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Integrated Corridor Management Transit Vehicle Real-Time Data Demonstration: Dallas Case Study

DECEMBER 2014

FTA Report No. 0077
Federal Transit Administration

PREPARED BY
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Volpe National Transportation Systems Center

U.S. Department of Transportation
Federal Transit Administration

COVER PHOTO

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SPONSORED BY

Federal Transit Administration
Office of Research, Demonstration and Innovation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liter	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

As part of the U.S. Department of Transportation's Integrated Corridor Management (ICM) Initiative, Dallas Area Rapid Transit (DART) purchased new automatic passenger counter (APC) technology for its Red and Orange line light rail vehicles to provide real-time passenger counts to its train control center and to provide data to the ICM decision support system. By gaining access to real-time passenger counts, DART hopes to respond more effectively to unplanned incidents on the rail network by enabling more responsive service adjustments. This report summarizes how DART responded to incidents before ICM, addresses what has changed after ICM deployment, and identifies constraints to optimum responses.

EXECUTIVE SUMMARY

The Integrated Corridor Management (ICM) Initiative is a U.S. Department of Transportation project designed to aid the integration of multiple transportation networks and modes located within a corridor. The ICM Initiative selected two sites for a Pioneer Demonstration, Dallas and San Diego. Within those sites, critical data gaps limiting ICM adoption were identified [1]; one such data gap was real-time transit vehicle passenger loads. To address this data gap in Dallas, Dallas Area Rapid Transit (DART) was awarded $900,000 by the Federal Transit Administration (FTA) to install automatic passenger counter (APC) equipment that was capable of transmitting passenger load data in real-time back to the train control center (TCC) and ICM system.

Prior to the start of the ICM project, DART had already installed APC equipment on 48 of its Light Rail Vehicles (LRVs). The award provided funding for 20 additional LRVs to cover the entire Red line with APC equipment and communications software upgrades on all equipped LRVs for real-time transmission to the TCC. This combination of APC, improved communication technologies, and pre-existing automatic vehicle location (AVL) information allows DART to track passenger loads in real-time within the network. These data are used by the Dallas ICM Decision Support System to recommend transit strategies and at the TCC to allow controllers better insight into passenger loads on trains and situations involving overcrowding.

Coincident to the DART funding, FTA sponsored this case study, conducted by the Volpe Center, to better understand how this new technology is being used and what benefit it can have for transit agencies. To best focus on situations with the greatest potential impact from real-time APC data, the Volpe Center was interested in incidents in the transit network, both planned and unplanned. It was envisioned that the APC/AVL technology, combined with closer inter-agency coordination, would result in a change in incident management, possibly with better transit load balancing or mode shift recommendations. Notably, this report addresses issues of how APC and AVL technologies can be leveraged within DART to improve its own operations whether or not these operations are part of an ICM strategy.

Following site visits and interviews before and after the demonstration, it was clear that DART controllers had changed some aspects of incident management, specifically targeting improving the customer experience, although benefits could not be maximized due to various infrastructure and policy constraints and limitations.

Despite some technical difficulties (since addressed with additional instruction to controllers), controllers consistently articulated changes to how incidents are managed, identifying situations where decisions about passenger offloading are made earlier, deferred until later, or made with more confidence about the outcome, based on the specifics of the situation. Moreover, controllers are more comfortable with turning back trains before the terminus to address crowding due to incidents. All such interventions remain rare, but are notably different compared to the pre-deployment period, especially as these changes are without any formal changes to policy or standard operating procedures.

DART rarely was able to add additional service through additional consists or adding cars to existing consists. Any additions are limited to off-peak periods and are not commonly used. This additional flexibility to respond to incidents and overcrowding is limited due to a combination of existing infrastructure, policy choices of the agency, and the inherent nature of a fixed guideway transit system. LRVs and operators may not be close to the location of an incident to add capacity, nor may the LRVs and operators be co-located, and agencies rarely have large supplies of unused vehicles or staff, particularly in peak periods. Specific to DART, all rail lines converge to move through the Central Business District on a shared track, further reducing capacity to add service due to very short headways, time required to use the crossovers at either end of the area, and short platforms at some stations.

DART has traditionally had a policy of not offloading trains or skipping stops to maximize customer convenience. However, the APC data have allowed controllers to get a better sense of the trade-offs facing customers as well as capacity available on trailing trains to better trade-off delays faced by groups of customers across the system. This change likely is due partially to the growth of the DART rail system during the observation period, significantly expanding two lines, and the increasing sophistication of transit users as the system ages.

To benchmark the DART experience, particularly in light of the limitations DART faced to adding service, the Volpe Center surveyed four additional transit agencies operating light and heavy rail transit. In general, these agencies faced similar constraints, although they have responded in different ways; some are more willing to express trains, for example. Infrastructure-based constraints are common, and the Volpe Center team collected projected costs from agencies that have considered projects to alleviate constraints.

Generally, new applications of technologies such as use of real-time APC data may allow transit agencies to be more flexible in how they respond to unplanned incidents by better understanding passenger load and demand across the network. Agencies can use this information to enact new strategies that were previously unavailable, impractical, or unreliable. To obtain and use real-time information, agencies may need to invest significant resources in updating equipment and software as well as training employees to use the new equipment.

While ICM and APCs have eased one major constraint—the ability to obtain real-time passenger load data—it has not eased other constraints such as network capacity and organizational policy. DART and other agencies around the country face issues such as platform length restrictions, headway limitations, and LRV availability that impact their ability to respond to passenger demand issues in real-time. Additionally, agencies may need to examine their own internal policies to understand how much impact ICM and APC technology could have on their operations. For instance, whereas ICM and APC units might provide incentives to use operational strategies such as deadheading and expressing, if institutional policies prevent this, agencies may not be able to use this technology to its full potential. Thus, while ICM-supporting ITS technologies may better inform strategies to address transit-related problems, they must be coupled with organizational, collaboration, and infrastructure improvements to address other possible constraints to implementing these strategies.

FTA may wish to initiate additional research or guidance to agencies on how to encourage flexibility into fixed guideway transit operations and to share best practices and lessons learned from those who have found innovative ways to respond in real time to unplanned incidents and customer loads.

SECTION 1

Introduction

What is ICM?

Integrated Corridor Management (ICM) focuses on managing a transportation corridor by creating a framework for interaction and coordination among the various agencies that operate facilities along that corridor. This is in contrast to traditional management, in which individual agencies manage their respective networks (e.g., a highway agency is concerned only with performance on the highway system). With ICM, agencies work together to optimize travel within the corridor by providing travelers with actionable information and implementing innovative operational practices and strategies, enabled by Intelligent Transportation Systems (ITS) technologies. For example, if a highway is experiencing higher than normal traffic (e.g., congestion caused by an accident), a diversion strategy can be crafted to redirect travelers to frontage roads or arterials and/or to park-and-ride lots to take transit.

To plan and implement these strategies, technology often plays a strong role. These technologies include parking management systems, Automatic Vehicle Location (AVL) and Automatic Passenger Counter (APC) technologies on transit, traffic-sensing technology on roads, and methods of information dissemination (e.g., variable message signs, 511, mobile alerts), both for travelers and transportation managers. It is anticipated that having access to and using this information will support better situational awareness and response than before ICM.

At the core of the cooperation among agencies are data and an agent that can synthesize the data and input from agencies to propose solutions to problems. This agent could be a person whose job it is to work with this information and create solution plans, a machine that conducts this same process through automation (generally referred to as a Decision Support System or DSS), or some combination of the two in which, for instance, a computer would present one or more solutions to a human to decide the best way to proceed.[1]

For example, a highway agency might have technology that enables the collection of real-time traffic data. Similarly, the transit agency would have information on the location of transit vehicles and capacity within those vehicles. Upon receipt of this information, the agent recognizes that highways are becoming congested (and the location of that congestion) while transit vehicles are running on time

[1] Within the ICM Initiative, San Diego is using a fully automated system, and Dallas employs an ICM Coordinator to review and disseminate output from the DSS.

and had spare passenger capacity. The agent could then decide to employ a transit diversion strategy and direct the highway agency to change its variable message signs and direct automobile commuters to park-and-ride lots before they reach congested highway sections. The agent also would notify the transit agency to expect more traffic to its parking lots and increased transit boardings and would allow the transit agency to adjust its operations to best serve travelers.

ICM Initiative and Real-Time Transit Component

The ICM Initiative is sponsored by several administrations within the U.S. Department of Transportation,[2] supporting the ICM goal of integrating multiple modes and agencies. The ICM Initiative selected two sites for the Pioneer Demonstration, Dallas and San Diego. Within those sites, critical data gaps limiting ICM adoption were identified [1]. One such data gap was real-time transit vehicle location and passenger load.

As part of the ICM Initiative Pioneer Demonstration, Dallas Area Rapid Transit (DART) was awarded $900,000 by the Federal Transit Administration (FTA) to install APC equipment that was capable of transmitting passenger load data in real time back to the train control center (TCC) and ICM system. Prior to the start of the ICM project, DART had already installed APC equipment on 48 of its Light Rail Vehicles (LRVs).[3] The award provided funding for 20 additional LRVs to cover the entire Red line[4] with APC equipment and communications software upgrades on all equipped LRVs for real-time transmission to the TCC.

This combination of AVL, APC, and improved communication technologies allows DART to track passenger loads in real time within the network. These data are used by the Dallas ICM DSS to recommend transit strategies and at the TCC to allow controllers better insight into passenger loads on trains and situations involving overcrowding. To be clear, it was the need to fill an ICM transit data gap to improve situational awareness of travel conditions (demand

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[2] The work is being sponsored by three agencies of the U.S. Department of Transportation: the Federal Transit Administration (FTA), the Federal Highway Administration (FHWA), and the ITS Joint Program Office within the Office of the Assistant Secretary for Research and Technology.

[3] DART refers to these as Super Light Rail Vehicles, as they are extended version of the previous LRV they operated. This report refers only to LRVs, as the distinction is not germane to the report.

[4] The ICM corridor includes LRV service on the Red line. See the next section for more information.

and capacity) in the US-75 corridor and transportation operator decision-making that spurred the FTA grant.[5]

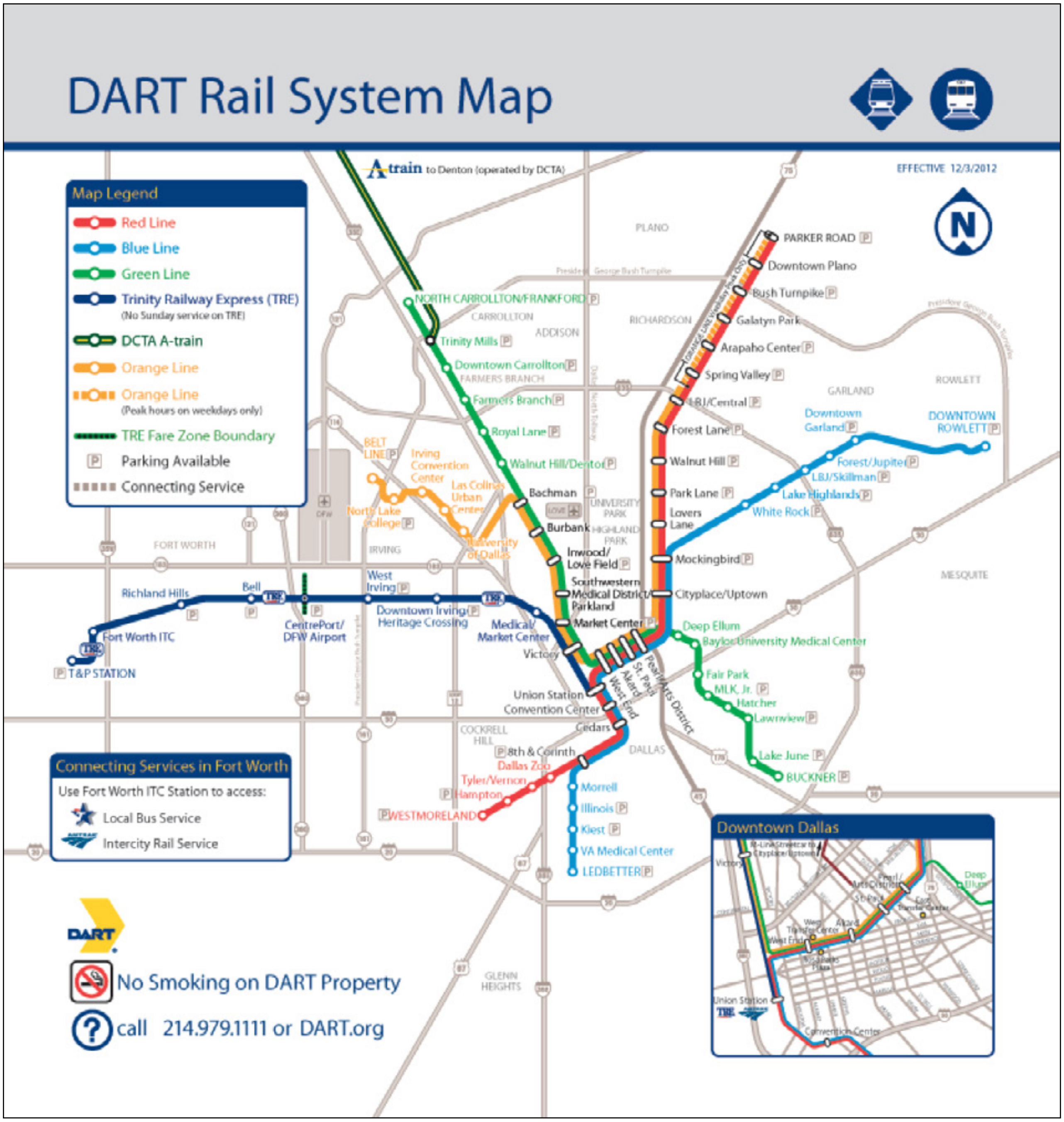
Dallas ICM Transit Network

The Dallas ICM Corridor comprises US-75 north of downtown Dallas, parallel arterials, frontage roads, and the DART Red and Orange lines that run along the highway. These two transit lines in the corridor are the focus of this project. The Red Line runs from Parker Road Station in Plano (northeast of Dallas) to Westmoreland Station in the southwest. The section from Parker Road to downtown is also covered by the Orange Line, which then proceeds toward Dallas–Fort Worth International Airport to the northwest.[6] These routes are shown in Figure 1-1. The Red and Orange lines typically operate 2-LRV consists, and the rest of the network is a mix of 2-LRV and 3-LRV consists. 1-LRV consists are operated during off-peak times. DART also operates the Blue and Green lines, which pass through the CBD on common tracks with the Red and Orange lines and radiate outward in other directions.

Prior to this project, DART possessed an AVL system that sent real-time data back to the TCC. APC data were collected onboard the vehicle, downloaded at the end of the day, and used primarily for planning purposes. As part of the ICM Initiative, DART purchased new real-time-enabled APC equipment to improve ICM operations and demonstrate the usefulness of transmitting transit occupancy data to a transit management center in real-time to inform operational decisions.

[5] The utility of the data for DSS will be explored in the forthcoming evaluation of the ICM Initiative Pioneer Demonstration, being conducted by the Battelle Memorial Institute, in 2015.

[6] The airport Orange Line stop opened shortly after the case study period ended; Figure 1-1 shows the terminus of the Belt Line Station and is accurate for this time period.



Source: DART

Figure 1-1 *DART Rail Network*

SECTION

2

Case Study

Coincident with the DART funding, FTA sponsored this case study, conducted by the Volpe Center, to better understand how this new technology is being used and what benefit it can have for transit agencies. Specifically, this project examines how AVL and APC technologies that were integrated/acquired by DART as part of the ICM Initiative have been used.

To best focus on situations with the greatest potential impact from real-time APC data, the Volpe Center was interested in incidents in the transit network, both planned and unplanned. It was envisioned that the APC/AVL technology, combined with closer inter-agency coordination, would result in a change in the way incidents were handled, possibly with better transit load balancing or mode shift recommendations. Notably, this report addresses issues of how APC and AVL technologies can be leveraged within DART to improve its own operations whether or not these operations are part of an ICM strategy.

The Volpe Center conducted interviews in February 2013 to determine DART's baseline pre-ICM conditions. The Volpe Center also identified constraints that may prevent DART (or other agencies) from being able to fully take advantage of the information presented by real-time APC data. The interviews were complemented by an observation of the TCC to gather more information about working environments for DART staff and a corridor tour. After ICM implementation, in June 2014, the Volpe Center again conducted interviews and observations with DART staff to see how operations had been impacted by ICM, potential improvements they could envision, and any other exogenous changes that took place over the period between interviews.

Other Agency Interviews

As it became clear that some of DART's experience was typical of other agencies facing challenges to developing and deploying real-time strategies to address incidents, the Volpe Center also initiated interviews with other transit agencies to compare their experience with DART's. Relevant information from these interviews is presented in boxes throughout the report. The agencies interviewed include:

- Chicago Transit Authority (CTA)
- Denver Regional Transportation District (RTD)
- San Diego Metropolitan Transit System (MTS)
- Portland TriMet

This report addresses the Light Rail Transit (LRT) network in Dallas both before and after ICM implementation. Specifically, the report addresses:

- Environment – this includes rail network, software, TCC setup, and other relevant attributes that will serve as background information as to how the DART Red/Orange lines are managed.
- Documenting the processes surrounding real-time data – this includes commentary from DART staff on issues such as procurement, use of data, and equipment installation cost, among other variables.
- Incidents – how rail network incidents as well as highway incidents may impact ICM, how they were handled prior to ICM, and how they are handled post-ICM.
- Constraints in making adjustments – to the degree that DART is unable to make all real-time adjustments to incidents due to constraints, they are explored and compared to other agencies.

Working Environment

The TCC is located in a building that also houses other operations offices, including maintenance and the bus control center. The TCC has a large video information display at the front that covers a full wall and shows the entire rail network, including the location of trains, switch configurations, signals, and problems in the network. Facing the screen, controllers sit in a number of desks in two rows, one above the other. In the pre-ICM period, two of these desks typically were staffed at one time and the controller at each desk was responsible for two sections of the network. The chief controller sat at another desk behind the controllers. In the post-deployment period, one additional desk was occupied by a controller, for a total of three controllers and one chief controller.[7] The two primary controllers continue to handle half of the network each. The third controller serves as an assisting controller who also performs administrative duties such as logging information. This relieves the other two controllers to concentrate more fully on network operations.

To the left of all controllers sits a representative at another computer who is responsible for DART's rider alerts through social networking. On the right wall is a monitor displaying a security camera feed in the network. In the pre-ICM period, this was controlled by the Transit Police; in the post-ICM period the chief controller controls this feed.[8]

[7] This change in staffing was due to the expansion of the DART system over the period and not due to ICM or the Real-Time Data project.

[8] This change in camera display control was due to planned software upgrades and not due to ICM or the Real-Time Data project.

Each controller has access to several systems, including:

- A radio system to communicate with LRV operators.
- A Vehicle Business System (VBS),[9] an automated system that provides train information and train location and can be used to communicate with train operators from the TCC. Controllers also can send a canned message to the interior or exterior speakers of the train from the TCC. In the post ICM-period, this system also displays real-time passenger count information.
- LRT applications:
  - Passdown, a database system that displays unusual conditions in the system (e.g., personnel in the right-of-way, personnel at a substation, or individuals at a grade crossing, etc.) to improve controller situational awareness.
  - Work Requests, a form that authorizes contractors to be present on the right-of-way.
  - Temporary Restrictions, which displays any operational restrictions associated with work requests.
  - Operating Clearance, a form sent to train operators informing them of any extraordinary operating conditions or restrictions.
  - Mainline info, which includes troubleshooting guides, emergency procedures, and pullout-from-the-yard information.
- Record of Train Movement (RTM), a log system to record issues encountered (e.g., a stuck door on a train) on the network. Also records when trains arrive and depart at various stations; these data are not automated but are entered into the TCC manually.
- SCADA (Supervisor Control and Data Acquisition), used to monitor and alert controllers to system status and alarms in the network (e.g., a fire alarm in a station) as well as control much of the system.[10]
- Checklists and standard operating procedures to address common issues.

In total, there are six screens shown to controllers that display information. The chief controller has the same setup as other controllers with an additional screen that provides access to and control of all cameras in the DART system.

Images of the Train Control Center are shown in Figures 2-1 and 2-2.

[9] While controllers refer to this system as VBS, the full VBS contains many components beyond those listed here that are of use to other departments within DART. Within this report, VBS is to refer to these capabilities only.

[10] Some older portions of the power system must be controlled by technicians at the substations.

Figure 2-1

DART Train Control Center

Source: FTA

Figure 2-2

DART Controller Workstation

Source: FTA

Real-Time Transit Data

Prior to ICM, DART had installed APC equipment on 48 of its cars. This technology allowed DART to collect an accurate count of passengers and download the data at the end of each day. It could then be used be used for planning and reporting purposes on a medium- to long-run scale, but extremely short-run planning (minutes or hours) and operations could not be impacted by this information.

As part of the ICM project, DART was awarded $900,000 by the FTA to install APC equipment that was capable of transmitting data in real-time back to the TCC as well as equipping an additional 20 LRVs with APCs. The additional APC units were from the same manufacturer as the previous 48 APC units. One of the reasons cited for selecting this particular manufacturer was that DART staff viewed integration with the previous system as important. Additionally, emphasis was placed on economies of scale and the simplicity of having a uniform system. The procurement of these additional 20 units was performed by modifying an existing contract.

As part of the new real-time transmittal capabilities, onboard software changes were necessary. For example, the updates allowed vehicles to aggregate the counts from each door's APC onboard the car rather than transmit each APC's data individually and aggregate on the backend. This was necessary because transmitting APC counts separately for each door would have exceeded the available bandwidth for data transfer; in fact, DART initially was concerned that bandwidth would be limited to a single character, allowing only a transmission of capacity utilization rounded to the nearest 10% (e.g. 0=0–10%, 1=11–20%, etc.). However, as of June 2014, DART stated that it had the ability to see the actual number of passengers in each car. The software change for on-board vehicle equipment was budgeted at $110,000, but the contractor was able to make this change for $107,000.

AVL

Multiple agencies stated that they use their SCADA systems for AVL purposes. However, one has GPS receivers onboard newer vehicles (unused to date). Another agency discussed its use of SCADA for AVL purposes but also noted its intent to move to a different system.

APC

Much like the pre-deployment scenario at DART, agencies with APCs download loading data at the end of the service day. Similarly, agencies do not necessarily have a high degree of APC coverage, ranging from 0–40%.

During the TCC observation and interviews, DART staff shared that, as of June 2014, although the APC units were reporting back to the TCC, the data were not believed to be accurate. While some controllers were skeptical about the ability of the APC to generate a correct count, much of the concern was due to seeing counts only from a single LRV of a multi-LRV consist. Some DART staff (primarily those in management) believed the first-car passenger load could be doubled to estimate the total number of people in the consist, and others (primarily controllers) thought that unbalanced loads were common so doubling the passenger count would not be accurate. To the researchers' knowledge, this claim has not been tested either way with end-of-day APC data from consists of multiple equipped LRVs. Additionally, DART engages in routine validation of the APCs and generally has found them to be more accurate than hand-counts.

Following the interviews, DART further investigated this reporting issue and determined that the default configuration used by controllers did not show the second vehicle, although the data had been available within the software. DART management provided instructions to controllers on editing the defaults to view all cars in a consist.[11] This solution is not reflected in any further discussions as it was not in practice at the time of the case study.[12]

While this solution was quick, a disagreement about importance of all-car information remains notable, as most agencies (including DART) do not have sufficient APC coverage to include all vehicles on all routes and may frequently have consists with mixed APC availability. Controllers mentioned that specifically having information from both cars would be useful in the case of maintenance issues. An example of this is how DART might use passenger load information in the case of an air-conditioning breakdown, as further explained in a later section.

Controller Impressions of Real-Time APC Data and the Benefits of ICM

In the pre-ICM period, there was a mix of opinions among controllers regarding real-time passenger count data and whether or not having it would be beneficial. Some controllers were unsure how the addition of this new capability would aid in their work. However, one controller remarked that having information would be useful and could allow the TCC to add cars or consists as available (see Limitations and Flexibility).

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[11] The passenger load for each car is shown in the "vehicles" list of the application. Controllers need to add the passenger counts of each car in a consist to obtain the total passenger load of the consist. If one or more of the cars in a consist is not APC-equipped, the controlled would need to assume a relatively equal distribution of passengers on the consist.

[12] It would be a fruitful research opportunity for DART or FTA to follow-up with the TCC in Spring 2015 to see if any further changes can be documented following this fix.

Both controllers and management could identify potential benefits of real-time information, both for transit services specifically and for implementing ICM strategies as a whole. Some staff members said that ICM was a good extension of the investment that the "public [had] made in agencies and infrastructure" by leveraging information sources from various agencies. As a result of this information, ICM allowed corridors and agencies to better understand unusual situations and assess the entire corridor. For instance, if a transit agency saw higher-than-average passenger loads on its cars, knowing about an accident on an adjacent highway may help in understanding how to better deal with the situation.

According to one DART employee during the pre-ICM interviews, incident management was "mainly reactive." For instance, in the case of bus bridging, the number of passengers was not precisely known and individuals coordinating the bus bridge needed to rely on the train operators for estimated counts of passengers. It was then hoped that real-time technologies would allow DART to address situations in real time and be proactive. In this case of bus bridging, real-time technologies could assist an agency in understanding how many buses to provide for the bridge.

In the post ICM-period, these opinions largely stayed the same. There was an increased willingness to employ certain operational strategies as a result of APC technology, as well as a novel use of APC with regard to passenger comfort, both of which are explained in a later section.

Staffing

It was not envisioned that there would be any necessary additional staffing necessary to complete tasks associated with the ICM real-time transit project.[13] Certain staff, however, did receive additional training regarding APCs. For instance, some members of DART staff said that there would be training on the new SmartNET system that they had put in place for ICM. SmartNET is a web-based application that allows ICM operating agencies to log, share (with each other), and manage transportation event information (e.g., incident information). Staff in the train operations center[14] were trained on how to properly identify APC units so that it was ensured that consists with at least one APC unit left the yard for travel in the corridor. Following interviews in the post-ICM period, it did not appear that any substantive changes had been made in terms of staffing in the wake of ICM. It was unclear from interviews how much training train controllers received to make them aware of the real-time APC data or what strategies they may use to take advantage of the data.

[13] For the ICM project overall, a new position of ICM Coordinator was created. These responsibilities were added to the duties of an existing member of staff as well as his subordinates (in his absence). While this role did not require hiring additional staff directly, the change in roles may have follow-on effects within DART over time.

[14] This is the group tasked with coupling LRVs into consists and assigning consists to operators/routes.

SECTION 3

Incident Response

What is an Incident?

From DART's perspective, an incident is any event that causes a disruption to normally-scheduled transit service; this includes planned events.[15] DART faces both planned and unplanned incidents in its operations and has several methods of managing them.

Planned incidents include events at the American Airlines Center, conventions, the annual State Fair held every September/October at the fairgrounds just east of downtown, and the Texas/University of Oklahoma (OU) football game held at the Cotton Bowl on the State Fair grounds. These events are known ahead of time and often include foreknowledge of attendance and likely transit use based on experience over the years. To a limited extent, DART is able to adjust its schedules to accommodate these types of incidents.

Unplanned incidents include situations such as unforeseen platform crowding and transit demand, train malfunction (including stuck doors), medical emergencies, and deteriorating operations/network conditions such as a car being stuck on a track at a grade crossing or on at-grade right-of-way.

Incident Response

This section discusses how both planned and unplanned incidents are handled pre- and post-ICM. In both phases, DART has, and will continue to have, certain constraints that reduce its ability to meet that ideal, including operational policy, consist availability, network capacity, and driver availability. These constraints are discussed in the section on Limitations and Flexibility.

Pre-ICM

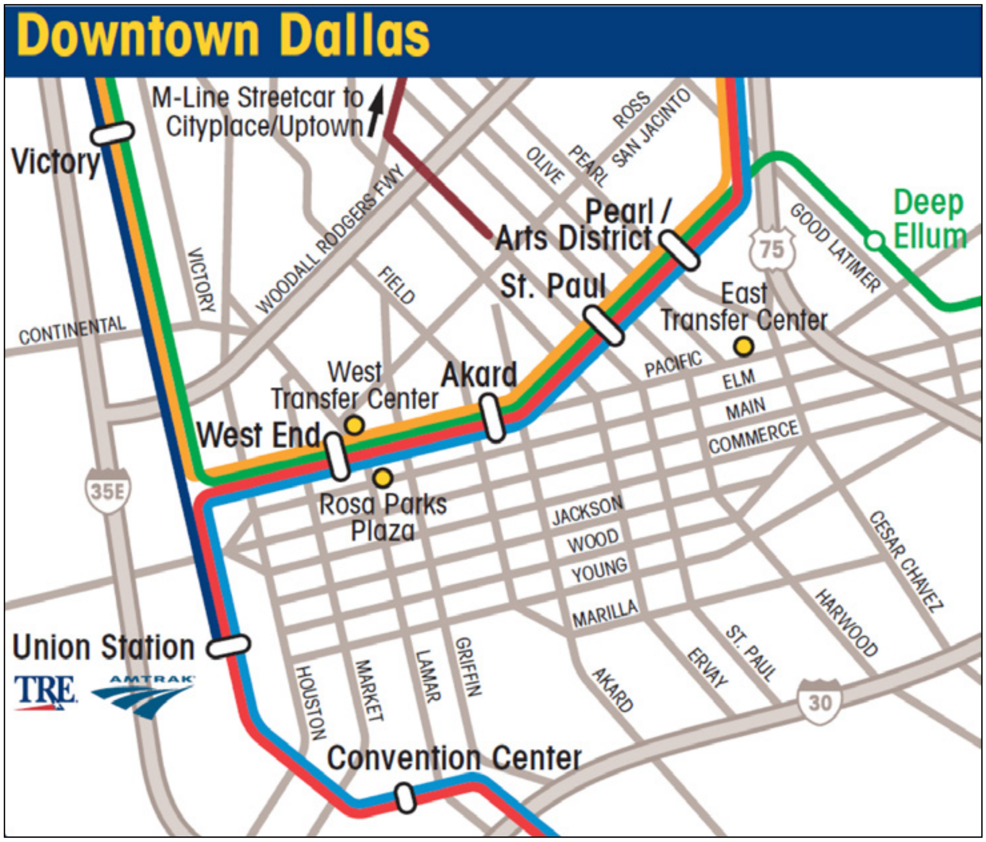
Planned incidents often involved changes in operations and planning to accommodate crowds. Following events at the American Airlines Center, the Green, Orange, Red, and sometimes the Blue line, trains depart from the adjacent Victory Station, even those that do not normally serve it (Blue and Red lines). Spare consists are held at Victory Station until an event is over, at which point they are filled and deployed. Those trains that do not normally serve the station are routed through the CBD and continue their normal route, avoiding

[15] This definition was chosen based on conversations with DART TCC staff who said they treat events and incidents similarly.

the need for travelers to transfer trains in this busy portion of the network. The downtown rail network is shown in Figure 3-1.

Figure 3-1

Downtown Dallas Rail Map



Source: DART

Two other major events that require an adjustment strategy are the Texas/OU football game and the Texas State Fair. Both events take place at the State Fairgrounds to the east of the CBD. Because the CBD can become congested, trains servicing these events headed to the southwest sometimes bypass the CBD via the Central Rail Operations Facility yard.

With regard to unplanned events, DART single-tracks trains if necessary, adds shuttle service, and, to a limited extent, deploys additional consists to the network. For example, due to a medical emergency onboard a train in February 2013, DART single-tracked that section while emergency crews offloaded the affected passenger from the train. If a train becomes disabled in the CBD, rather than single tracking, DART opts to deploy shuttle service due to the high amount of rail traffic that uses CBD tracks.

Any issues with crowding, whether on train platforms or within actual consists, are relayed to the TCC using voice communications. Consistently across interviews, respondents said the point at which operators radio the TCC is when passengers are being left at the platform. At the point when this occurs, the TCC examines possible causes for the crowding and what strategies can be deployed.

These spikes are rare, and when they occur, DART often is unable to respond to these incidents by adding more trains or train cars. The causes of these constraints are discussed in Limitations and Flexibility.

If crowding possibly is caused or exacerbated by tardy trains, the TCC also employs yard supervisors as temporary LRV operators to alleviate service issues. For instance, if a late train is approaching its terminus (within a few stops), the TCC might ask the yard operator to take a consist out from the terminus yard and begin a scheduled journey towards the center of the city. Once the late consist and the newly-deployed consist meet at an intermediate station, the operator and rail yard supervisor switch places and the rail yard supervisor continues the remainder of late consist's run back to the yard, and the other operator regains his/her on-time run.

Post-ICM

Despite the concerns about the data presented (see above and note this issue has since been corrected) as well as various constraints on controller ability to react (see below), it was evident there had been shifts to operational decisions between the pre-ICM period and the post-ICM period. In previous interviews, TCC staff signaled an unwillingness to turn back trains[16] to meet schedules; in the post-ICM period, controllers seemed more likely to use this strategy to resolve delays. While turnbacks were not used significantly in either the pre- or post-ICM periods, there was a noticeable shift in attitude and a willingness to consider strategies that had not been in the pre-ICM period.

Some of this shift may be attributed to the APC technology. In one interview, a controller said the real-time ability to know how many passengers are on trains may impact the decision to turn back trains. For instance, if trains are bunched in the network and cause a delay, the TCC may opt to offload a train if a trailing train is available and has sufficient room for the offloaded passengers. This strategy would inconvenience a few passengers but would provide better on-time performance for customers in the opposite direction of service.

However, it is important to stress that large-scale changes to operations or operational strategies did not occur. One common theme throughout the interview process was customer service and not wanting to inconvenience

[16] This is also called short-turning by other agencies, wherein the controller would have an operator empty a train before the terminus, asking the passengers to board the next train in their direction. The operator would then return in the direction the train came from, carrying passengers in regular service.

passengers. This policy (both formal and informal) affects controller reactions to incidents and also leads to many of the limitations and constraints discussed later.

Aside from operational strategies, real-time APC data may be used to maximize passenger comfort. As an example noted by DART staff, if a consist is made of two LRVs and one has an air-conditioning unit fail, it may be possible to offload passengers from one LRV to the other, taking the non-functioning LRV out of service. One controller remarked that with information regarding passenger load on each LRV, it would be possible to make a decision on whether capacity was available in the functioning LRV and if dwell time could be kept sufficiently low to allow passengers to move from the non-functioning LRV to the LRV with the functioning air conditioner while maintaining the required schedule.

Other responses to unplanned events did not change significantly pre-ICM to post-ICM due to the constraints discussed below. Response to planned events also did not change due to DART's satisfaction with the responses discussed above.

From the perspective of ICM as a whole, there had been limited opportunity as of the time of the interviews to understand how mode shift due to highway and arterial incidents affects transit operations. As of the time of the post-ICM interviews, only one incident had occurred that would have resulted in significant, dynamic mode shift to LRT in the corridor; however, that incident did not generate a response plan that encouraged shift to transit due to an issue with the ICM system, which was since corrected.[17]

[17] This incident actually sparked the identification of the ICM system issue, as DART and other ICM partners expected the incident to generate a response plan including a shift to transit and investigated accordingly.

SECTION 4

Limitations and Flexibility

The installation of APC and AVL technology could allow an agency to address passenger loads in real time by adjusting capacity dynamically. However, while theoretically possible, in practice this may be difficult. Limitations at transit agencies include infrastructure, equipment, staffing, and policy constraints.

Network and Capacity

During peak periods, DART is theoretically able to operate trains in the CBD at a 2.5-minute spacing. However, actual throughput is reduced, as the 2.5-minute spacing requires near-perfect achievement of dwell-time goals that can be confounded by issues such as passenger delays, door jams, etc. Attempts at this level of frequency resulted in a "cascading series of delays," as crossovers, switches, dwell times, and traffic signal timing did not match actual vehicle locations. Planned service was altered so that the spacing between trains was 3.75 minutes.

Because DART is at its maximum capacity in the peak period due to CBD congestion, it is precluded from being able to inject a train into service that includes the CBD during the rush periods.[18] DART has indicated that in the event of a major influx in passengers to the Red and Orange lines north of downtown Dallas, the agency would use express buses in the short term to maintain adequate levels of service, although this response is not considered part of the adopted ICM strategies. DART has a limited ability to inject a train into the network during off-peak periods (when network capacity is not full), although this would also be subject to spare consist and operator availability as well.

Trunk Lines

Trunk lines present an issue for other transit systems as well. Some systems have medium-term ability to overcome this constraint through longer consists or by upgrading signal systems. Although this service pattern allows for lower headways in the core of the system and reduces costs to establish the system, it limits the ability to increase frequencies on lines using the trunk as the system grows. Although a reasonable strategy at system creation, agencies may want to consider adding various "triggers" in long-range plans to begin planning for necessary capacity improvements or service changes before trunk lines become a binding constraint. However, even with these plans in place, funding must be found at the appropriate time; one agency discussed being unable to implement the planned project for this reason.

[18] Injecting trains to run for a portion of a route not including the CBD was not considered, as traffic patterns did not support a demand for this type of service, even if other network and logistical barriers could be overcome.

City Blocks

Another interviewed transit agency faced the same problem extending trains due to city-block length. Consequently, any attempt to lengthen trains and platforms was considered "cost prohibitive."

In regards to adding LRVs to existing consists, DART is limited by platform length on the Red and Orange lines. While the Green line can run consists of three cars, the Orange and Red lines are limited to two-car consists because some platforms on those lines are not long enough to accommodate an extra car. In total, 29 stations in the DART network are unable to accommodate three-car consists.[19] DART projects costs to address this system-wide would be as much as $188 million. It is important to note that this estimate was not produced for this report and includes other required work associated with upgrades at these stations. That is, these adjustments would not merely be lengthening of platforms, but would also include modifying the type of wheelchair access from train-to-platform, relocating utilities, and other changes unrelated to simply adding additional feet of platform.[20]

Three-car operation is further limited to situations in which vehicles are able to reliably run on-time through the CBD. This is necessary because some city blocks between (but not at) stations within the CBD are shorter than three-car consists; therefore, successful operation of these vehicles without blocking automobile traffic requires on-time progression through timed traffic signals[21] to avoid blocking traffic at intersections. Moreover, a missed signal (for either two-car or three-car consists) can cause cascading delays through the CBD.

Equipment

Whereas DART maintains a maintenance reserve fleet beyond the needs for peak service and vehicles used only for the peak may be available off-peak, a consist may not be immediately ready to respond during the off-peak, or the maintenance reserve railcars may be out of service. The nature of a fixed guideway covering long distances also reduces the ability of any rail-based transit agency to deploy an additional vehicle to the exact location of an incident.

DART currently runs all lines at a minimum of 15-minute headways[22] and has 163 LRVs available. Running high frequency headways, for example, would require DART to use more consists than it has available.[23]

Equipment

Most spares at surveyed agencies are out-of-service for maintenance or overhaul. For example, at one agency, only 8 cars are able to be deployed as "hot spares" from its 47 out-of-service vehicles. Reported reserve ratios ranged from 20–37%.

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[19] DART recently added to its financial planning documents to begin this project in the next few years. As that project continues, DART may be able to provide a more detailed and accurate breakdown of the various costs.

[20] To be clear, this estimate should not be used to determine agency-agnostic cost-per-station or cost-per-platform-foot estimates of platform extension costs.

[21] DART controllers refer to this system as "Greenband."

[22] For most riders, this manifests as 7.5-minute (or better) headways, as many of the stations, particularly those closer to the CBD, have two (or more) lines serving them.

[23] Although other constraints, notably around interlockings and network capacity in the CBD, prohibit six-minute headways, the point was raised by DART specifically in relation to necessary equipment as well.

As part of the platform lengthening project (see Footnote 19), DART's need for more vehicles to support expanded three-LRV service caused an increase in the targeted reserve fleet from 14% of the fleet in 2009 [2] to approximately 28%. Once complete, DART will have additional options to add a third card to a two-car consist at Parker Road (or other termini) to respond to incidents.

Staffing

Even when on-track network capacity and spare consists may be available, DART may not always have excess staff available at the termini to add supplemental service dynamically. In the off-peak, staff (including rail yard operators) may be available at the terminus (e.g., Parker Road) who could deploy an extra consist. However, there did not appear to be a specific established plan to have extra staff available for the deployment of extra consists in the off-peak hours (peak-hour consist injection is not possible due to capacity constraints noted above.)

Policy

A major consideration to the strategies that are used by DART is policy. In the pre-ICM period, DART rarely, if ever, used the following strategies:

- Selective Hold – holding vehicles at stops to make schedule adjustments.
- Short-turning (DART refers to this as a "turnback") – vehicles turn around before the end of their route and return back in the opposite direction, carrying passengers and making regular stops.
- Skip Stop and Expressing – running vehicles with passengers on them while skipping stops to restore schedules/headways and potentially to smooth out vehicle and passenger traffic along the route.
- Deadheading – using empty vehicles to skip stops and resume regular service at another location or direction (frequently at a terminus or key station).[24]

In the pre-ICM period, DART claimed it did not use any of these strategies more than a few times a year. Following the implementation of ICM, there seemed to be a slightly higher willingness to short-turn trains. However, the majority of these strategies are still not being used partly due to perceived expectations of DART customers. For instance, trains are not expressed by DART because there is an expectation that trains will stop at all stations. Controllers added that this

[24] The official American Public Transit Association definition includes other reasons for deadheading. In interviews, deadheading for the purpose of repositioning vehicles for revenue service was the only reason of interest. The official definition is "the movement of a transit vehicle without passengers aboard, often to and from a garage or to and from one route to another, http://www.apta.com/resources/reportsandpublications/Documents/Transit_Glossary_1994.pdf.

expectation extends to automobile drivers[25] such that not stopping at a station may result in an accident by someone who mistakenly believes the train is going to stop and may be caught in a grade crossing.

Policy Choices

In the case of "skip stop" and "expressing," some agencies use this strategy to address "cascading delays" that result in a large gap in service along a section of a line. Real-time APC data may help to better understand when these strategies should be used. For instance, it may make more sense for a transit agency to express a full train rather than an empty train to reduce dwell time of a full consist that is already running late. An agency may decide to short-turn vehicles in a low-demand portion of the network or an area with multiple lines of trunk service if it knows that a particular section of the network is experiencing abnormally high demand. Real-time APC data may help in making this decision by quickly alerting the agency operations center of the location where high demand is occurring and aiding controllers in identifying cars without many current passengers. Other agencies had a range of opinions on these operational strategies. One agency used all four strategies, and another used selective hold (for correspondence between lines) and short-turning but not skipping and expressing; deadheading was used sparingly.

Table 4-1 shows how many of the interviewed agencies (not including DART) used each strategy.

Table 4-1

Other Agencies Interviewed that Engage in Various Operational Response Strategies

Strategy	# of Agencies (of 4)
Selective Hold	2
Short-Turning	4
Skip-Stop/Expressing	1
Deadheading	4

[25] While this assumption reasonably also applies to pedestrians, it was not mentioned during the interviews.

Costs of Addressing these Limitations

Throughout interviews, agencies were asked for rough estimates of costs for various improvements that may aid in adding flexibility to the system. Although these are inexact estimates from a small set of agencies, they may provide useful information for an agency considering how to prioritize investments to aid in real-time response to incidents. Table 4-2 shows these estimates.

Table 4-2

Cost Estimates of Various Infrastructure Improvements

Improvement	Estimate 1 ($million)	Estimate 2 ($million)	Estimate 3 ($million)
Additional vehicles	$2.1–2.3 per vehicle	$3.5 per vehicle	$4.5 per vehicle
Additional track	$20–40 per mile		
Universal crossover	$6	$10–30	
Switch	$2–3		
Updated signaling	$22.5 per mile		
Platform extension	$2 per station		

SECTION 5

Conclusion

New technologies such as real-time APC may allow transit agencies such as DART to be more flexible in how they respond to unplanned incidents by better understanding passenger load and demand across the network. Agencies can use this information to enact new strategies that previously were unavailable, impractical, or unreliable. To obtain and use real-time information, agencies may need to invest significant resources in updating equipment and software as well as training employees on the new equipment.

While ICM and APCs have eased one major constraint—the ability to obtain real-time passenger load data—it has not eased other constraints such as network capacity and organizational policy. DART and other agencies around the country face issues such as platform length restrictions, headway limitations, and consist availability that impact their ability to respond to passenger demand issues in real time. Additionally, agencies may need to examine their internal policies to understand how much impact ICM and APC technology could have on their operations. For instance, although ICM and APC units might provide incentives to use operational strategies such as deadheading and expressing, if institutional policies prevent this, agencies may not be able to use this technology to its full potential. Thus, while ICM-supporting ITS technologies may better inform strategies to address transit-related problems, they must be coupled with organizational, collaboration, and infrastructure improvements to address other possible constraints to implementing these strategies.

Based on changes from the pre to post-ICM periods, it is clear that DART has made changes with the introduction of this technology, including finding use-cases they did not anticipate. Looking ahead, DART and transit agencies nationwide may use real-time APC technology more frequently and discover novel uses for the data it provides.

ACRONYMS

APC	Automatic Passenger Counter
AVL	Automatic Vehicle Location
CBD	Central Business District
DART	Dallas Area Rapid Transit
DSS	Decision Support System
FTA	Federal Transit Administration
GPS	Global Positioning Satellite
ICM	Integrated Corridor Management
ITS	Intelligent Transportation System
LRT	Light Rail Transit
LRV	Light Rail Vehicle
OU	University of Oklahoma
RTM	Record of Train Movement
SCADA	Supervisor Control and Data Acquisition
TCC	Train Control Center
VBS	Vehicle Business System

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[2] AECOM. 2009. Dallas Area Rapid Transit Light Rail Transit: Rail Fleet Management Plan Revision I, Dallas Area Rapid Transit (DART), February: 44-46.

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