Headway Management

More consistent and frequent bus service

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TRANSITMATTERS

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Top-Level Summary

High-frequency bus corridors, routes with bus frequencies of 15 minutes or less, are more reliable and useful for riders if buses arrive at consistent intervals rather than according to a pre-set schedule. Operating by headway, the time between buses, rather than a schedule requires new operational practices. This practice, known as headway maintenance, which is widely used across other cities, is currently used on the MBTA subway system and is easily adaptable to the bus network.

Currently, about 30 MBTA bus routes are high-frequency routes for at least part of the day, but none of these bus routes utilizes a headway maintenance approach. The Bus Network Redesign project proposes increasing frequency on many routes, doubling the number of frequent routes to almost half of all MBTA bus routes. In effect, this creates a large "high frequency" network within the transit system. If adopted, headway maintenance will improve the reliability and efficiency of this bus network, improve the rider experience, and ultimately increase ridership levels and rider satisfaction which leads mode shift.

Overview

Maintaining a reliable and consistent experience is one of the key ways to build bus ridership. Central to reliability is minimizing wait times for riders. For less frequent routes, having buses stick closely to scheduled time points allows riders to arrive at their stop shortly before a bus arrives with minimum extra waiting time; read more about this practice, pulse points, here. As frequency increases, riders depend on buses coming at regular, predictable intervals. However, high-frequency buses operated on a timepoint schedule will often run early or late due to variable ridership, traffic congestion, and other factors which create unpredictable long gaps between some buses and bunching between others. At higher frequencies, focusing on maintaining a consistent gap, or headway, between buses results in a better rider experience.

Justification for Headway Maintenance: Bus Bunching and Gaps

As buses move along a route, they may experience delays caused by variable ridership across stops and times of day, traffic congestion, weather conditions, street conditions, and other factors. With infrequent routes, delays tend to have less impact due to longer intervals between buses. Riders plan to use a specific scheduled bus and arrive at predictable times. On the other hand, for frequent routes, riders arrive more variably depending on the frequency of the buses. When one vehicle is delayed and moves along the route more slowly than the one ahead or behind, uneven gaps emerge and escalate as larger numbers of riders wait and boarding times increase. The following bus boards fewer people and catches up, leading to bunching.

The more frequent the service, the harder it is to avoid bunching, and the longer it can persist and worsen. The result is that a fraction of riders have a short wait but on average riders have longer waits for buses that are more crowded thus leading to longer travel times and thus poor rider satisfaction and less efficient use of the bus fleet and operators. This is particularly important given the current bus operator shortage.

However, these conditions of bunching and gaps in service persist on high-frequency routes despite the T's current schedule-based dispatching operations, justifying the use of headway maintenance. For example, in April 2022 the 66 bus significantly bunched around several stops. When bunching is defined as buses that run within two minutes or less of each other, inbound buses towards Nubian Square bunched 10% of the time at Brigham Circle, 9% at Brookline Village and Roxbury Crossing, and 8% of the time at Coolidge Corner. Bunching is even more dramatic outbound towards Harvard Square where buses bunched over 35% of the time at Winship St, 13% at Coolidge Corner and Harvard Ave at Commonwealth Ave, and 12% at North Harvard St at Western Ave. View more data about bus bunching through the TransitMatters Data Dashboard here.

Shifting from schedule-based operations, where a bus leaves at a specific time or as soon as possible if already running late, to headway maintenance, where each bus aims to keep a consistent gap with the previous bus, makes service more consistent and easier for riders to understand and use, ultimately driving mode shift.

Best practices for Headway Maintenance Operations

To implement headway maintenance, the following best practices need to be implemented by operators, dispatchers and supervisors.

1) Dispatching: When implementing headway maintenance, central operations dispatches buses based on previous vehicles at regularly spaced intervals, rather than at a set time, which is what the T currently does whether a bus is late or early. This requires real-time GPS and/or AVL (automatic vehicle location) data display at dispatch points to allow for accurate headway calculations.

2) Operator Practices: Headway maintenance requires that operators monitor distance from the leading and following bus and maintain an equal distance between the three buses to minimize variance across headways. Operators need training in headway management strategies, indicators for using these strategies, and when to alert dispatch about severe gaps.

3) Use of On Bus Technology: Headway maintenance requires real-time GPS and/or AVL technology and an on-board display that shows the operator the gap with the previous and following buses. The current system shows minutes ahead of/behind schedule but could be adapted to show headways instead.

4) Communication: Headway maintenance depends on real time enroute coordination between buses. This requires direct communication between operators of leading and following buses to coordinate the separation of bunched buses. Central dispatch and field supervisors coordinate headway maintenance using information about bus arrivals at preset locations and time points, passenger load based on operator input and/or APC (automatic passenger counter) data, and information from operators. They make decisions and communicate with operators when higher level interventions are needed.

5) Reserve Buses: Headway maintenance may require dispatching reserve buses and/or staging reserve buses and operators at strategic locations to fill in and provide additional capacity and correct headways when a bus gets delayed and gaps occur.

6) Infastructure Changes: Infrastructure such as dedicated bus lanes, queue jump lanes and signal priority may be needed to eliminate key points of traffic variability. While these practices have speed benefits when done along entire corridors the focus should be on points that introduce significant variability in travel time. A continuously congested corridor will lead to similar headways, albeit with a large number of resources required, but a traffic signal that has a long cycle time which some buses must wait at while others move through quickly disrupts headways. Often only a very short section needs attention, such as the approach to an intersection (queue jump lane) or a few blocks (dedicated bus lane) to get through a congested area.

7) Shared Corridors: Lengthy trunk sections of overlapping routes which together have frequencies of 15 minutes or less and that share a terminal should have managed headways such that buses on the trunk section should be regularly spaced regardless of what route each bus is on.

Existing Operations:

A recent survey of 16 cities[1] found that headway-based service has been fully implemented on one or more routes in several locations:

- Austin, TX (Capital Metro)
- Montgomery County, MD (Ride On)
- Snomish County, MD (Community Transit)
- Honolulu, HI (TheBus)
- Washington, DC (Washington Metropolitan Area Transit Authority)

TheBus, in Honolulu. Credit: Pink 91119 - Wikimedia Commons

The following systems are transitioning to and/or testing headway maintenance on one or more bus lines:

- Oakland, CA (AC Transit)
- Houston, TX (Metropolitan Transit Authority of Harris County)
- Los Angeles, CA (Los Angeles Metro Bus)
- Philadelphia, PA (Southeastern Pennsylvania Transit Authority)

In 2020 the Muni transit system in San Francisco shifted some bus lines from a schedule-based system to a headway system, too.

Across the agencies that have adopted headway maintenance on one or more lines, all have reported that service has improved across a broad variety of metrics including passenger wait time variability, bus travel time variability, and overall passenger satisfaction.[2]

Muni Route 21 trolleybus at Ferry Plaza. Credit: Pi.1415926535 - Wikimedia Commons

While in practice modern technology is not used, MBTA shuttle buses are a good example of headway maintenance. Dispatchers direct operators to leave the terminal when the desired headway has been reached, for example, 5 minutes after the previous bus left, or sooner if a train arrives and the bus fills up. Without real-time bus location information, supervisors assign enough buses to the route to ensure that there will always be a bus ready to start a trip even if there are delays along the route. In modern practice, headways are automatically adjusted by a computer system so there need not be so many buses sitting idle at the terminal.

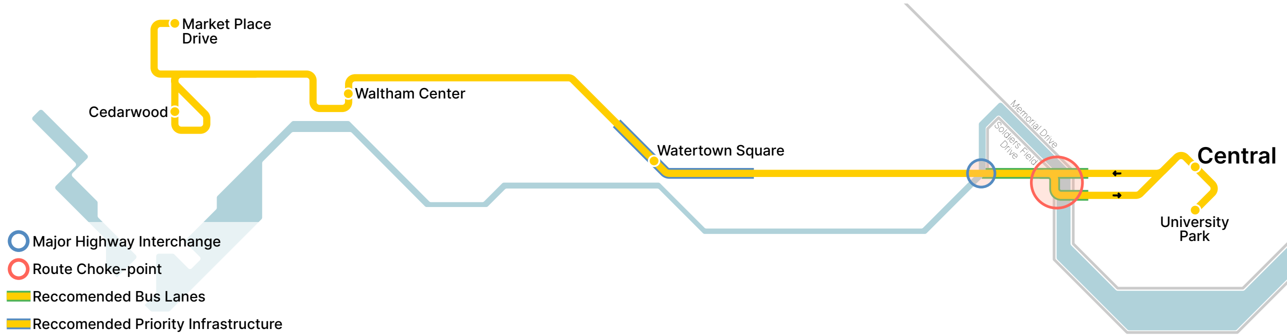
Applicable MBTA bus routes

Headway maintenance is most important for routes with a frequency every 15 min or less where riders arrive at a bus stop without checking a schedule or app. This currently includes key routes and with Bus Network redesign this will include many more. The MBTA's dispatching is currently primarily driven by time points at origin stations only. Operators are instructed to leave the starting point at the scheduled time or as soon as possible if running late rather than holding the second bus to space out capacity. This often results in two buses leaving at the same time.

Examples where headway maintenance could meaningfully improve rider experience and corridor performance:

1) Route 70

Route 70 is one of the longest routes in the MBTA system. It has good geometry, being nearly straight, and most parts of the corridor are seeing significant additional housing adjacent to the route. However, due to the length, insufficient frequency and short average distance between stops, buses frequently bunch and arrive late, often departing in pairs as a result. Shifting to headway maintenance could avoid overcrowded buses and stops in the limited waiting areas near Central Square and allow a smoother shift towards high-frequency service that enables car-free trips throughout the corridor. Headway maintenance should be paired with realigned stops and priority infrastructure especially in Watertown and at the highway crossings. Getting across Memorial Dr and Storrow Dr currently takes between 5 and 20 minutes. Inconsistent travel times cause bunching and can only be solved with dedicated bus lanes on Western Ave (westbound) and Storrow Dr (eastbound) so that each bus gets through as fast as the previous one.

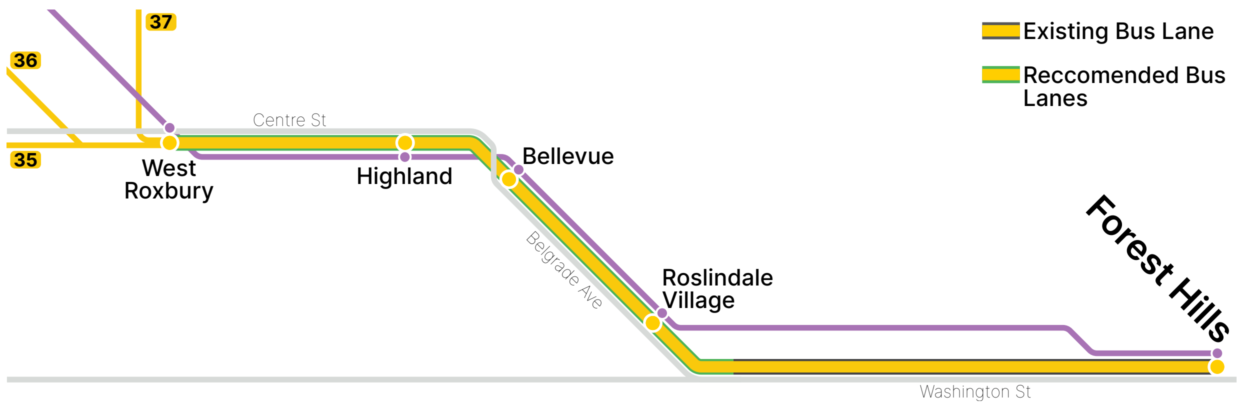


Map of the route 70 bus, showing key choke points for the route.

2) Routes 35, 36, and 37

Routes 35, 36 and 37 share the same corridor for the majority of their length, from Forest Hills station into West Roxbury. While each route's scheduled frequency ranges from 15 to 30 minutes, the resulting combined frequency on the corridor is 5-10 minutes on average. However, poor schedule coordination or a delay for one bus can translate into a long gap when riders expect short waits. Headway maintenance across routes can provide a consistent high-frequency experience even when individual vehicles are delayed, and prevent bunching from causing three buses every 20 minutes rather than one every 6 minutes.

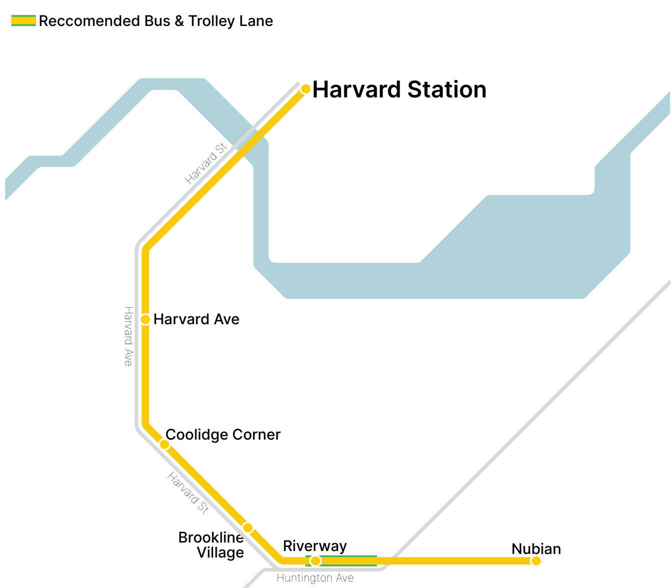
There have been successful implementations of priority measures around these routes but much more can be done. For example, the bus lane on Washington St has been successful but needs to be extended further west with longer hours. The bus lane is only operational between the hours of 2PM - 7PM on weekdays, ultimately not alleviating morning traffic.



Map of the routes 35, 36, and 37 during their shared segment, showing existing & reccomended bus lines.

3) Route 66

Route 66 runs every 10-15 minutes all day, providing key circumferential capacity between Harvard and Nubian Squares, with riders hopping on and off along the entire route. Although there are enough buses to accommodate the total number of riders in any given hour, the bunching and long gaps mean that some buses are overcrowded while others are underutilized and most riders face longer than expected waits. Simply adding buses will not solve these problems. Only headway maintenance combined with targeted priority measures can ensure buses arrive evenly spaced, minimizing wait times and allowing all riders to be comfortably transported. The segment on Huntington Ave causes a disproportionate amount of delay and variability and should be resolved by reserving the center lanes for buses and trains only, as well as modifying signals at the ends to keep buses moving.



Map of the route 66 bus, alongside its key choke points

Implementation Details:
A technical guide to changes needed & Best Practices

Appropriate Conditions:

- **Focus on High-Frequency corridors:** Headway maintenance works best on routes with headways of 15 minutes or less, where riders simply show up without checking a schedule or app.
- **Plan using existing data:** Determining contributors to bunching and gapping requires analyzing data to see where and when recurrent headway issues occur. Data collected by the MBTA, Transit Matters and others can be used to proactively plan and train for dynamic headway management. Relevant data includes ridership at different time points using automatic passenger counter data, recent and historic travel speed data, route specific headway by the time of day, and operator reports regarding recurrent backups at signals and/or intersections.
- **Coordinate with Municipalities:** The MBTA should work with Municipalities in reviewing available data regarding ridership, roadways, traffic signals, intersections, and other factors associated with delays.

Credit: Jacklyn Thibodeau

Operational Changes:

Implementation of headway maintenance requires committing to separate operational standards for high-frequency and low-frequency bus routes. Service provision is rooted in consistent headways between buses rather than specific schedules. Buses depart in relation to the departure to the previous bus and according to specific needs that may arise due to high rider volume, e.g. in times of high ridership departing more frequently. This may require shifts in policies regarding layovers, operator breaks, availability of buses at different times of day, and availability of backup buses and operators.

The MBTA currently does real-time monitoring of vehicle locations using GPS and Automatic Vehicle Location (AVL), a key layer of electronics. Shifting to headway maintenance would require new policies and procedures providing guidelines about how to use this data, the types of corrective actions to use, specific thresholds to use for implementing these actions, and specific responsibilities of operators and central operations personnel for implementing headway maintenance. Operators, dispatchers and route supervisors will need training in these policies and procedures. One effective approach to setting policy and providing guidance to operators, dispatchers, street supervisors, and other operations staff on what actions to take when headway issues arise is a Service Management Manual such as those used by Austin's Capital Metro and Washington, D.C.'s WMATA. Performance standards for personnel will need to be altered to reflect the goals of headway maintenance rather than scheduled maintenance.

Headway maintenance depends on operators adjusting their speed according to real-time data about leading and following buses provided by onboard AVL technology. Dispatchers and field supervisors use GPS, AVL, and APC (automated passenger count) data, as well as input from operators, to make decisions about interventions to use across a corridor when more significant issues develop. Either on their own or through communication with dispatchers and field supervisors, operators adjust headways by using techniques such as brief holds at predetermined hold points, slowing down or speeding up, limiting boarding, shifting to drop-off only, leapfrogging, stop skipping and short turns, or turning around early.

Some level of automation is required to allow dispatchers and field supervisors to troubleshoot problems without spending excessive time watching a computer screen or waiting for operator reports. In-vehicle technologies exist and/or can be designed with specific algorithms to send alerts to dispatch when an intervention may be required. Active coordination between central operations and operators, and availability of standby buses that can be activated as needed are necessary to assure reliability and minimize inconvenience to riders when these techniques are used.

Infrastructure Upgrades:

Traffic conditions, traffic signal issues and bottlenecks can significantly impact headway maintenance. It is essential to identify the times, roadways, intersections and signals where delays occur to determine the infrastructure improvements needed. Data can be collected utilizing corridor data and consulting with operators. Upgrades that can significantly improve reliability and decrease bunching and gapping may include dedicated and enforced bus priority lanes, transit signal priority, signal retiming, sidewalk extensions and queue jumps, among others.

Infrastructure upgrades and changes require active collaboration with municipalities that own and operate roadways and traffic signals utilized by buses. It is critical that the MBTA partner with municipalities to establish a joint approach to improving bus transit speed and reliability which includes infrastructure changes needed and implementation plans for priority upgrades. See the Mobility Hubs Toolkit for more information on upgrading bus stop infrastructure.

Cautions

It is important to ensure that any high-frequency route has enough vehicles and operators for the expected ridership and that foundational obstacles such as missed trips are kept to an absolute minimum. Additionally, headway maintenance requires sufficient numbers of dispatchers and/or route supervisors. While headway management is effective at dealing with the occasional disruption or breakdown, it cannot overcome chronic staffing shortages or lack of capacity.

ITS systems[4] use different algorithms potentially creating confusion if multiple systems are used. Transit systems need to choose a system that works for local conditions and communicate and train staff on how to interpret and use the data.

Attention needs to be paid to the balance between headway maintenance and providing enough time for operator breaks and recovery. The MBTA should work with the union to establish equitable policies around break time, split shifts, clock-out times, and consider changing operator schedules to allow more flexibility and increased recovery time. MBTA must make strong fiscal investments into hiring as it is integral to this level of service, making the implementation of headway maintenance go hand in hand with Bus Network Redesign.

Summary:

Headway maintenance is a useful tool for making frequent routes more reliable by reducing wait times between buses. When riders can arrive anytime and be confident their bus will arrive soon, they can depend on transit to get around and be independent. Instead of unpredictable and excessive wait times pushing riders toward car use, reliable bus service attracts new riders and enables existing riders to travel more.

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1. National Academies of Sciences, Engineering, and Medicine 2021. Intelligent Transportation Systems in Headway-Based Bus Service. Washington, D.C.: The National Academies Press. https://nap.nationalacademies.org/read/26163/chapter/5#21.

2. Ibid, https://nap.nationalacademies.org/read/26163/chapter/5#25

3. MBTA Bus Network Redesign Executive Summary, https://cdn.mbta.com/sites/default/files/2023-03/2023-03-03-bnrd-executive%20summary-of-final-report-english-accessible.pdf

4. Intelligent Transportation Systems (ITS) applied to a bus network refers to an integrated system that coordinates information from data sources including GPS, AVL (automatic vehicle location), APC (automatic passenger counting), and that includes onboard data display and two-way communication between the vehicle and central operations/dispatching.