ITS DEPLOYMENT EVALUATION

Executive Briefing

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ITS for Transit Asset Management

Introduction

One of the most important activities transit agencies do to ensure safe and reliable service is effectively managing and maintaining their buses, rail cars, railroad tracks, and other assets. By law, the Federal Transit Administration (FTA) requires all transit agencies in the United States to maintain a Transit Asset Management (TAM) plan which requires transit agencies "to set performance targets for capital assets, create data and narrative reports on performance measures, and coordinate with their planning partners" [1].

TAM is a significant task for many transit authorities. For example, the Metropolitan Transit Authority (MTA) in New York City operates and maintains a fleet of 6,455 rail cars and 5,780 buses, as well as the infrastructure for 472 subway stations and over 16,000 bus stops [2]. Even smaller transit agencies maintain many assets: the City of Dubuque, Iowa has over 270 buses serving its population of 60,000 [3], [4].

In recent years, transit agencies have begun to employ digital and Intelligent Transportation System (ITS) tools with the goal of making TAM easier and more efficient. These tools include digital twin modeling, Internet of Things (IoT), data fusion, and Artificial Intelligence (AI) and Machine Learning (ML).

The goal of these tools is to make TAM simpler, more proactive, and more precise. By collecting detailed information about the state of transit assets and using ITS tools to perform analysis, transit agencies may potentially predict when assets are going to fail well in advance of actual failure and take corrective action.

However, since many of these technologies are just emerging, robust evaluation studies are not always available and many of the benefits of these technologies are still being estimated.

Highlights

- Transit agencies have begun to employ digital and Intelligent Transportation System (ITS) tools with the goal of making asset management easier and more efficient.
- Advanced ITS solutions such as AI/ML, Digital Twin modeling, and IoT Sensing allow agencies to develop cost-efficient operational strategies that maintain or improve service outcomes.
- Predictive maintenance systems may also reduce downtime by identifying potential failure points, especially those that inspections may have missed before they become problematic.
- Agencies seeking to deploy these advanced solutions should focus on developing staff expertise and obtaining leadership buy-in to maximize their impact.

This brief is based on past evaluation data contained in the ITS Databases at: www.itskrs.its.dot.gov. The databases are maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments. The brief presents benefits, costs, and best practices from past evaluations of ITS projects.

U.S. Department of Transportation
Intelligent Transportation Systems
Joint Program Office

Table 1: Popular ITS Applications for TAM

Tool	Description
AI/ML	AI/ML are algorithms that allow "computer models to train [themselves] to find patterns and make predictions" . In transit, AI/ML can be used to build predictive maintenance systems that forecast when equipment might fail and prioritize maintenance based on these analyses [6].
Data Warehouses	Data warehouses are "one stop shops" (i.e., repositories) where data from multiple sources or databases are stored. Typically, data are processed and standardized before being stored in a data warehouse. Data warehouses facilitate data fusion of multiple, discrete data sources into one dataset [7]. Data warehousing and fusion is usually a prerequisite for further AI/ML analysis. Typical datasets that transit agencies handle include weather data, vehicle location information, passenger information, maintenance records, and traffic data [8].
Digital Twins	Digital twin solutions create realistic digital models of the infrastructure, assets, and systems of a built or natural environment by combining a variety of information sources such as geographic information system (GIS) data and building information modeling (BIM) data. They are used to model, understand, or optimize processes in these environments [9], [10].
IoT	In transit contexts, IoT typically refers to the use of networked, embedded, and low-cost sensors to collect information in real time about a variety of activities such as passenger boarding and alighting, vehicle status, vehicle location, track conditions, and more [11], [12].

Benefits

One of the primary benefits of ITS for TAM include cost savings, particularly from reduced maintenance costs. Traditionally, asset maintenance and inspection are performed on a scheduled basis and can be labor intensive. However, the use of AI/ML for predictive maintenance can potentially reduce the amount of inspection work and materials needed to maintain a system, which can result in cost savings. Predictive maintenance systems may also reduce downtime by identifying potential failure points, especially those that inspections may have missed before they become problematic.

In Ravenna, Italy, a mid-sized city located along the Adriatic Coast, a group of researchers deployed and tested an algorithmic (i.e., AI/ML) predictive maintenance system for transit buses as part of the European Bus of the Future grant program. Because the condition of engine oil is highly correlated to vehicle breakdowns, the system was designed to collect and process data related to engine oil maintenance. The research team initially prototyped the monitoring system before deploying it on six buses in revenue service. Data was then collected between September 2016 and April 2017 (2022-B01703).

After analyzing the data, the research team found that the system reduced breakdowns by about 8 percent. Additionally, the system reduced energy consumption of the buses by about 12 percent. However, the research team's evaluation concluded that their predictive maintenance system did not reduce operating costs or total maintenance costs. This was likely due to the need for additional staff time to manage the back-end data systems (2022-B01703).

Figure 1: Predictive maintenance can save staff time and money (Source: iStock)

In the United States, a modeled studied of predictive maintenance showed that these systems can identify equipment failures before they occur and hence reduce system downtime. A research team from Rutgers University collected "signal equipment registry and the trouble call history from a major rail transit agency in the United States" and then combined this data with weather information from the National Oceanic and Atmospheric Administration. This information was then fed into a predictive maintenance algorithm to forecast signal breakdowns across the rail system (2022-B01708).

After cross-validating the predictive model, the Rutgers team found promising results. Specifically, the team found that predictive maintenance algorithms, such as the one used in the study, can predict up to thirty-five percent of signal failures a month ahead of actual failure. This suggests that predictive maintenance systems can play a valuable role in preventing system breakdowns and reducing downtime in passenger rail operations (2022-B01708).

Other technologies, such as the use of digital twins, can yield benefits for transit operators. Network Rail, which operates the passenger rail network in the United Kingdom, is piloting a project to create a digital twin of Reading Station. Network Rail and its partners will then use this twin to explore the impact of energy-saving techniques at the station. The advantage of using a digital twin is that National Rail can experiment with different energy saving techniques without having to conduct costly field trials. For example, National Rail can simulate the effects of diming lights in the station. Initial modeling results suggest that findings from the digital twin project may reduce energy consumption at the station by up to 20 percent [13]. However, these results are speculative and actual results may vary after full evaluation.

Costs

Because many of these ITS for TAM technologies are still being refined, precise cost information is not always available. However, new grant programs from FTA give a sense of the cost for some of these technologies.

In 2020, FTA awarded approximately $1.37 million dollars to organizations across six states as part of its Real-Time Asset Management Program [14]. The objective of this program is to demonstrate and evaluate the use of innovative technologies that help transit agencies manage their capital stock and facilities. Table 2 summarizes the projects and the federal funding awarded for these projects.

Note that the federal funding is only 80 percent of the cost of the project; recipients must provide at least a 20 percent funding match [15].

Table 2: List of FTA Sponsored Projects Source: FTA [16]

Project Site	Description	Federal Funding
University of Illinois at Urbana-Champaign (UIUC)	UIUC, along with four transit agencies, is deploying smart sensing technology to provide real-time information of rail tracks and rolling stock.	$395,000
Maryland Department of Transportation (MDOT)	MDOT is conducting an electronic inventory of its light-rail tracks to find deficiencies and maintenance defects.	$150,000
Regional Transportation Commission (RTC) of Washoe County (Nevada)	RTC, in partnership with the University of Nevada, is installing a system of electronic sensors to do real-time transit infrastructure monitoring in Reno, Nevada.	$131,661
Southeastern Pennsylvania Transportation Authority (SEPTA)	SEPTA, the transit authority for Philadelphia and the surrounding area, is using its funding to automatically scan and assess the state of its overhead catenary systems (overhead wires).	$170,000
Dallas Area Rapid Transit (DART)	DART is using “drones, laser imaging, and photogrammetry [e.g., 3 modeling, mapping]” to monitor the condition of its rail tracks, stations, bridges and more. This information will assist DART with maintaining a state-of-good-repair throughout the system [16].	$184,000
Utah Transit Authority (UTA)	UTA is using advanced optical imaging technology to monitor the state of repair in its light-rail system.	$338,155

Best Practices

Although the use of advanced technologies for TAM can be beneficial to transit agencies, it is not without its challenges. Issues in implementing ITS for TAM typically include the need for large capital outlays, gaps in institutional understanding of relevant technologies, limited evaluations of the reliability and effectiveness of the technologies, and conflicting data standards across vendor products.

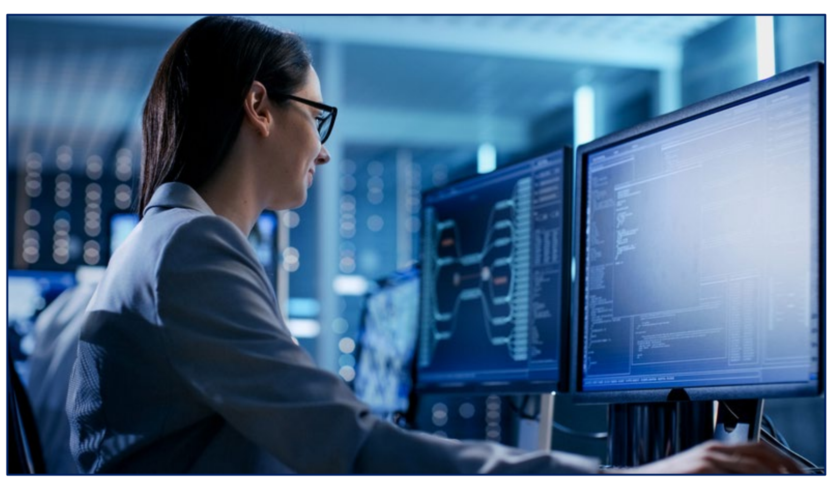

Figure 2: Agencies must have the right staff to analyze and validate data. (Source: iStock)

Lack of staff expertise and staff acceptance of ITS TAM solutions is another key barrier. In a survey conducted by the American Public Transit Association (APTA), 63 percent of respondents agreed that “a lack of internal staff expertise was an obstacle” to the use of Big Data (2022-

L01166). To counteract this challenge, APTA recommends getting leadership buy-in and committing to fostering a culture of data expertise and hiring staff with data analytics skills.

Issues with conflicting data standards and vendor products are some of the most common barriers to successful implementation of advanced technologies for TAM. To combat this issue, agencies should consider, preemptively, how they can standardize and integrate datasets to improve the usefulness of collected data (2022-L01153). For example, agencies might consider investing in a data warehouse that ingests, standardizes, and centralizes data from multiple sources. Having a central data warehouse allows for easier data access within the transit agency and facilitates the use of predictive analytics for TAM (2022-L01166).

Additionally, many of these technologies, especially predictive maintenance systems, may not be mature enough to apply to safety critical systems. According to engineering experts "the benefit of [Predictive Maintenance (PdM)] for safety is [currently, largely unknown], as witnessed by the fact that safety standards still consider that many enhancement steps are necessary to make the PdM technology mature enough to be implemented in safety critical systems"[17, p. 9]. Further complicating these efforts, AI/ML are inherently designed to improve over time as they are fed more data. Thus, AI/ML models may produce false negatives or positives when initially deployed. Therefore, agencies need to have a plan in place to validate the findings from predictive maintenance models and understand that the models may need fine tuning and manual oversight [17, 18].

Lastly, it is important for deployers to understand the limits of AI/ML predictive maintenance models and be realistic about their abilities. Importantly, predictive maintenance systems do not provide a complete picture of the health of an asset. Only a certain number of parameters can be monitored, and these systems may work best when applied to limited and well-defined problems (2022-L01153).

Success Story

The Greater Cleveland Regional Transit Authority (RTA) operates 55 bus routes, including three bus rapid transit lines, one heavy rail line, three light rail lines, a trolley service, paratransit service, and van share service in the Cleveland metro area (Figure 3). As such, RTA has numerous facilities, vehicles, stops, tracks, and ancillary equipment to maintain.

As part of its plan to enhance fare collection, improve rider satisfaction, and continuously improve its services, RTA targeted its farebox collection system for a new predictive maintenance program. This was a comprehensive, cross-departmental effort that involved numerous divisions in RTA such as the maintenance planning division, ITS department, and revenue department.

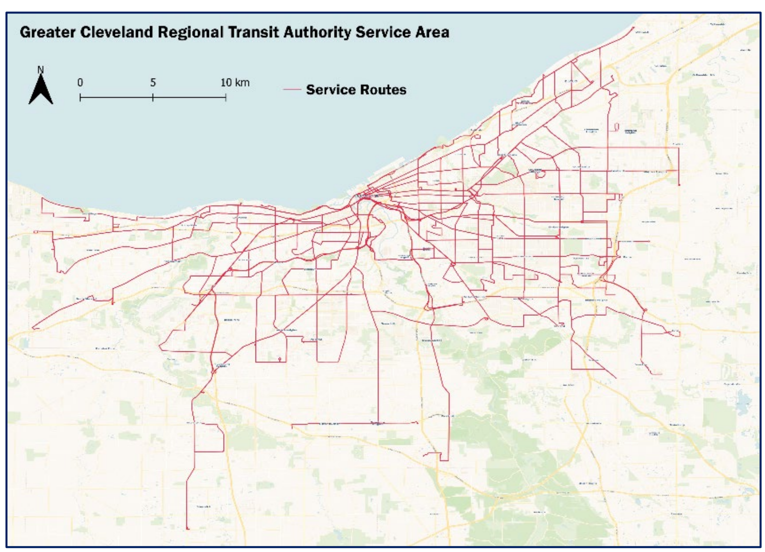

Figure 3: RTA Service Area in Cleveland (Source: USDOT, GTFS, OpenStreetMap CC-BY-3.0)

To implement this preventative maintenance program, RTA first overhauled its entire farebox maintenance program, building a new repair facility, upgrading and standardizing its fare collection equipment, providing additional training for staff, and implementing a program to collect and analyze fare collection failure data [19].

Figure 4: RTA improved its farebox reliability with predictive analytics. (Source: Oran Viriyincy/Wikimedia Commons CC-BY-SA-2.0)

With this upgraded fare collection equipment, RTA then developed a system to intake and analyze nightly probe data from all the fareboxes in the system. Using this system, the Electronic Repair Department can analyze fare media errors trends over a ten-day period. Based on this data, RTA "structured its maintenance and replacement [program] for different conditions" and began to conduct targeted maintenance based on these analyses [para. 4, 20].

After two years of using this approach, RTA had 259,000 fewer fare processing errors and by 2019, RTA had a fare media error rate of just 2.28 percent, which was a record low for the system [21].

Such dramatic reductions in fare media errors were only possible using ITS technologies, probe data, and data analytics. RTA's success suggests that these approaches can save transit agencies time and money.

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