-by-task time and KSA requirements. The differences between the current and projected condition will be aggregated to output, for each job:
- The change in hours of labor.
- The number of impacted current employees (i.e., employees whose job will be changed).
- The number of jobs gained or lost.
- A list of changes to knowledge, skills, and abilities.

The data owner is the FTA and producer/steward is TTI.

2.3. FUTURE DATA STREAMS (PHASE 2)

As listed above, Phase I of the CapMetro YARD Program will identify and architect new vehicle automation data streams that may become available in Phase 2. Phase 2 may include multiple Level 4, automated 40' battery electric buses (BEBs) and a longer timeframe to complete additional maneuvers and develop and test the automated fleet dispatch software. This is a critical component to determine viability of a fleet of automated BEBs. In this DMP, the project team identifies these expected new data streams and intends to describe their purpose at a high-level. If awarded, Phase 2 will include a more detailed DMP for these new systems with the ability to monitor automated fleet movements in real-time.

2.3.1. AUTOMATED FLEET DISPATCH SYSTEM

Phase I will develop the foundation for an automated yard dispatch system that can provide fleetwide automation instructions. Clever Devices will develop a generalizable software architecture schematic for the industry that illustrates the dispatch system's functional and technical requirements, building on their expertise with the SmartYard product. Elements that will influence the design include (but not limited to):
- Vehicle position
- Future charging system preferences and scheduling,
- Scheduled Service needs,
- CapMetro maintenance system and regiment for preventative maintenance (PM) and corrective maintenance (CM),
- Current state of charge,

- Yard Activities such as Parking & recall, precision-docking, bus wash, and automated charging.

Based on the findings of from Phase 1 and if awarded Phase II, Clever will then develop a proof-of-concept software demonstrating the automated fleet dispatch system functionality. The detailed data exchanges will be identified through workshops during phase 1, described as a chapter in the final report.

2.3.2. CHARGING INFRASTRUCTURE

One of the key benefits of bus yard automation is the synergies of retrofitting battery electric buses. This project will help to validate the expected reduction in charging infrastructure required through shared, autonomous rotation through chargers. The second demonstration of the CapMetro YARD project will include testing with an overhead pantograph dispenser (Schunk) and a high-speed charger (Heliox). The Charging cabinet, pantograph dispenser, and mast are actively being procured and are estimated to be installed by mid/late Summer 2024 to begin testing with the Level 4 automated battery electric bus.

Specific data that will be captured is when the charging sessions is initiated and once the charging session is completed. CapMetro will likely use MobilityHouse for their charge management solution. Once the system is commissioned, the project team will get access to the API and dashboard which will be incorporated into the final DMP. The goal is to be able to accurately demonstrate and illustrate the automated BEB pulling under the pantograph dispenser, charging to appropriate State-of-Charge (SOC) and then drive to its assigned location.

3. ACCESS LEVEL

The data that this project will provide does not require controlled access. As acknowledged in the STAR plan, the confidential algorithms and methodologies will not be provided as data.
Data created through the project will comply with CapMetro's "MetroLabs" Open Data Portal, hosted by the State of Texas:

CapMetro provides transit data, including real-time feeds of our bus and rail services, on the State of Texas Open Data Portal to promote transparency and encourage developer participation to create innovative apps that will help Central Texans use our services efficiently. This data is provided by CapMetro and is available for everyone to use, explore, and share. The Portal has tools to easily search, filter, map, and visualize specific data sets for research, collaboration, and innovation.

4. RE-USE, REDISTRIBUTION

Data for this project will have a CC-BY 4.0 license as linked below. This license enables:

- **Attribution**: *Anyone using my work must include proper attribution*.
    - As an FTA grant, users should provide credit to the FTA and YARD project partners that are disseminating the information.
- **Commercial Use**: *Others can use my work, even for commercial purposes.*
    - The project is intended to encourage further innovation and collaboration to fully realize the nascent benefits of bus yard automation.
- **Derivative Works**: *Others can remix, adapt, or build upon my work.*
    - Same as above, allowing the public creative freedom to expand upon data provided.

- **Adaptations of work**: *Others must use the same CC license if they adapt my work.*
  - o Expect other users to just retain attribution for the data source, which is the one restriction for this license.

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5. DATA STORAGE, ARCHIVING, PRESERVATION

The dataset will be archived in the National Transportation Library (NTL) Repository and Open Science Access Portal (ROSA P). Prior to archiving, the data are stored on the secured BTS networks and drives, which are backed up nightly. The US DOT systems are secured from outside users and backed up daily. The dataset will be retained in perpetuity.

Files in ROSA P are backed up on NTL drives at DOT daily; at the Centers for Disease Control, the repository managing facility, daily; and on Amazon Web Service Cloud servers in Virginia and Oregon daily.

NTL staff will mint persistent Digital Object Identifiers (DOIs) for each dataset stored in ROSA P. These DOIs will be associated with dataset documentation as soon as they become available for use. The DOIs associated with this dataset include https://doi.org/10.21949/vkvh-c865.

The assigned DOI resolves to the repository landing page for the CapMetro Yard Automation Research & Deployment (YARD) dataset so users may locate associated metadata and supporting files.

ROSA P meets all the criteria outlined in the Guidelines for Evaluating Repositories for Conformance with the DOT Public Access Plan.