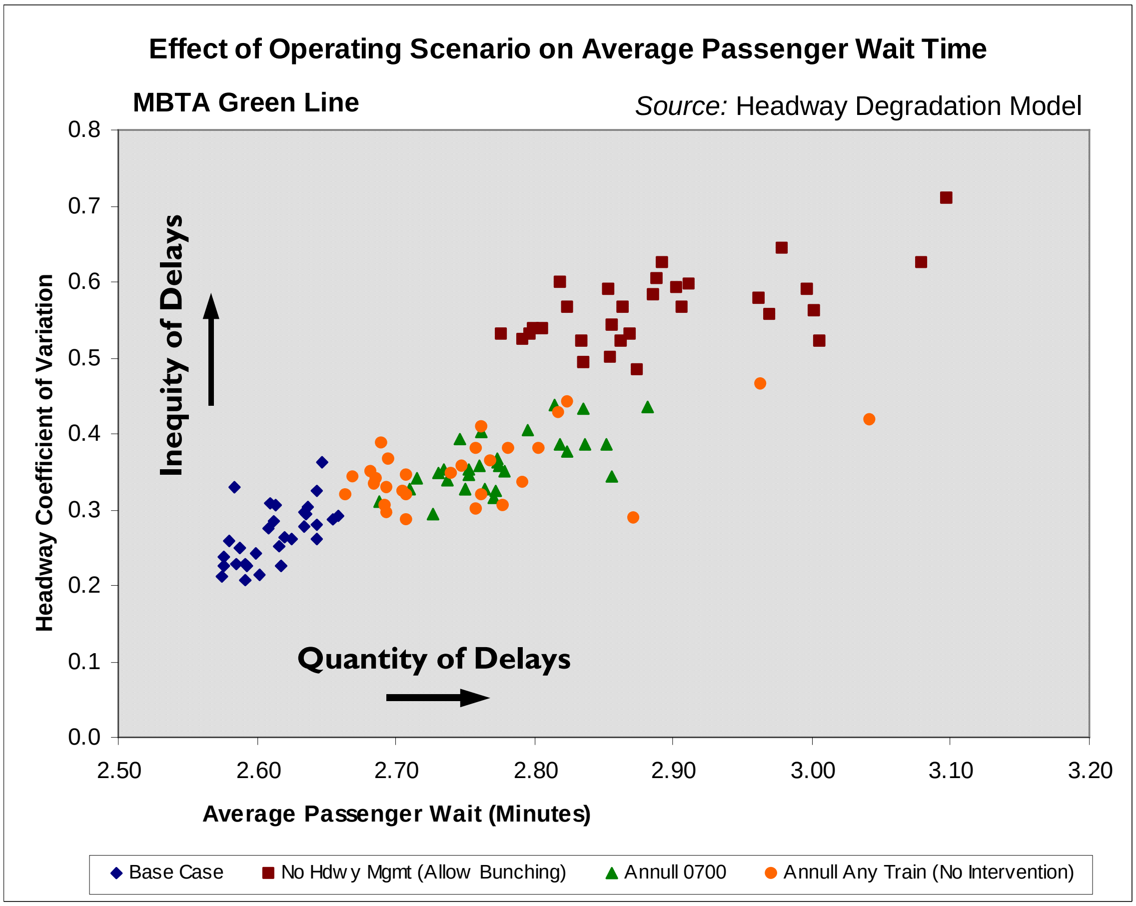
Effect of Operations Intervention on Average Passenger Wait Time

Real-time operations intervention is achieved in one of two ways:

- On rail based transit system, a hold-circuit is used: station departure signal will not clear until the previous train is a number of blocks ahead unless overridden by supervisor.
- On bus based systems, an official is posted at critical locations to ensure that buses are sufficiently temporally separated to proactively prevent bunches from forming.

The following chart shows simulation results based on the MBTA Green Line, B-branch ridership and operating patterns:



Each point on the graph represents the simulated operating results in terms of the average waiting time experienced by passengers from one AM rush hour period. The model used simulated headways (resulting from a particular operating policy) at 9 stops[1] and the 1993 passenger loading data to determine the delay experienced given simulated headways.

- **The red square** illustrates how Green Line was generally operated during July 2003 – trains are allowed to get as close to each other as they physically can (an effective minimum headway of 30 seconds).

[1] Lake St., Chestnut Hill, Washington, Harvard Ave, Blandford, Kenmore, Copley, Park, Scollay Sq.

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- **The blue diamonds** illustrates what would happen if supervisors were positioned at three stops[2] along the route and trains were held if the headway has degraded below 3 minutes (i.e. if the previous train departed less than 3 mins ago, the train isn't allowed to leave until at least 3 mins later than the previous train). In this simple operating policy, gaps larger than 3 mins are simply ignored.
- **The green triangle** illustrates the impact of dropping the 0700 departure from Lake St. Clearly, dropping a trip increases the average delay, but it does not increase the delays by nearly as much as allowing bunched trains to get within 30 seconds of one another. In this case, no attempt was made to adjust the headways for the dropped trip (i.e. departure times were 06.50, 06.55, 07.05, 07.10 plus or minus 90 seconds[3], etc.)
- **The orange circle** illustrates the impact of dropping a random trip from Lake St. Clearly, if the trip dropped was a very busy one (e.g. 08.00 from Lake St.), the average delay increases dramatically. If it isn't a busy one (e.g. 06.15), then it is basically not noticed. In reality, terminal supervisors will try to drop the less busy trips.

The Coefficient of Variation

The coefficient of variation is a measure of how different one headway is to the next. If the headways were 5,5,5,5 minutes then the coefficient of variation would be zero (it does not vary). If the headways were 9,1,9,1 minutes then the coefficient of variation would be large. Larger coefficient of variation generates more complaints and incur larger delays for a number of reasons:

1. With 9,1,9,l headways (compared to say, 6,4,6,4), most passenger have to try to board crowded trains (because the loads on trains and the number of pax waiting for trains will be much larger on leaders of the pack that arrives after a 9-min gap, versus followers that arrives after a 1-min gap), generating overcrowding complaints.
2. With 9,1,9,1 headways the average passenger has to wait 4.1 minutes for the train to arrive (90% of passengers wait an average of 4.5 mins, while 10% of passengers wait an average of 0.5 mins), whereas with 5,5,5,5 headways the average passenger has to wait 2.5 minutes for the train to arrive.

In simple terms, the coefficient of variation is a measure of the inequity of delays. With 9,1,9,1 headways most of the delays is absorbed by people who arrived just after two trains left the station within 1 min of each other (max wait = 9 mins). With 5,5,5,5 headways the wait is absorbed by the larger fraction of people who arrive just after one train has left (max wait = 5 mins).

The simulations demonstrate that an operating policy that leads to high headway variability also leads to large delay inequities, whereas a far more uniform headway leads to a more even distribution of delays, **even when** one random trip is dropped during the AM rush.

See Appendix for more details on how the extent of headway degradation are predicted using the model.

[2] Washington, Brighton Ave, Blandford St.

[3] It was assumed that the terminal do not always depart trains on time, but they would depart trains within 90 seconds of the scheduled time – so that a 06.00 departure left sometime between 05:58:30 and 06:01:30.

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Why is this Important?

1. On high frequency transit lines (more than about one train every 10 minutes), headway is the driving factor behind **customer perception** of service reliability. If the headway is 5 minutes and every train is 5 minutes late, the customer couldn't care less and wouldn't know the difference.
2. On high frequency transit lines, the carhouse can easily drop a trip and very few people would notice provided that the other trips are spaced out such that the headway changes are barely noticeable. The difference between actual departure times of 07.00, 07.05, 07.10, 07.15 and 07.20 are imperceptibly different from departure times of 07.01, 07.07, 07.13, and 07.19.
3. In high frequency, high-loading, high congestion bus service (Nos. 1, 28/31, 33, 39, 57, 66, 749, 77, and on the Washington St. Corridor), none of the regular riders look at the schedules. They only care about headway. These lines need to be managed differently, with emphasis on maintain headway rather than keeping to schedule or worrying about vehicle availability. VA is what it is; headway can be actively managed by the Transportation Dept.
4. In low frequency, lower-loading services (Nos. 62, 76, 68, etc.), these should be managed the traditional way with strict adherence to schedules and minimization of dropped trips.

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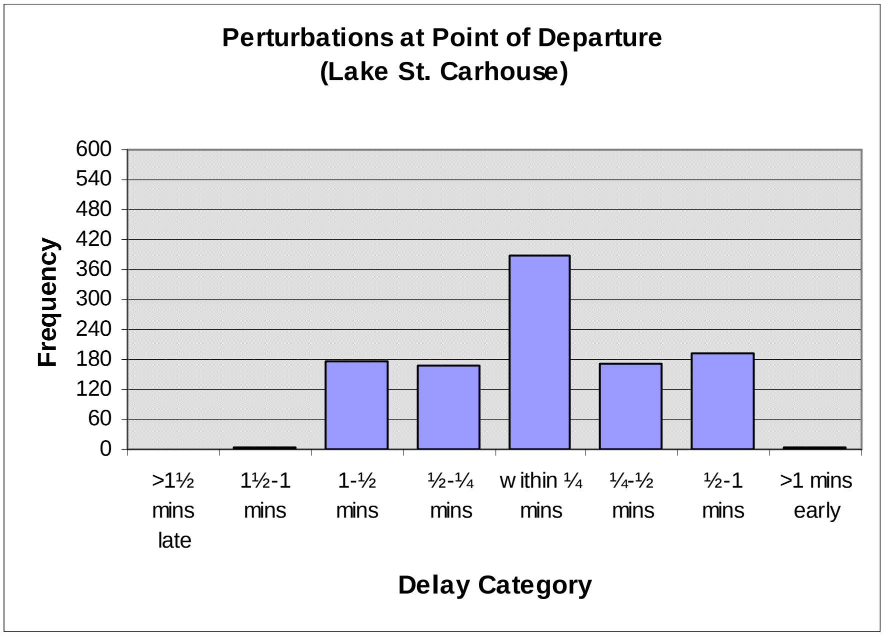
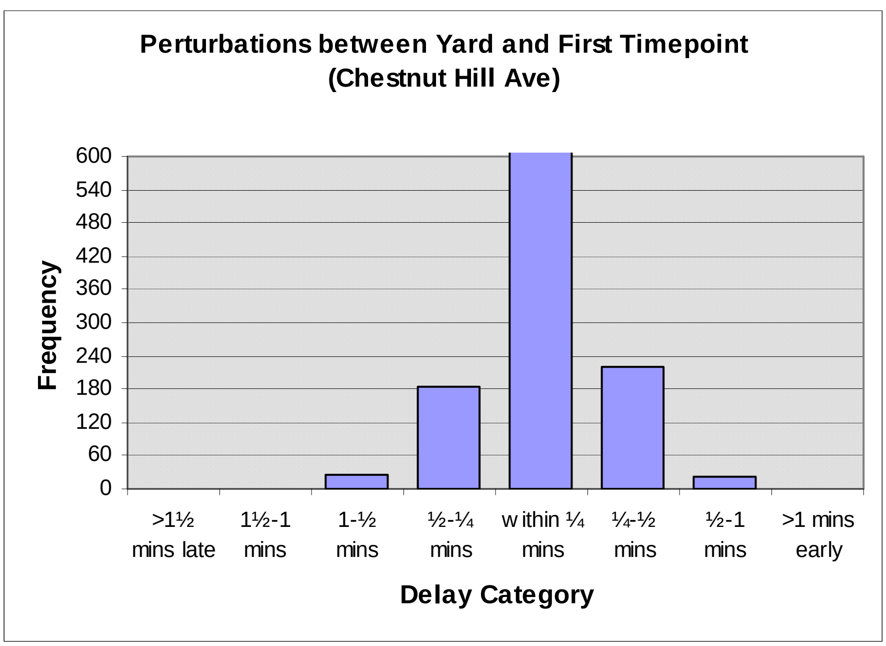
Appendix: How Headways are Predicted

A random number generator generates a "delay" (could be positive or negative) based on a distribution. The results for one particular rush hour shows that many trains depart within 0.5 minutes of the intended departure time, but because things happen at the terminal, some leave early and some leave late. See the figure below:



This delay is then propagated through the system, with later trains tending to get later and earlier trains tending to get earlier. "How much earlier" or "how much later" a train gets along the route absent any supervisor intervention was based on empirical data collected in 2003. Even without intervention, the perturbations at the first timepoint (Chestnut Hill Ave) isn't so bad, and might even be better than the situation at the carhouse:



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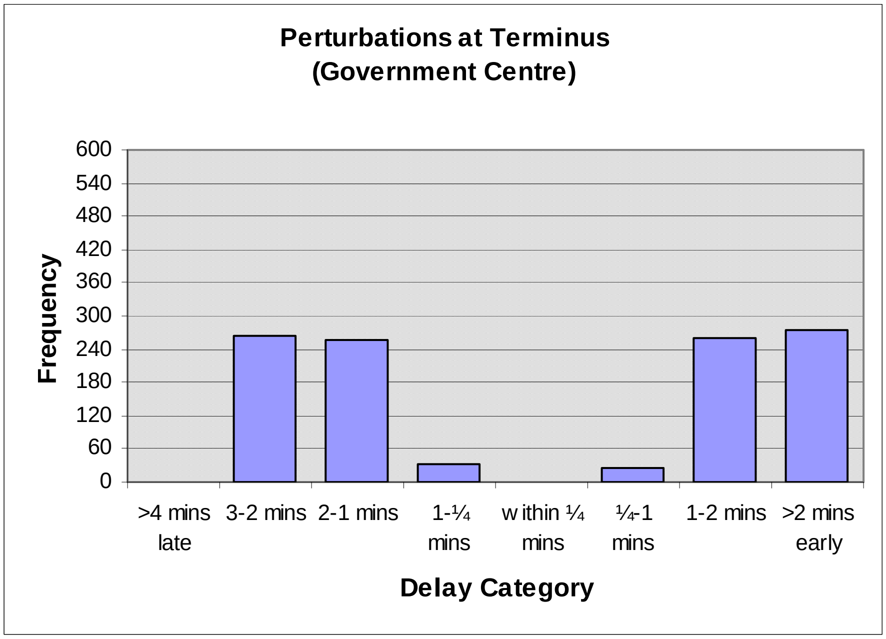
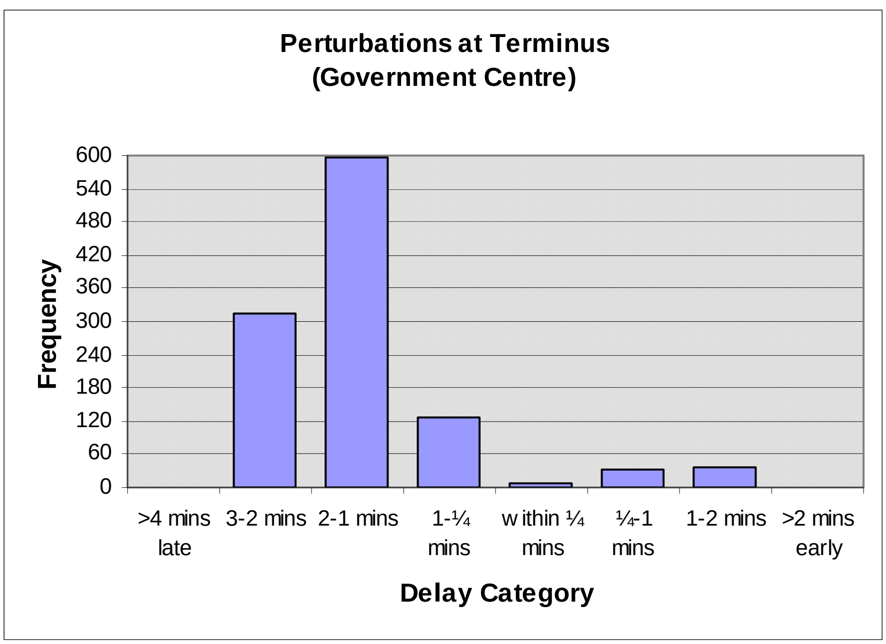
However, by the time the train reaches the last stop (Scollay Sq.), the early trains are really early and the late trains are really late. In bus, this would be even worse, because vehicles can actually pass each other and is not constrained by the lack of passing track. See graph below for rail:



On the other hand, with operating intervention, a completely different picture is seen. Most trains arrive later, because the trains that depart on time are held back if its predecessor departed late (so that there would be a >3 minute gap between the trains). However, with not many trains arriving early and the same number of trains being 2-3 mins late, the *overall relative effect* is that headways are much more *uniform*, resulting in lower total passenger delay.



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