Regional Rail

What, Why, and How

What Is Regional Rail?

- Different things to different people!
- We're not talking about SEPTA commuter trains (in Philadelphia) here
- Proposal by TransitMatters: regionalrail.net
- I don't work for TransitMatters so this is my interpretation of their basic idea

Concise definition

Regional Rail is a transportation system that repurposes existing commuter rail tracks and stations to:

- Make today's commutes faster, more reliable, and more comfortable
- Enable travel patterns and user communities that traditional commuter rail does not support
- Reduce per-passenger operating costs by simplifying staffing, service patterns, and equipment rosters

How is this different?

- Commuter rail is based on an operating paradigm that has changed little since the 1890s: get wealthy people in the outskirts of the metro to their 9–5 white-collar jobs in the city center

- Regional Rail enables other kinds of travel: “reverse commuting” and “suburb-to-suburb”, and makes these accessible to non-9-to-5 workers through high-frequency, all-day service

- Regional Rail provides “rapid-transit-like” frequencies along trunk rail lines in the most densely populated areas
  - It’s as if you built whole new rapid-transit lines serving Dorchester, Lynn, Chelsea, Framingham, Brockton
- At the outer edges, speed improvements can take as much as 40 minutes off travel times to the center
- All-day high-frequency service helps parents and service workers who need to travel outside peak

Why Regional Rail?

- Land for transportation uses is limited in high-demand areas
  - Must make best use of available rights of way
  - Commuter rail tracks link high-demand areas and are severely underutilized
- Existing commuter rail service:
  - passes without stopping through many disadvantaged communities that would benefit from better transit options;
  - fails to serve existing transportation demand from service workers and counter-peak travelers

What's Wrong Today?

- Current diesel locomotives are slow, smelly, noisy, unreliable
  - They also have high maintenance costs and generate significant amounts of CO_2 and particulate pollution in environmental justice communities
- Current commuter coach design slows boarding and alighting
  - They are also unreliable and crowded
- Many stations are not accessible or have very limited access for both ADA and non-disabled riders with encumbrances like strollers, shopping carts, and bikes
- Conductors required to open doors, operate "traps" at low-platform stations

Regional Rail program elements

- Full high-level platforms at all stations
- Electric multiple-unit trains
- Fare system integration
- Frequent all-day service
- Infill stations to improve connectivity

High-level Platforms

- ADA requirement for at least one car (and toilet) in every train to be accessible without climbing stairs
  - MBTA meets this requirement at most pre-ADA stations with a “mini-high” platform that only one passenger coach serves
  - MBTA builds 800-foot “full high” platforms at all new stations; Amtrak builds 1050-foot platforms but most T stations are not Amtrak stations
  - Many older stations do not have even mini-highs if not renovated recently (ADA requirement applies only to new or substantially altered stations)
- Northeast US platforms are 48” high, taller than anywhere in Europe, Asia, or much of the US

High-level Platforms

- Step-free access from the platform to the train (“level boarding”) also benefits non-ADA communities: elderly, people traveling with infants or children, people carrying luggage
- Automatic door operation only possible at stations with level boarding
  - There is no automatic system for raising and lowering “traps”
  - This means conductors (not passengers) must operate doors and “traps” manually at low-platform stations

High-level Platforms

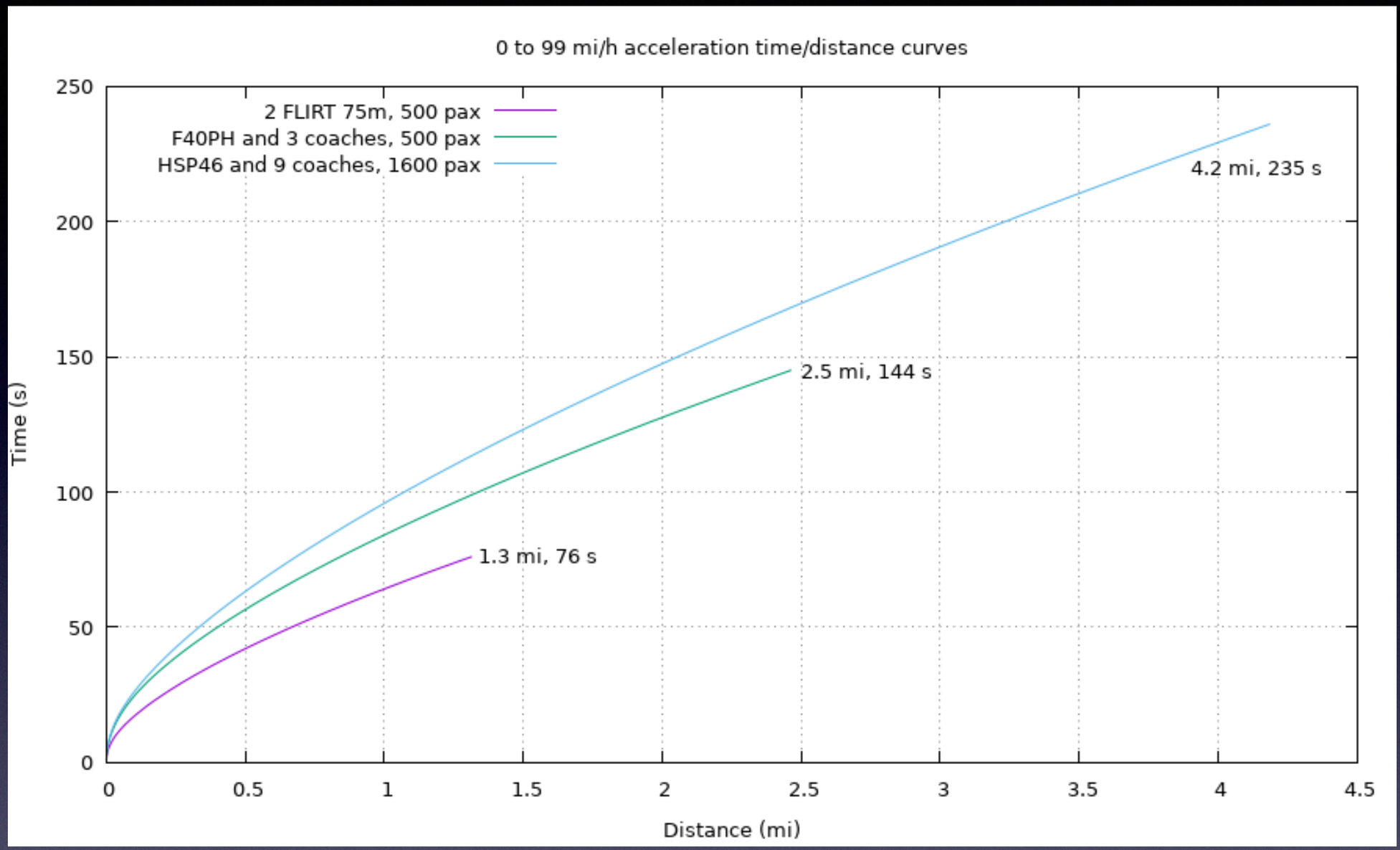
- Level boarding significantly speeds boarding and alighting
  - 15 to 30 seconds *at every stop*
- Door traps in passenger coaches are a mechanical component requiring frequent maintenance
- If all lines have level boarding at all stations, the T can buy equipment that only supports one platform height, reducing cost and fleet complexity
  - Bad example: CalTrain and CalHSR can’t get their act together, so CalTrain has to buy trains with boarding doors at two different levels!

Commuter Rail Equipment

- Current commuter rail service uses 17 types of equipment:
  - Diesel locomotives (4 models, 101 units built 1975–2014)
  - Single-level passenger coaches (4 models, 179 units built 1979–1990)
  - Bi-level passenger coaches (5 models, 170 units built 1991–2014)
  - Control coaches (may be single-level or bi-level, 4 models, 106 units built 1990–2014) allow operation of inbound trains with loco at rear
- Every train must have at least one accessible coach and one control coach (these can be the same)

Equipment for Regional Rail

- The greatest opportunity to improve trip times comes from reducing the “stop penalty”
  - Faster trips are a baseline requirement to support more frequent service!
- Two sources of “stop penalty” to address:
  - *Dwell time*: Reduce time spent at station through all-door level boarding, wider doors, optimizing door placement
  - *Acceleration time*: Reduce time spent stopping and starting through use of lightweight, fast-accelerating electric trains



Acceleration to 99 mi/h

Purple and green lines show the same passenger capacity with different equipment. Blue line shows the heaviest current MBTA commuter train. (99 mi/h is the top speed likely to be operated on the Providence Line.)

Why Not Expresses?

- Local trains must “clear the track” ahead of expresses, severely limiting schedules
  - This could be fixed where there is enough room to add passing tracks
- Express trains primarily benefit commuters from the farthest reaches of the lines (Worcester, Providence, Haverhill, Newburyport)
  - Express trains hurt everyone else by reducing service at all the stations where they don’t stop (given track time and terminal station platform constraints)
- There *is* a place for express trains in Regional Rail
  - Expresses can manage crowding by distributing passengers among more frequent trains, reducing consist length and capital investment required

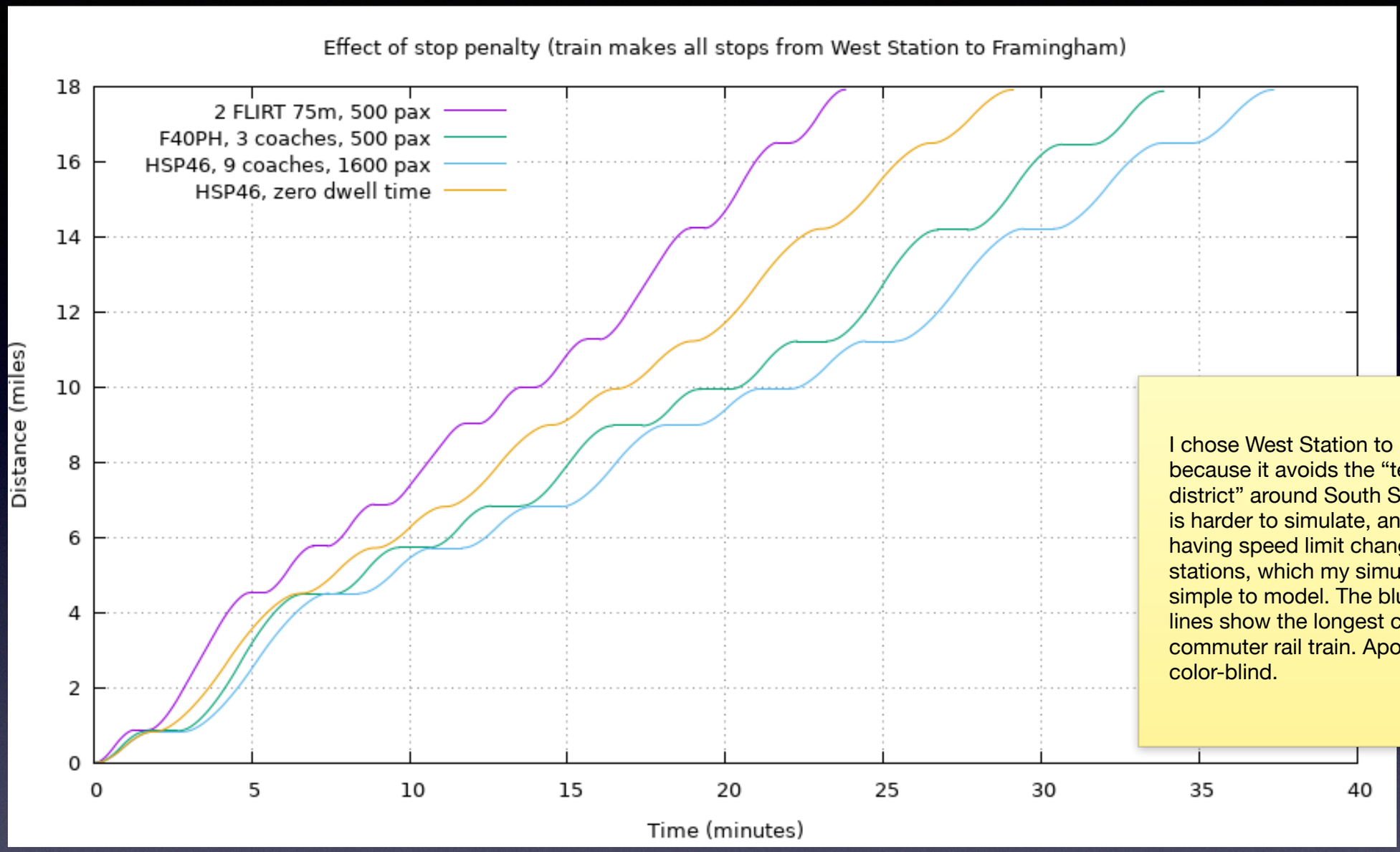
Better Service without Expresses

- Making these service improvements gives outlying commuters a local service that's actually ***better*** than the express service they have now
  - Trip times are faster
  - More stations are served, providing convenient access to non-downtown-Boston destinations
  - Service frequency increases dramatically, providing more flexibility and allowing early/late trips home for school/ daycare pickup and drop-off

Worked Example: Framingham/Worcester Line

Trip	Current local	Current express	“Heart to Hub”	RR local	RR express
Worcester to South Sta.	94 min	80 min	66 min	58 min	50 min
Framingham to South Sta.	53 min	34 min	no stop	33 min	25 min
Boston Landing to South Sta.	15 min	no stop	no stop	9 min	9 min

Based on schedule modeling by Alon Levy



I chose West Station to Framingham because it avoids the “terminal district” around South Station, which is harder to simulate, and also avoids having speed limit changes between stations, which my simulator is too simple to model. The blue and yellow lines show the longest current commuter rail train. Apologies to the color-blind.

Simulating the “stop penalty”

Chart compares three train configurations on the F/W line between (future) West Station and Framingham; the yellow line shows the effect of dwell time (same as blue line, makes each stop but does not open doors)

Capital Requirements

To achieve this schedule requires a significant capital investment

- Rolling stock: replace obsolete locomotives & coaches with Electric Multiple Units
- Track and signal improvements (including superelevation to increase curve speeds)
- High-level platforms on both tracks at all stations
- Overhead electrification

Electric Multiple Units?

- In railroad jargon, “multiple units” means multiple sources of motive power operating under control of a single operator
- This is how all our subway trains operate
- Given access to “unlimited” power, acceleration limited only by the weight of the train
- Diesel trains carry their (heavy) power source with them, hence limited power and slow acceleration
  - All trains, even diesel trains, use electric motors to drive the wheels

Electric Multiple Units

- EMU trains can be constructed two different ways:
  - Traditional coupled passenger coaches with controls and motors in each one (example: LIRR, Metro-North)
  - Long, articulated “trainsets” with multiple car-bodies permanently coupled together (visually similar to Acela, but Acela doesn’t have multiple-unit operation)
- Some US-based advocates don’t have an *a priori* preference between traditional (LIRR-style) and articulated EMUs

Which Electric Multiple Units?

- In my view, articulated EMUs are clearly better:
  - Less duplication of control, safety, and passenger comfort equipment leads to lighter weight, lower costs, less energy use
  - Doors need not be placed at the end of a “car”, allowing wider doors better spaced through the seating area thus faster boarding
  - No need for gangways or vestibules (where seating is forbidden), allowing more seats per unit length (or weight)
- Rest-of-world best practice is also for longer articulated EMUs, to amortize fixed per-train equipment costs and weight over more seats

Single or Bi-Level?

- There are bi-level EMUs available on the global market
- Bi-levels slow boarding and alighting without adding much capacity, while complicating accessibility
  - In part because our high platforms are so high—would be less of a problem with 600mm platforms
- Bi-levels a reasonable option if already running maximum feasible frequency (e.g., 15 trains per hour) and still have overcrowding on a line or branch
- Bi-levels are OK if at least half of the riders are heading to a terminal station

These Electric Multiple Units

Shown here: parts of two coupled 75-meter (250-foot)
Stadler FLIRTs passing Hartwall Arena in Helsinki

The Stadler FLIRT

- Available in a variety of lengths, power ratings, and gauges
- Not currently made with 48” platform height but feasible (UK platforms are not *much* lower)
- Finnish version has two 1300 kW motors for a total power of 2600 kW (2000 kW sustained); a three-motor version is available for longer trainsets
- Can operate in two- or three-trainset consists (Helsinki uses only two)
- This version holds 250 seated and 340 standees (when 34 folding single-passenger seats are raised; total 556)

Only 250 seats?!

- The busiest current train on the MBTA commuter rail regularly carries 1,600 passengers at crush load
- However, that service (Worcester express) operates at 40 minute headways
  - Impractical to increase train length — need higher frequency anyway!
- At 15-minute headways, 1,600 passengers could be distributed across three trains instead of just one (six trains for those heading to express-and-local stops, and they'd still get home faster)
  - At 540 passengers per train, nearly everyone gets a seat with only two-trainset consists of 250-seat FLIRTs (of course, the improved service will attract more passengers, although this is limited in the short-term by parking availability at suburban lots)
  - Based on my simulations, 300 units would be more than sufficient for all lines, and represents ≈20% increase in seating capacity

Why not longer?

- Articulated EMUs are by definition longer than traditional coaches (200–300 feet vs. 90 feet)
- All trainsets in a train need to be able to stop and open doors at the platform
  - Some existing MBTA high platforms are as short as 600 feet
  - Need some “slop” to allow for inconsistent stopping distance due to weather, track conditions

Why not longer?

- All things being equal, more frequent service provides greater public benefit than running more seats on the same schedule
  - Some outstanding questions about passenger needs to either arrive or depart at specific times due to business opening hours, school/childcare closing time, and how this affects capacity
- EMUs between 250 and 267 feet long are optimal for MBTA platform lengths
  - Allows two-trainset consists on most lines, triples on lines with all standard 800-foot platforms

Challenges for Boston

- ~~Lightweight EMUs like these will require a waiver of FRA rules that require trains to be ridiculously heavy — this should be easier in 2021 after Positive Train Control is fully deployed~~ (FRA just proposed a rule reform)

- Our maintenance facilities are old and not built to handle electric or articulated trains (but need upgrading anyway)

- There are old stations on every line (except Old Colony) without high platforms: a systemwide upgrade program is needed (but accessibility demands this anyway)

Opportunities for Boston

- With the exception of the 2014 locomotives and coaches, nearly all of our commuter rail equipment is not only functionally obsolete but in need of replacement or heavy overhaul just to maintain the current poor level of service

- If we can quickly commit to Regional Rail and start building high platforms, it should be possible to get a “pilot” EMU order delivered in CY2021 and start regular deliveries in 2023, while building platforms and electrification in parallel

- This would allow us to retire, rather than replace, outdated diesel locomotives and passenger coaches, as lines are converted

More Opportunities

- We have the potential to buy into a system of rolling stock that includes diesel and battery power options
- Didn’t I just say those were sub-optimal? Yes!
- But some parts of the rail network won’t be electrified for a while, if ever
- If we have a system with common parts and maintenance practices, rather than seventeen different equipment types, rail operations are greatly simplified
- Potential for expansion outside the MBTA system: Springfield, Manchester, Cape Cod services would all require alternative power

Diesel Multiple Units?

- Fort Worth's transit system is buying a diesel-powered version of the exact same FLIRT as shown in a previous slide
  - Has a Tier-4 diesel generator section inserted in the middle
  - Longer (about 267 feet, as it happens) to maintain the same seating capacity; also quite a bit heavier
  - Less than half the power (1040 kW) as the regular electric FLIRT, and quite a bit more expensive per-unit, so a good deal slower
  - Final assembly by Stadler in USA for "Buy America" compliance
  - If we can drive down cost/time for electrification, better to do that

Dual-Mode Battery-Electric

- To maintain attractive schedules, trains need 10–12 kW of power per metric ton of weight ($a_{max} \approx 1$ m/s$^2 \approx 0.1g$)
- Battery trains are unlikely to deliver this any time soon (at least continuously over long distances)
- But a train with a smaller battery pack that normally gets its power from overhead wire has significant advantages:
  - Can operate in yards and on station sidings where catenary has not (yet) been installed
  - Can operate through work zones where overhead power must be turned off or removed

MBTA Fare Integration

- Many areas in the inner core are served by commuter rail, rapid transit, *and* bus services
- Commuter rail is priced at a significant premium to rapid transit
  - **Sustains racial and economic segregation of public transportation**
- Heavy rail is the most efficient way to move hundreds of people at a time
  - One 250-passenger train ≈ four 60-foot buses (but with only one operator salary)
- Rail fares should be no higher than parallel bus, subway, or LRT

MBTA Fare Integration

MBTA should encourage, rather than discourage, passengers to use surface rail rather than overcrowded subways, especially for trips that require changing subway lines downtown

- e.g., Forest Hills to Broadway
- Red Line connections at South Station, Green/Orange Line connections at North Station reduce congestion at Park St. and Downtown Crossing
- SL1/SL3 connections at South Station reduce congestion at Government Center and State
- North-South Rail Link, if implemented, makes this even better

RTA Integration

- At the outer ends and many intermediate stops of MBTA rail lines, local transit service is provided by a Regional Transit Authority
  - Some RTAs provide real service, others are social-service “last resort” systems with poor service used only by captive audiences
- The Commonwealth should encourage last-mile transit to outlying rail stations
  - Will require capital investments and increased operating subsidies until non-captive passengers are confident in quality and reliability of RTA service
  - RTAs should be expected to coordinate with train schedules as a condition of state subsidy
  - Fare integration is highly desirable, but note that MBTA’s economic incentive is to fill park-and-ride lots, not subsidize last-mile access in Lowell, Worcester, Brockton

Frequency = Mobility

- Transit users should be able to “show up and go” — just like auto owners
- Current service patterns have long headways and even longer, irregular, gaps in service
  - Riders must plan their whole day around train schedules…
  - …or just drive — if they are able
- Frequent service (every 15 minutes or better) enables more trips to be taken by transit, reduces penalty/stress of missing a train
- Increased operator staffing costs partially offset by savings elsewhere (fewer split shifts, elimination of conductors) and new fare revenue (from trips that were not previously practical)

All-Day Service

- Current service has very long gaps in service at midday and on weekends
  - Also fails to support restaurant, hospitality, and travel industry workers who start early or leave late
  - Doesn't even support *patrons* of early-morning and late-night flights, never mind late-closing bars, clubs, music venues, and restaurants
- All-day, every-day service reduces stress and costs of uncertainty for workers, enables shift from car to transit:
  - For parents who might need to take a sick child home from school
  - For health and retail workers whose shifts run early or late based on demand
  - For people who occasionally work weekends or who mainly work from home

Infill Stations

- Many current rail lines pass through desirable stop locations (dense residential or office neighborhoods, recreational resources)

- Because of the “stop penalty” it’s not practical to add full-time stops in these locations today

- With reduced stop penalty, new stations can be added, and reduced-service stations can receive full-time service

Infill Stations

Some places where an infill station might be desirable

- Providence Line: Pawtucket (being built!), Cummins Highway, Forest Hills (exists but trains don’t stop)
- Worcester Line: New WooSox ballpark, Worcester Biotech Park, Newton Corner
  - Note that the newly built Boston Landing station has been extremely popular, despite limited service
- Fitchburg Line: Walden Pond, Alewife, Union Square
- Eastern Route: Sullivan Square

New Lines and Branches

- I have been supporting a service to Marlborough, Northborough, and Clinton via the Agricultural Branch Railroad
  - Also serves Bose, Sanofi, Staples, and Framingham State University, all within the City of Framingham
- South Coast Rail phase 2 as currently planned requires electrification for environmental reasons, but service would be infrequent
- Other new lines? Full-time service to the Cape? New Hampshire? West of Worcester?

Service Simplification

- Current schedules require advance planning for most trips
- Regional Rail service at the outer ends of the network would still require planning
  - One, two, or three trains per hour
  - Making these trains run on a consistent hourly schedule (“clockface headways”) would improve access to the service (easier to remember the schedule) and make it easier for RTAs to schedule connecting bus service (most use a “pulse” system)

Service Simplification

- Running a single equipment type (or at most two, closely related, equipment types):
  - Provides a better, more consistent customer experience
  - Improves vehicle availability
  - Reduces training costs for operators and maintenance workers
  - Reduces time spent qualifying new equipment across all lines
  - Reduces parts inventory at maintenance facilities
  - Allows better economies of scale on rolling stock purchases

Implementation Considerations: Order of Lines

1. Providence
2. Fairmount
3. Framingham/Worcester
4. Eastern Route (Newburyport/Rockport)
5. Lowell
6. Western Route (Haverhill)
7. Fitchburg
8. Franklin

Missing Lines: Old Colony

- Old Colony trunk line is single-tracked through Dorchester and Quincy (where it parallels the Red Line), limiting capacity
- Cannot substantially increase frequencies without double-tracking
  - Possible conversion to diesel multiple units as an interim measure for fleet rationalization and state-of-good-repair
  - But at least all the platforms are already the right height!
- Frequent service as far as Brockton on the Middleboro branch would be valuable if capacity issue addressed

Missing Lines: Needham

- Needham Line is entirely single-track and has a flat junction with the Providence Line, limiting capacity
- Needham Line should be converted entirely to rapid transit (extending the Orange Line from Forest Hills and branching the Green Line from Newton Highlands)
  - Needham Line upgrades are very similar in scope, but different in technology, whether Regional Rail or Orange Line
  - Green Line “D-prime” branch would serve significant fast-growing corridor with TOD potential, but requires reversing a rail-trail conversion, type 10s
  - Enables new travel patterns in and between Newton, Needham, and West Roxbury

Missing Lines: Stoughton

- Stoughton Line is planned for South Coast Rail phase 2, so where it fits in the schedule is uncertain given SCR's lack of fiscal plan
- Stoughton Line needs double-tracking and new station locations if SCR phase 2 is canceled or rerouted; existing Stoughton station cannot support high platforms due to grade-crossing location
  - Were it not for these issues, Stoughton ought to be done at the same time as Providence, because slow diesels and fast EMUs serving the same stations further complicates scheduling
  - Can't do DMUs here because of the platform issue
  - Run Stoughton trains express north of Canton Junction until converted

Implementation Considerations: Providence Line

- Thanks to Amtrak's Northeast Corridor electrification, nearly all the required overhead catenary already exists, and operates at global standard voltage (25 kV)
- Amtrak substation in Sharon was built with room for expansion in anticipation of electric commuter trains on Providence Line
- Yard and maintenance facility upgrades needed at Pawtucket, Readville, Southampton; also additional catenary at stations
- Must build passing track at Mansfield for wide freight loads that cannot clear high platforms ($10–15m with platforms, elevators)
- Most stations from Attleboro to Hyde Park need high platforms

Implementation Considerations: Fairmount Line

- Most stations on Fairmount Line are new and have high platforms; two exceptions: Fairmount itself and Readville
- Can draw electrical power from Sharon substation
- Resiliency benefits for Providence Line and Amtrak: offers alternate route to South Station
- Line is short and could easily support 4–6 trains per hour with a fairly small equipment roster (round trip ≈1hr including recovery and turnaround) and a captive platform
- Line would be useful for early acceptance testing of EMUs

Implementation Considerations: Framingham/Worcester Line

- Low overpass at Beacon St. (Boston) needs to be addressed (possible interim application of dual-mode battery EMUs? would also allow service to operate during Allston I-90 construction)

- Needs new electrical substation in MetroWest area (ideally adjacent to existing N–S high-voltage transmission paths)

- Needs new layover facility in Framingham (at Tech Park on the Ag Branch if built, otherwise Nevins Yard on the Main Line at Fountain St.)

- May require freight passing tracks at stations west of Framingham; third track east of Framingham would improve operational flexibility

Implementation Considerations: Framingham/Worcester Line

- Requires second platforms and vertical circulation at Worcester (design contract signed in 2018), Auburndale, West Newton, and Newtonville
  - Infill station at Newton Corner should be built at the same time
    - Frequent service lessens need for backup elevators at Newton stations
- Requires high platform construction at all stations west of Boston Landing (Natick Center is in design)
- Local service terminating at Riverside (Green Line) station would require new flying junction at Riverside Jct.
  - Much better to run high-frequency service all the way to Framingham anyway

Implementation Considerations: North Side Lines

- Significant choices to be made regarding branch routing
  - Make Reading a full-time terminal, reroute all Haverhill service via Lowell Line and Wildcat? Extend Orange Line to Reading?
  - Infill stop at Sullivan (on Eastern Route) for Orange Line access?
  - Infill stops in Somerville (on Lowell and Fitchburg Lines) to connect with GLX?
  - Need to build at least one substation for each line; optimize locations (separate terminal district substation?)

Implementation Considerations: Grand Junction Branch

- Huge demand for transit access to Kendall Sq. area, immediately adjacent to Grand Junction, which would be well served by EMUs
- GJ is the only connection between North Side and South Side networks east of Worcester; South Side requires GJ to access Commuter Rail Maintenance Facility in Somerville
- Full electrification is incompatible with existing bi-level coaches because of limited clearances: must wait until bi-levels are all gone from South Side — possible interim application of battery option?
- Service could replace Kendall area shuttles given double tracking; higher frequency requires grade-crossing elimination
- North-South Rail Link would remove bottleneck, allow conversion of GJ to rapid transit

Cost of Implementation

- Already programmed expenditures on new locomotives and coaches would pay for Providence Line conversion, including platforms and rolling stock

- Fairmount Line is a relatively inexpensive add-on because it is short and Readville needs to be upgraded for Providence Line layover and maintenance anyway

- Substantial expenditures start with Worcester Line

- Total cost around $5–7bn, offset by canceling $3–5bn of state-of-good-repair spending (anticipated over 10yr)

Capital Costs

- Helsinki paid €7m each for FLIRTs shown earlier, in 2015; US version with a similar level of customization should cost around $8–10m in 2018 dollars
  - Fort Worth is paying $14m for their diesel FLIRTs, but it's a small order for a (so far) unusual configuration
- Platform upgrades may cost $2–3m per station where elevators are not required, $10m+ otherwise
  - Ramps to sidewalk level are sufficient vertical circulation at many stations
- Electrification *should* be under $2m per mile, but will likely cost closer to $4–5m (based on Amtrak's cost for New Haven-to-Boston 20 years ago)

Capital Cost Containment

- Capital costs could easily get out of control given the history of heavy civil construction in the northeast
- By committing to the full program, the MBTA can limit design and project management costs by packaging multiple design and construction elements
  - Design-build for early action items (Providence Line stations)
  - Systemwide design and PM contracts for longer schedule items
  - Common design and permitting for all station upgrades
  - Single project manager for EMU procurement, PTC integration, testing
  - Single construction contract and oversight team for each line conversion

Operating Costs

- Moving to a more “rapid transit” style of operation means single-person train operation, elimination of conductors
  - Some will naturally attrit, others become fare inspectors or CSRs
  - MBTA should encourage qualified conductors to enter operator training
- Increased costs of electricity, outside plant maintenance, operator salaries partially offset by reduced costs of diesel, lower maintenance costs, and fare revenue from new users
  - Social benefits of reduced auto traffic more than justify increased opex

Operating Costs

- Longer term, moving some passengers from bus or subway to Regional Rail will reduce operating costs of those services
  - E.g., some suburban bus services could be eliminated or cut back to shorter, more efficient routes serving rail stations with a free transfer
- Essential that the state have a long-term commitment to high service levels in order to drive housing and commercial development decisions
  - Explore value capture and statewide by-right zoning for car-restricted TOD at stations to lock in land-use benefits

North-South Rail Link

- NSRL is a proposed rail tunnel under the O'Neill Tunnel that would bypass existing North and South Stations (but connect with all subway lines)
  - Intercity trains (Acela Express, Northeast Regional, Lake Shore Limited, Downeaster) and any remaining diesels continue to serve existing surface stations
- NSRL would eliminate frequency constraints caused by stub-end operations at current downtown terminals
  - Also eliminates need for $1bn South Station Expansion
- NSRL requires electrification but is independent of Regional Rail
  - Hybrid battery-diesel locomotives would work with NSRL but not Regional Rail

North-South Rail Link

- Regional Rail would benefit greatly from NSRL but does not require it for successful implementation
- NSRL provides a maximum one-transfer ride to all destinations on the rail or subway network
  - Major benefit to riders is in easier access from North Side communities to major job centers which are mainly on the South Side (Seaport, Logan, Longwood, East Cambridge)
  - NSRL would also support expansion of employment in North Side communities like Chelsea, Lynn, Salem, Lawrence, Lowell

Summing Up

- Regional Rail would improve service for existing Boston commuters
- Regional Rail would provide new and better service options for non-traditional commuters
- Regional Rail would serve more people more cost-effectively than maintaining the existing commuter rail service
- Early action on Regional Rail can be paid for using capital spending already programmed for commuter rail state of good repair, which would become unnecessary

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Latest version of this presentation is available at:
https://bimajority.org/~wollman/Regional%20Rail.pdf

More information and analysis at:
https://blog.bimajority.org/

Last updated: 2018-10-26

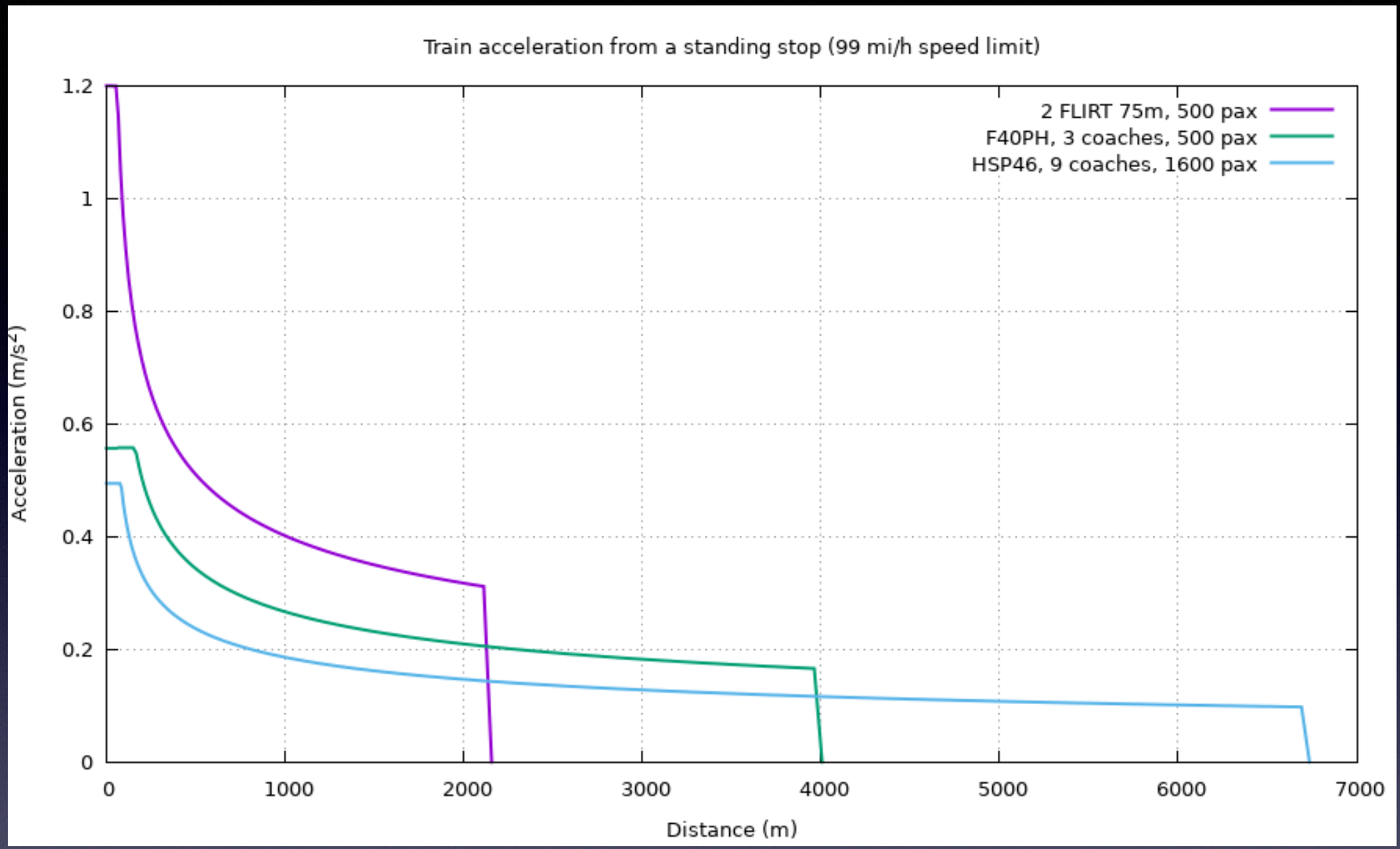
Links to specific blog posts

- Interlude: Physics of train acceleration (includes older versions of graphs presented here)
- Restoring passenger service to the Agricultural Branch
- Next steps for Regional Rail
- Service delivery standards for Regional Rail
- Rolling stock for Regional Rail: What and how to buy
- The cost of implementing Regional Rail
- Every American transportation planner should spend a week in Helsinki (part 2 of 3)

Reusing this presentation

Aside: Acceleration Limits

- The force ("tractive effort") exerted by a motor cannot be greater than the input power, times the time taken to travel, divided by the distance traveled (by conservation of energy)
  - assuming straight-line travel; in symbols, $F \leq P/v$ where v is the scalar velocity
- Newton's Second Law says $a=F/m$: acceleration equals force applied divided by mass
- Therefore, $a \leq P/mv$
  - To improve acceleration, must increase power or reduce mass!
  - Battery-only operation is impractical for reasonable service profiles: over the full length of a trip, it would require far too much battery weight and charging time



Effect of *P*/*m* on acceleration

2 coupled 75m FLIRTs: 377.5 t, 5200 kW; *P*/*m* = 13.8 W/kg
F40PH, 3 coaches: 305.4 t, 2237 kW; *P*/*m* = 7.3 W/kg
HSP46, 9 coaches: 701.5 t, 3035 kW; *P*/*m* = 4.33 W/kg