

# Performance Measurements on Mass Transit – New York City Transit Case Study

*Alla Reddy*

*Anthony Cramer, John Cucarese*

*Minh Tran, Alex Lu*

**System Data & Research  
Operations Planning  
New York City Transit**

Presented at the 88<sup>th</sup> Annual Meeting of the  
Transportation Research Board  
Washington D.C. (2009)



IRT Broadway-Seventh Avenue Line, 96 St. Station

Photo: David J Greenberger



New York City Transit

# Program Design

- **Automated system generates 95 ± 5% statistical sample**
- **Subway Route Selection**
  - 23 major subway routes carry > 5 million weekday riders
  - Every subway route carried > 80,000 daily riders in 2006
  - 6 line is busiest (700,000 daily riders)
- **Bus Route Selection**
  - Selected 42 of the 193-route NYCT bus system
  - Representing all Boroughs
  - Top 45 routes in the bus system carry between 60,000 and 16,000 passengers a day

Line	Description	Ridership
6 6	City Hall/Pelham Bay Park	700,000
1	South Ferry/Van Cortlandt Park 242 St	600,000
F	Coney Island/Jamaica 179 St	575,000
4	Utica Av Crown Heights/Woodlawn	550,000
A	Far Rockaway/Inwood 207 St	525,000
E	World Trade Center/Jamaica 179 St	475,000
7 7	Times Square 42 St/Flushing Main St	450,000
2	Flatbush Av/Wakefield 241 St	375,000
5	New Lots Av/Nereid Av	375,000
R	Bay Ridge 95 St/Forest Hills 71 Av	350,000
B	Brighton Beach/Bedford Park Blvd	300,000
D	Coney Island/Norwood 205 St	300,000
N	Coney Island/Astoria Ditmars Blvd	275,000
3	New Lots Av/Harlem 148 St	250,000
L	Canarsie Rockaway Pkwy/8 Av-14 St	250,000
Q	Coney Island/7 Av-57 St	225,000
J Z	Broad St/Jamaica Parsons-Archer	175,000
C	Euclid Av/Washington Heights 168 St	125,000
V	2 Av-Houston St/Forest Hills 71 Av	125,000
G	Smith-9 Sts/Forest Hills 71 Av	100,000
S	Times Square 42 St/Grand Central	90,000
W	Whitehall St/Astoria Ditmars Blvd	90,000
M	Bay Pkwy/Middle Village Metropolitan Av	80,000
S	Prospect Park/Franklin Av	18,000
S	Rockaway Park/Broad Channel	5,000

# Measurement Standards

- **Headway Regularity**

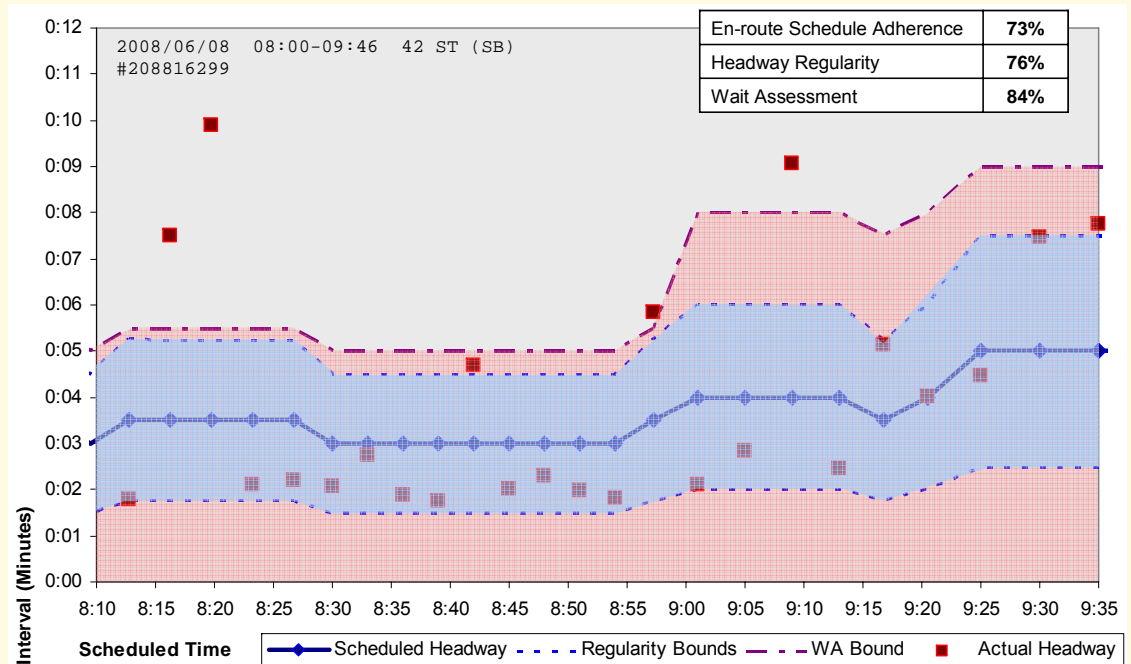
- How evenly distributed actual bus or subway service is in relation to scheduled service

- **En-route Schedule Adherence (ESA)**

- Assesses timekeeping and schedule accuracy along en-route timepoints

- **Wait Assessment (WA)**

- Sets a fixed threshold for acceptable service
- Not penalized in bunched and unevenly spaced service



# Analysis Algorithm

<b>Regularity</b>	Pass: Y within Range R
	Fail: Y out of Range R
<b>Reg Criteria:</b>	± 5 min of scheduled intervals equal to or greater than 10 min. ± 50% of scheduled intervals that are less than 10 min.

<b>Wait Assessment</b>	Pass: Y ≤ W
	Fail: Y > W
<b>BUS:</b>	+3 min peak (7am-9am; 4pm-7pm)
<b>SUB:</b>	+2 min peak (6am-10am; 3pm-7pm)
<b>WAY:</b>	+4 min off-peak (10am-3pm; 7pm-midnight)

## INSTRUCTIONS

- A= Scheduled time
- B= Next scheduled time (sched. Max)
- C= Actual time
- D= Next actual time
- A-(B-A)= Sched. Min
- X= Scheduled time interval (B-A).
- Y= Actual time interval (D-C).
- R= ± 50% scheduled interval X (0.5X to 1.5X) OR X ± 5 min. for scheduled interval for X >10 min.
- W= add 3 or 5 min to scheduled interval X (X+3 or 5).

**Auto fail:** There's no next actual time within scheduled range between A-(B-A) and B, or the system find an actual time but was already used and passed (Both Reg. and Wait FAIL).

**Repeat match:** If the next actual time is not within A-(B-A) and B, and a previous actual time was already used and fail, it repeats the match.

**Skipped:** If an actual time does not fall within A-(B-A) and B, system skips that point.

**Computer Output (ATC Error Log)** calculates a scheduled interval (X), an actual interval (Y), a range to review actual data (s.min [A-(B-A)] to s.max [B]), and a pass/fail range at scheduled time.

### Steps in setting up and calculating Regularity and Wait Assessment (Algorithm Detail).

- Set up column A by lining up all the Scheduled Time within the Survey Start Time and End Time.
- Set up column B by lining up just as column A with a next scheduled time A, and also skip all scheduled time with CH.MISS (such as comfort relief), such as on line 29 below.
- Set up column A-(B-A) by calculating from columns A and B.
- Select a first actual time in column C to fit into the a first available scheduled range between columns A-(B-A) and B.
- Select a next actual time in column D (same row as column C).
- Set up all the actual time in columns C and D by applying the rules of **auto fail, repeat match, and skipped**.
- Continue selecting a next available actual time in column C (to fit in columns A(B-A) and B) and a next actual time in column D until the end of the survey data.
- Calculate columns X, Y, R, W, REG, and WAIT.

Computer Output Generated from ATC (Regularity Error Log)					Algorithm Detail												
BUS	Sched Prev	Next	Actual	Next	BUS	A	B	A-(B-A)	C	D	X	Y	( R )	W	REG	WAIT	
	1657																
	1700																
1	1705	1657	1713	1705	1723	1705	1713	16:57	17:05	17:23	8	18	4	12	11	F	F
2	1713	1711	1715	1723		1713	1715	17:11	17:23	auto fail						F	F
3	1715	1709	1721	1723		1715	1721	17:09	17:23	auto fail						F	F
4	1721	1713	1729	1723	1724	1721	1729	17:13	17:23	17:24	8	1	4	12	11	F	P
5	1729	1728	1730	1724		1729	17:30	17:28	17:45	auto fail						F	F
6	1730	1723	1737	1724	1726	1730	17:37	17:23	17:24	17:26	7	2	4	11	10	F	P
7	1737	1737	1742	1726		1737	17:42	17:32	17:45	auto fail						F	F
8	1742	1740	1744	1726		1742	17:44	17:40	17:45	auto fail						F	F
9	1744	1737	1751	1726		1744	17:51	17:37	17:45	17:47	7	2	4	11	10	F	P
10	1751	1745	1757	1747	1749	1751	17:57	17:45	17:47	17:49	6	2	3	9	9	F	P
11	1757	1755	1759	1749		1757	17:59	17:55	18:02	auto fail						F	F
12	1759	1753	1805	1749		1759	18:05	17:53	18:02	18:16	6	14	3	9	9	F	F
13	1805	1803	1807	1816		1805	18:07	18:03	18:16	auto fail						F	F
14	1807	1800	1814			1807	18:14	18:00	repeat	repeat	7	14	4	11	10	F	F
15	1814	1813	1815	1816		1814	18:15	18:13	18:16	auto fail						F	F
16	1815	1808	1822	1816	1826	1815	18:22	18:08	18:16	18:26	7	10	4	11	10	P	P
17	1822	1819	1825	1826		1822	18:25	18:19	18:26	auto fail						F	F
18	1825	1822	1828	1826	1828	1825	18:28	18:22	18:26	18:28	3	2	2	5	6	P	P
19	1828	1821	1835	1828	1828	1828	18:35	18:21	18:28	18:28	7	0	4	11	10	F	P
20	1835	1834	1836	1828		1835	18:36	18:34	18:40	auto fail						F	F
21	1836	1828	1844	1828	1829	1836	18:44	18:28	18:28	18:29	8	1	4	12	11	F	P
22	1844	1836	1852	1829		1844	18:52	18:36	18:40	18:40	8	0	4	12	11	F	P
23	1852	1844	1900	1840		1852	19:00	18:44	18:45	19:01	8	16	4	12	11	F	F
24	1900	1852	1908	1901	1902	1900	19:08	18:52	19:01	19:02	8	1	4	12	13	F	P
25	1908	1900	1916	1902	1904	1908	19:16	19:00	19:02	19:04	8	2	4	12	13	F	P



# Definitions and Examples

Indicator	Definition	Examples	Applicable Time Period	Indicator Publicly Reported
Headway Regularity	<p>% of scheduled intervals passing the Regularity Criteria. A <u>scheduled interval</u> passes the Regularity Criteria if and <u>only if</u> it:</p> <ol style="list-style-type: none"> <li>1. contain an actual vehicle departure (i.e. train or bus leaving the timepoint); and</li> <li>2. the actual service interval between that departure and <i>the following</i> actual departure fall within <math>\pm 50\%</math> or five minutes of the scheduled interval, whichever is less.</li> </ol>	<p>For a scheduled headway of 4 minutes, an actual headway of between 2~6 minutes (<math>-50\%</math> to <math>+50\%</math> of four minutes) would be permissible.</p> <p>For a scheduled headway of 15 minutes, an actual headway of 10~20 minutes (<math>-5</math> to <math>+5</math> minutes) would be permissible.</p>	<p>6 a.m. – 9 p.m.  (expanded to 6 a.m. – midnight in 2008)</p>	1994~2000
Wait Assessment (WA)	<p>% of scheduled intervals that passing the WA Criteria. A <u>scheduled interval</u> passes the WA Criteria if and <u>only if</u> it:</p> <ol style="list-style-type: none"> <li>1. contain an actual departure; and</li> <li>2. the actual interval between that departure and <i>the following</i> actual departure is less than the time-period and mode dependent maximum acceptable wait times of scheduled headway <math>+n</math> minutes: Subway: +2 (Peak), +4 (Off-peak) Bus: +3 (Peak), +5 (Off-peak).</li> </ol>	<p>For a subway line with off-peak headway of 8 minutes, a maximum wait time of 12 minutes (8 +4 minutes) is permissible.</p> <p>For a bus scheduled to operate every 10 minutes during the peak period, the maximum allowable headway is 13 minutes (10 +3).</p>	<p>6 a.m. – 9 p.m. (expanded to midnight in 2008)</p> <p><u>Peak:</u> 6 a.m. – 9 a.m. 4 p.m. – 7 p.m.</p> <p><u>Off-peak:</u> 9 a.m. – 4 p.m. 7 p.m. – 9 p.m.</p>	2000~present
En-route Schedule Adherence (ESA)	<p>% of scheduled trips that passing the ESA Criteria. A <u>scheduled trip</u> passes the ESA Criteria if and <u>only if</u> the scheduled trip is observed in service between one minute before and five minutes after the scheduled time.</p>	<p>The regularly scheduled Manhattan-bound <b>A</b> train leaves the Far Rockaway Terminal in Queens at 22:11, and is scheduled to depart 125 Street (an intermediate en-route timepoint) northbound at 23:37. If this train is observed leaving 125 Street between 23:36:00 and 23:42:00, it is considered on-time.</p>	<p>7 p.m. – 6 a.m.  (changed to 6 a.m. – midnight in 2008)</p>	1994~2007

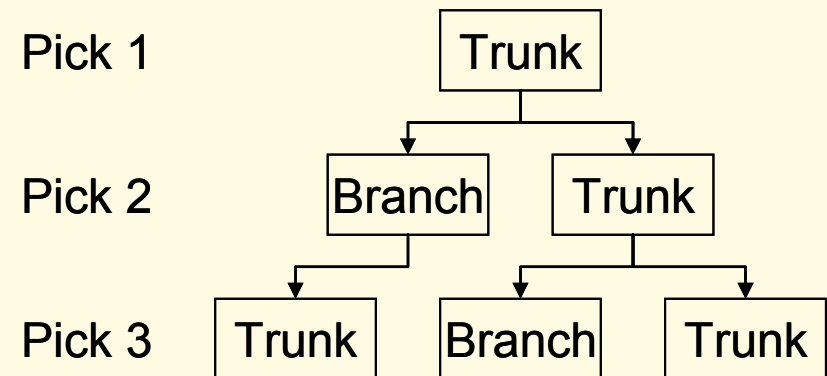
# Sampling Plan

- **Sample size based on**
  - Required accuracy and precision
  - Available survey resources
- **Combined sample creation and scheduling algorithm maximizes resource utilization**
- **Sample Design**
  - Weekday is divided into five shifts
  - Each shift is a six-hour assignment for one surveyor
  - Sample is picked by route, location, and block to maximally represent trunk locations

$$n = \frac{Z^2 p(1 - p)}{d^2}$$

where

$n$  = sample size,  
 $Z$  = confidence limit (1.960 for 95%, two-tailed),  
 $p$  = probability of successful (passing) trips, and  
 $d$  = expected margin of error (5%).



# Data Collection

- Traditionally Manually Collected by Field Surveyors
  - Pre-printed data collection forms
- Paper Forms for Bus Data Replaced in 2008
  - Electronic data collection
  - Personal Digital Assistant (PDA) application

New York City Transit  
Data Collection - Bus  
Operations Planning

A A A

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FORM SS

**BUS SAMPLE CHECK FORM**

S P H 0 0 6 3 3 8 6 8    Checker #: 254    Date: 07/11/2008    Day: FRIDAY    Start: 0630    Finish: 0930

Checker:    Route: S B S 1 2 FORDHAM RD - PELHAM    Route:

Route:    Direction: ARR : EB    LV : EB

To: BAY PLAZA BL    IFO JC PENNEY (43960),    ORCHARD BEACH    ORCHARD BEACH (53495)

Location: E FORDHAM RD    VALENTINE AV    21059    Weather: H O J

SPT	Route	Run #	Rel #	Bus	Destination	Arr Time	Ly Time	Notes
	S B S 1 2	205		5759	53495	0830	0831	
	S B S 1 2	206		5749	43960	0836	0837	
	S B S 1 2	207		5765	53495	0839	0841	
	S B S 1 2	208		5750	43960	0841	0843	
	S B S 1 2	209		5753	53495	0845	0847	
	S B S 1 2	210		5738	43960	0850	0851	
	S B S 1 2	211		5768	53495	0858	0859	
	S B S 1 2	212		5744	43960	0905	0906	
	S B S 1 2	213		5735	53495	0906	0908	
	S B S 1 2	214		5761	43960	0913	0914	
	S B S 1 2	215		5747	53495	0916	0917	
	S B S 1 2	216		5743	43960	0923	0924	
	S B S 1 2	217		5755	53495	0925	0927	

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The screenshot shows the MTA NYCT Bus PDA application interface. Red arrows point from text labels to specific fields in the application:

- Route ID**: Points to the 'Route' dropdown menu showing M101, M102, M103, LTD, NIS, NBP.
- Destination (Dropdown Menu)**: Points to the 'Destination' dropdown menu showing 'E 125 ST / LEXINGTON AV (13625)'.
- Run No. (Entry Field)**: Points to the 'Run' entry field showing '041'.
- Bus No. (Entry Field)**: Points to the 'Bus #' entry field showing '1125'.
- Relief No. (Entry Field)**: Points to the 'Rel #' entry field.
- New Bus**: Points to the 'NEW BUS' button.
- Note**: Points to the 'Note' button.
- Leave Time**: Points to the 'Leave' button.
- Arrive Time**: Points to the 'Arrive' button.

The application also displays a table of trip data:

Route	Dest	Run	Bus	Rel	Arrive	Leave	Note
M103	21342	032	1047		17:55:36	17:57:03	
M101	13625	041	1125		17:56:40		

Other interface elements include 'CoverSheet', 'Travellist', 'Details', 'ComfortRelief', 'Delete Trip', and 'Ver1.4.10'.

# Data Processing

- **Automated Traffic Clerking (ATC)**
  - client-server system
  - backend analysis engine
- **Bus Analysis Module**
  - Automatically match schedule and actual times
  - Computes Regularity, WA and ESA
- **Subway Analysis Module**
  - Uses Train Registers
  - Manual spreadsheet process
  - Import results into ATC

Oracle Forms Runtime

Action Edit Query Block Record Field Window Help

SP\_VALIDATION

### Surface Point Check Data Validation

Sched ID: 00633868 Status: 0 Fatal: 0 Warn: 0 Override: 0

Checker #: 2 Date: 07/11/2008 Daytype: W Start: 0630 End: 0930

Route1: SB512 FORDHAM RD - PELHAM Route2: Route3: Route4:

Location: 21059 E FORDHAM RD VALENTINE A Direction Arr: EB Lv: EB Weather Id: 00L

Trip Num	Status	Analyst	Error	Text

Trip	Route	Run1	Run2	Bus	Dest	Sched. ArTime	Arrive Time	Load	Offs	Ons	Load	Leave Time	Sched. LvTime	Note
1	SB512	204		5758	11111		062900	0	0	0	0	063100	063200	
2	SB512	205		5759	11111		063600	0	0	0	0	063800	063700	
3	SB512	206		5749	11111		064100	0	0	0	0	064200	064200	
4	SB512	207		5765	11111		064300	0	0	0	0	064400	064700	
5	SB512	208		5750	11111		065000	0	0	0	0	065100	065200	
6	SB512	209		5753	11111		065500	0	0	0	0	065600	065700	
7	SB512	210		5738	11111		065900	0	0	0	0	070000	070200	
8	SB512	211		5768	11111		070600	0	0	0	0	070700	070700	
9	SB512	212		5744	11111		071200	0	0	0	0	071200	071200	
10	SB512	213		5735	11111		071600	0	0	0	0	071700	071700	

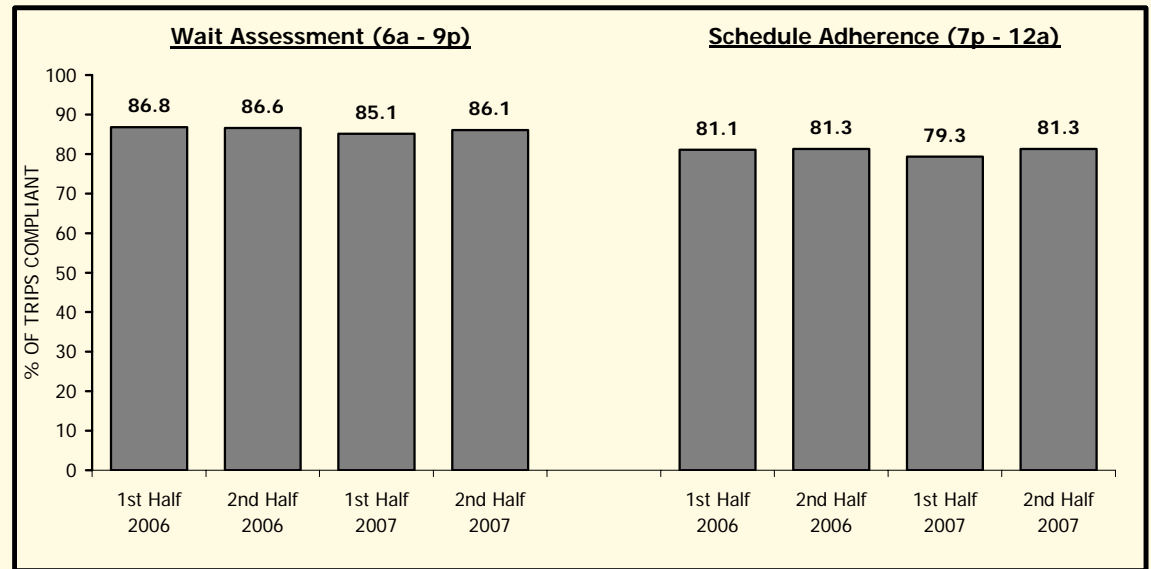
Record: 4/21 <OSC> <DBG>



# Public Reporting

- **Disaggregated Data**
  - Systemwide
  - by Borough
  - by Route
- **Main Purpose is to Monitor Service**
  - “Public Watchdog”
  - Transparency
  - Accountability
  - Public Trust
  - Used by Rider Advocacy Groups

Subway Performance Indicators



## Definition

Wait Assessment is measured during the day (6:00 a.m. – 9:00 p.m.), when service is relatively frequent. It is defined as the percentage of actual service intervals that are no more than the scheduled interval plus 2 minutes during peak (6 a.m. – 9 a.m., 4 p.m. – 7 p.m.) and plus 4 during off-peak (9 a.m. – 4 p.m., 7 p.m. – 9 p.m.).

Schedule Adherence, which is assessed in the evening (7:00 p.m. – 12:00 a.m.), is defined as the percentage of trips departing from all scheduled enroute timepoints between 1 minute before and 5 minutes after their scheduled departing time.

The results presented are for all subway lines.

**2007 Annual Goals:** Wait Assessment: 86.8%      Schedule Adherence: 75.6%

## Semi-Annual Results:

<u>Wait Assessment</u>		<u>Schedule Adherence</u>	
2nd Half 2007	86.1%	2nd Half 2007	81.3%
1st Half 2007	85.1%	1st Half 2007	79.3%
2nd Half 2006	86.6%	2nd Half 2006	81.3%
1st Half 2006	86.8%	1st Half 2006	81.1%

**Discussion of Results:** an increase/decrease of less than 1% is statistically unchanged.

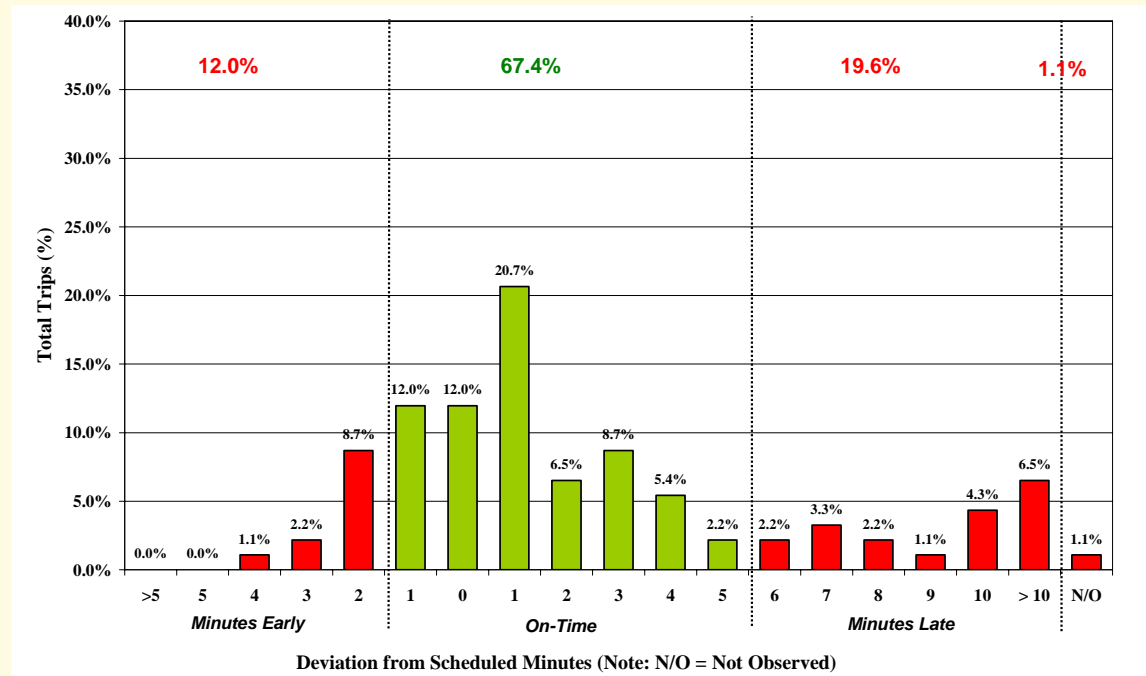
2nd Half 2007 vs. 2nd Half 2006: The differences in "Wait Assessment" and "Schedule Adherence" are less than 1%.

# Internal Reporting

- **Facilitates Corrective Actions**

- Developed internal reports in partnership with operating departments
- Troubleshoots consistently early or late problems
- Detailed reporting on a bi-weekly basis

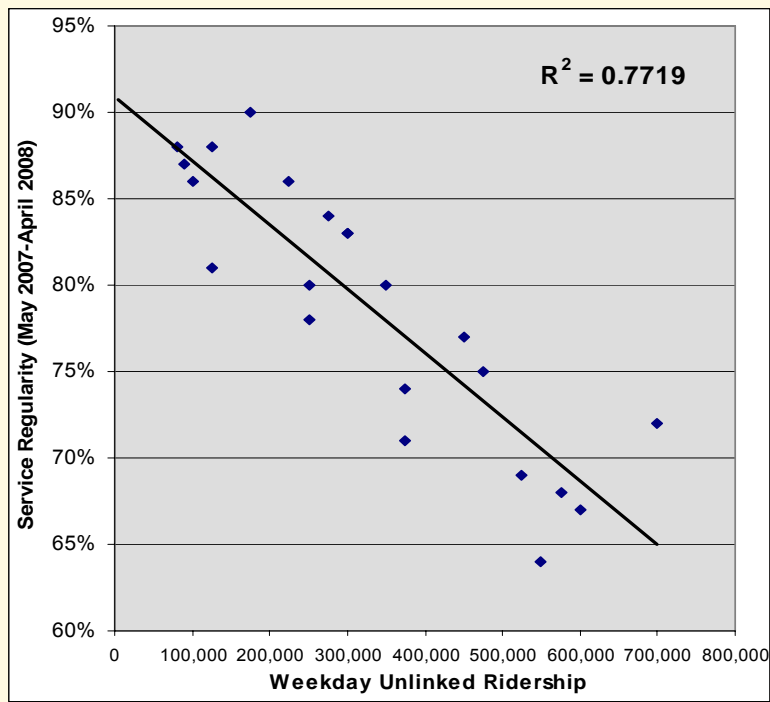
**M15 - Local Northbound 1 AVE / E 42 ST**  
**Weekday 01/01/07 - 12/31/07**  
**Enroute On-Time Performance (1900-0000)**



Q58	Local Trips												REPORTED						
	SPH	Date	Dir	StopID	Location	StartTime	EndTime	6	37	181	29	7	260	2.3%	14.2%	69.6%	11.2%	2.7%	Wait Assessment
	647130	10/2/08	EB	16465	CORONA AV / JUNCTION BL	1345	1645	0	4	15	4	0	23	0.0%	17.4%	65.2%	17.4%	0.0%	77.8%
	647160	10/3/08	EB	16465	CORONA AV / JUNCTION BL	2100	0	1	0	11	5	2	19	5.3%	0.0%	57.9%	26.3%	10.5%	76.5%
	647134	10/3/08	WB	48829	FRESH POND RD / METROP	1730	2030	0	2	23	7	1	33	0.0%	6.1%	69.7%	21.2%	3.0%	76.7%
	647200	10/6/08	EB	16465	CORONA AV / JUNCTION BL	630	930	2	1	29	3	3	38	5.3%	2.6%	76.3%	7.9%	7.9%	72.4%
	647320	10/9/08	EB	16465	CORONA AV / JUNCTION BL	2100	0	0	8	9	2	0	19	0.0%	42.1%	47.4%	10.5%	0.0%	82.4%
	647252	10/10/08	EB	11290	FRESH POND RD / METROP	1345	1645	1	5	18	3	1	28	3.6%	17.9%	64.3%	10.7%	3.6%	77.8%
	647747	10/13/08	WB	15630	GRAND AV / QUEENS BL	2100	0	0	9	15	0	0	24	0.0%	37.5%	62.5%	0.0%	0.0%	95.5%
	647714	10/13/08	WB	48829	FRESH POND RD / METROP	1015	1415	0	3	32	0	0	35	0.0%	8.6%	91.4%	0.0%	0.0%	97.0%
	647882	10/15/08	EB	48805	108 ST / HORACE HARDING I	1015	1415	0	3	16	5	0	24	0.0%	12.5%	66.7%	20.8%	0.0%	90.9%
	647914	10/16/08	EB	11290	FRESH POND RD / METROP	2100	0	2	2	13	0	0	17	11.8%	11.8%	76.5%	0.0%	0.0%	86.7%

# Operational Applications

- **Continual Performance Improvements**
  - through goal-setting and management processes
- **Data Mining**
  - Explanatory factors



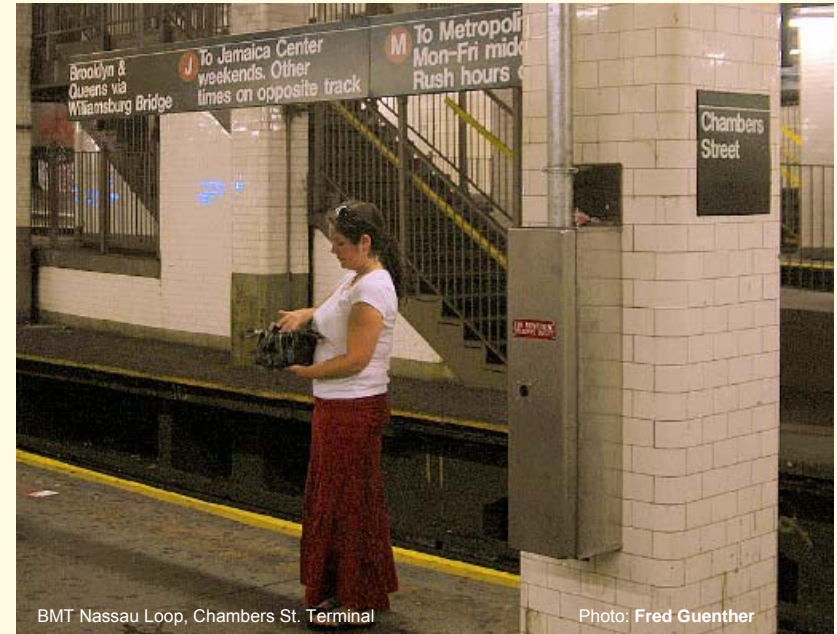
# Special Programs

- **Scheduled Running Time Recalibration**
  - Periodic Adjustment for Traffic Conditions
- **Dispatcher Programs**
  - Respond to performance declines
  - Respond to community reliability concerns
- **Pilot Program Monitoring**
  - Monitor new or revised operating plans
- **Dispatching Strategy Evaluation**
  - Monitor pilot subway dispatching methods



# Summary

- Rider advocacy groups adopt NYCT's performance measures
- Senior management set goals for operating areas
- Cooperation between Operations Planning and Field Management
- Extensive technology infrastructure to collect, process, and analyze large volumes of data
- Monitoring performance of pilot service plans, dispatcher programs, and dispatching strategy



BMT Nassau Loop, Chambers St. Terminal

Photo: Fred Guenther

# Future Work

- **Expanding Use of Automatically Collected Data**
  - Automated Passenger Counter
  - Passenger Load Sensors
  - Automated Fare Collection
  - Automated Vehicle Locator
- **Full PDA Deployment for Other Data Collection**
  - Passenger Environment Survey
  - Surface Ride Check



BMT Culver El, Bay Parkway

Photo: Fred Guenther

