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

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ABSTRACT

For all organizations, be they public or private, it is essential to establish measurements ensuring that the services provided are being done well and when they are not, that the organization can diagnose problems. New York City Transit's (NYCT) mission is essentially to provide timely and reliable mass transit to over seven million daily riders. NYCT has established three main Performance Indicators (PI) to ascertain how closely they are meeting this mission: En-route Schedule Adherence (ESA), Headway Regularity (HR), and Wait Assessment (WA). While ESA (–1 to +5 minutes) and WA is easily explained, Headway Regularity (± 50%) is a useful diagnostic for operations management.

NYCT selected 23 subway routes and 42 borough-representative principal bus routes for performance analysis. A stratified sample, designed to prevent undesirable sample bias, is generated using a fully automated system and achieves an accuracy of 95 ± 5% at the route level.

Computerized data processing and analysis was implemented in 1995. Recently, paperless data collection was initiated, further decreasing reporting lag and improving data quality. Indicators are reported semi-annually to the public, while detailed internal diagnostic reports are issued frequently to assist operations management in improving service performance.

PI statistics are now used by senior management for setting goals and by rider advocacy groups to assess agency performance. A partnership and spirit of cooperation has developed between operating areas and analytical staff in troubleshooting delay issues and continuous quality improvement. The PI infrastructure is tapped by pilot programs to assess performance of operations improvement initiatives.

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1 Program Design

Automated system generates and schedules all route and line level statistical samples

Route Selection

- All 23 major subway lines and 42 representative bus routes were selected for analysis and reporting
- All routes/lines carry equal weight in division and system-wide totals

SUBWAY

- 23 major subway lines carry > 5 million weekday riders
- Every subway line carried >80,000 riders in 2006
- 6 line is busiest (700,000 riders/day)

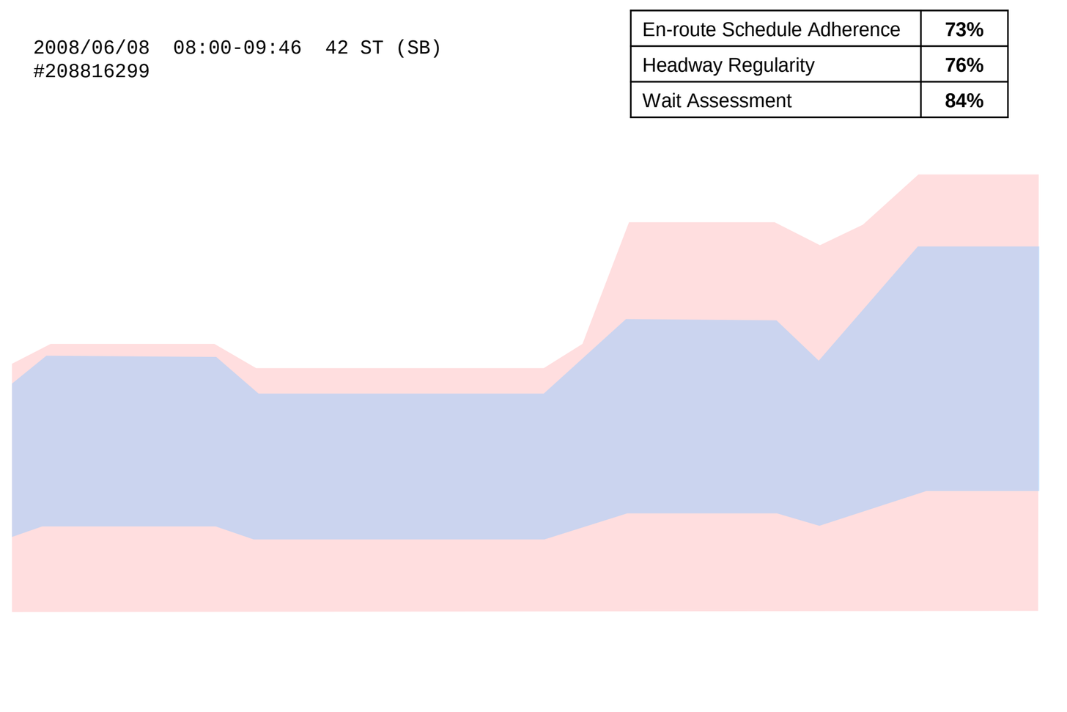
Line	Description	Ridership
6 ◆6	City Hall/Pelham Bay Park	700,000
1	South Ferry/Van Cortlandt Park 242 St	600,000
F	Coney Island/Jamaica 179 St	575,000
4	Utica Av Crown Heights/Woodlawn	550,000
A	Far Rockaway/Inwood 207 St	525,000
E	World Trade Center/Jamaica 179 St	475,000
7 ◆7	Times Square 42 St/Flushing 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

BUS

- 42 of the 193 NYCT bus routes were selected, representing approx. 45% of the 2.3 million weekday ridership
- Generally, routes with the most ridership and frequency in each borough were selected

Borough	Route	Description	2006 Weekday Revenue Ridership	System-wide Rank
Bronx	BX1/BX2, BX1/BX2 Limited	Grand Concourse/Melrose Av	42,531	5
	BX9	B'way/Kingsbridge Rd	27,119	18
	BX12, BX12 Select	Pelham Pkwy/Fordham Rd	42,410	6
	BX19	Southern Blvd/E 149 St	34,091	11
	BX36	E 180 St/E 174 St	30,416	12
	BX40/BX42	Tremont Av Crosstown	28,199	16
	BX41	Webster Av/White Plains Rd	29,110	14
	BX55 Limited	3 Avenue	16,942	41
Brooklyn	B6, B6 Limited	Bay Pkwy/Flatlands Av	43,374	3
	B15	New Lots Av	22,307	25
	B35, B35 Limited	Church Av/39 St	38,820	9
	B41, B41 Limited	Flatbush Av	40,951	7
	B44, B44 Limited	Nostrand Av	42,670	4
	B46, B46 Limited	Utica Av/Malcolm X Blvd	52,974	2
	B63	5 Av/Atlantic Av	15,332	53
Manhattan	M1	5 Av/Madison Av	16,241	46
	M2	5 Av/Adam Clayton Powell Blvd	15,544	52
	M3,	5 Av/St Nicholas Blvd	19,021	35
	M18	Convent Av Shuttle	901	186
	M4	5 Av/Broadway	23,887	22
	M7	6 Av/7 Av/Lenox	16,855	42
	M10,	8 Av/Frederick Douglass Blvd	11,334	82
	M20	7 Av/8 Av/Hudson St	5,731	133
	M14A/M14D	14 St Crosstown	40,479	8
	M15, M15 Limited	1 Av/2 Av	59,708	1
	M27	49/50 Sts Crosstown	4,027	153
	M50		4,580	146
	M31	57 St/York Av	14,923	57
	M66	66/67 Sts Crosstown	14,870	58
	M86	86 St Crosstown	29,036	15
	M101, M101 Limited	3 Av/Lex Av/Amsterdam Av	37,607	10
	M102	3 Av/Lex Av/Lenox Av	18,400	38
	M103	3 Av/Lexington Av	16,516	44
	M104	Broadway/42 St	24,264	20
Queens	Q43	Hillside Av	15,936	49
	Q20	Main St/Union St	22,962	24
	Q44/Q44 Limited	Main St/Cross Bronx Expwy	15,002	55
	Q46	Union Tpk	21,737	29
	Q58	Fresh Pond Rd/Corona Av	27,363	17
	Q83	Liberty Av/Murdoch Av	9,957	88
	Q85	Merrick Blvd/Conduit Av	12,919	72
Staten Island	S44/S94	Richmond Av	7,389	113
	S48/S98	Forest Av	8,170	106
	S53/S93	Clove Rd/Verrazano Narrows Br	9,093	96
	S74/S84	Richmond Rd/Arthur Kill Rd	5,990	129
	S76/S86	Richmond Rd/New Dorp La	5,005	140
	S78	Hylan Blvd	7,104	115
	S79	Hylan Blvd/Verrazano Br	8,404	102

2 Measurement Standards



- *The graph illustrates a listing of scheduled time and actual intervals for regions passing Regularity, WA, and ESA*

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

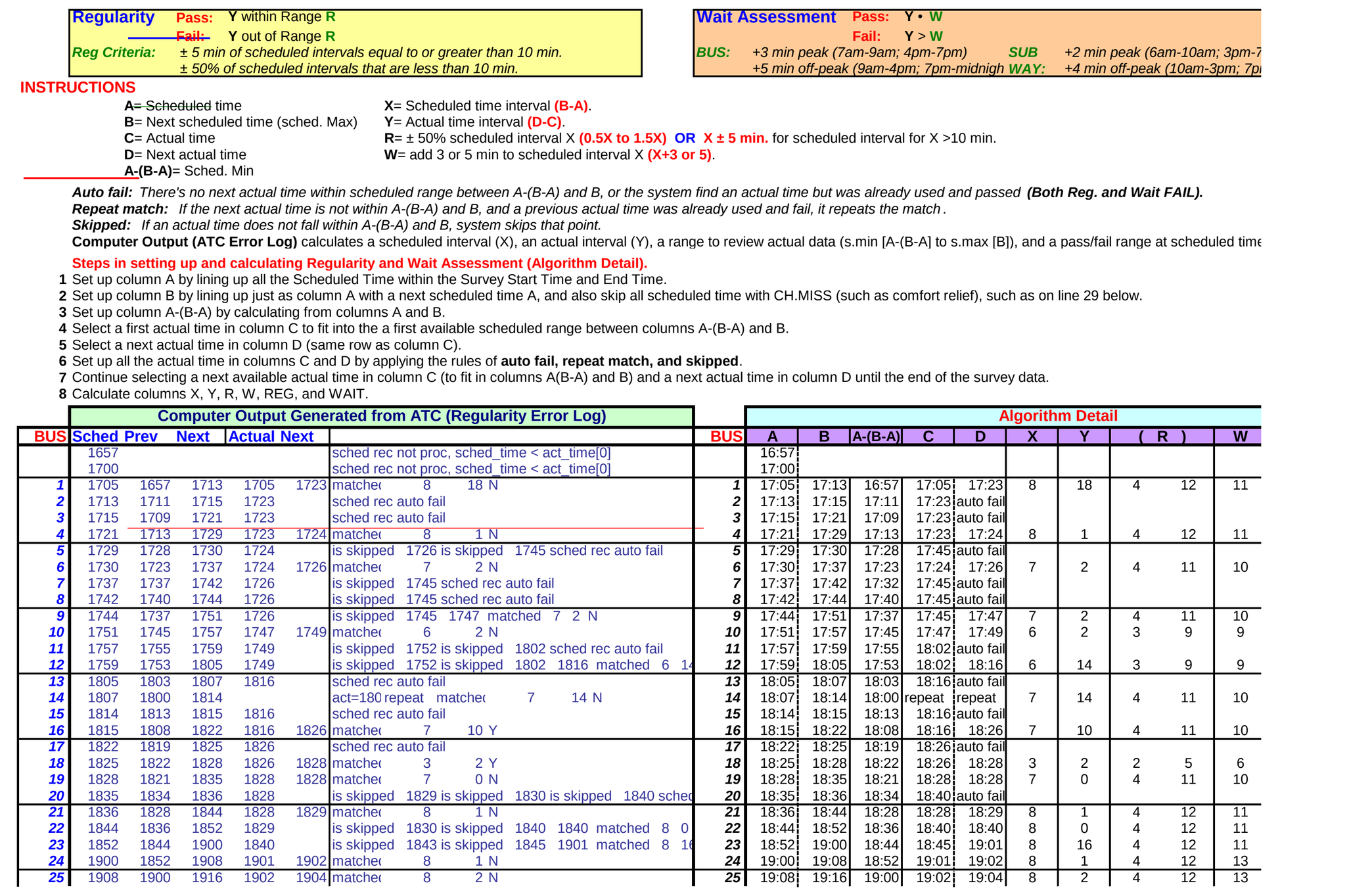
Wait Assessment

Sets a threshold for maximum acceptable wait times vs. schedule in peak and off peak periods

- *The above figure compares the three Performance Indicators*

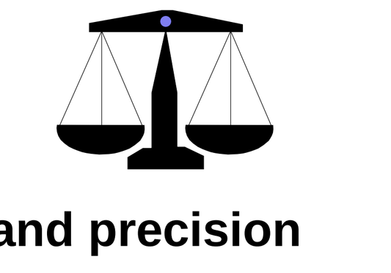
Indicator	Definition	Examples	Applicable Time Period	Indicator Publicly Reported
Headway Regularity	% of scheduled intervals passing the Regularity Criteria. A scheduled interval passes the Regularity Criteria if and only if it: 1. contain an actual vehicle departure (i.e. train or bus leaving the timepoint); and 2. the actual service interval between that departure and *the following* actual departure fall within ±50% or five minutes of the scheduled interval, whichever is less.	For a scheduled headway of 4 minutes, an actual headway of between 2~6 minutes (–50% to +50% of four minutes) would be permissible. For a scheduled headway of 15 minutes, an actual headway of 10~20 minutes (–5 to +5 minutes) would be permissible.	6 a.m. – 9 p.m. (expanded to 6 a.m. – midnight in 2008)	1994~2000
Wait Assessment (WA)	% of scheduled intervals that passing the WA Criteria. A scheduled interval passes the WA Criteria if and only if it: 1. contain an actual departure; and 2. the actual interval between that departure and *the following* actual departure is less than the time-period and mode dependent maximum acceptable wait times of scheduled headway +*n* minutes: Subway: +2 (Peak), +4 (Off-peak) Bus: +3 (Peak), +5 (Off-peak).	For a subway line with off-peak headway of 8 minutes, a maximum wait time of 12 minutes (8 +4 minutes) is permissible. For a bus scheduled to operate every 10 minutes during the peak period, the maximum allowable headway is 13 minutes (10 +3).	6 a.m. – 9 p.m. (expanded to midnight in 2008) Peak: 6 a.m. – 9 a.m. 4 p.m. – 7 p.m. Off-peak: 9 a.m. – 4 p.m. 7 p.m. – 9 p.m.	2000~present
En-route Schedule Adherence (ESA)	% of scheduled trips that passing the ESA Criteria. A scheduled trip passes the ESA Criteria if and only if the scheduled trip is observed in service between one minute before and five minutes after the scheduled time.	The regularly scheduled Manhattan-bound A 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.	7 p.m. – 6 a.m. (changed to 6 a.m. – midnight in 2008)	1994~2007

- *The table illustrates how Regularity, Wait Assessment and En-route Schedule Adherence are measured.*



- *The above figure illustrates the matching algorithm of PI Regularity and Wait Assessment*

3 Sampling



- Sample size based on
  - Required accuracy and precision (95 ± 5%)
  - Available survey resources
- Combined sample creation and scheduling algorithm maximizes resource utilization

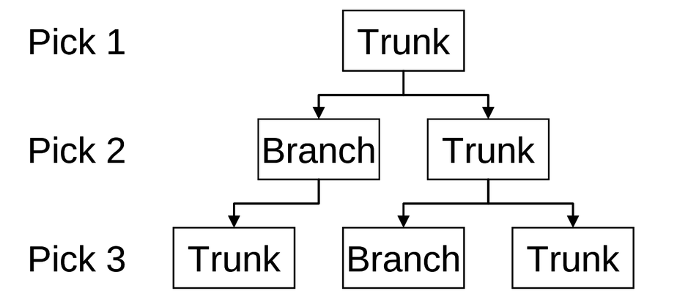
$$n = \frac{Z^2 p(1-p)}{d^2}$$

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%).

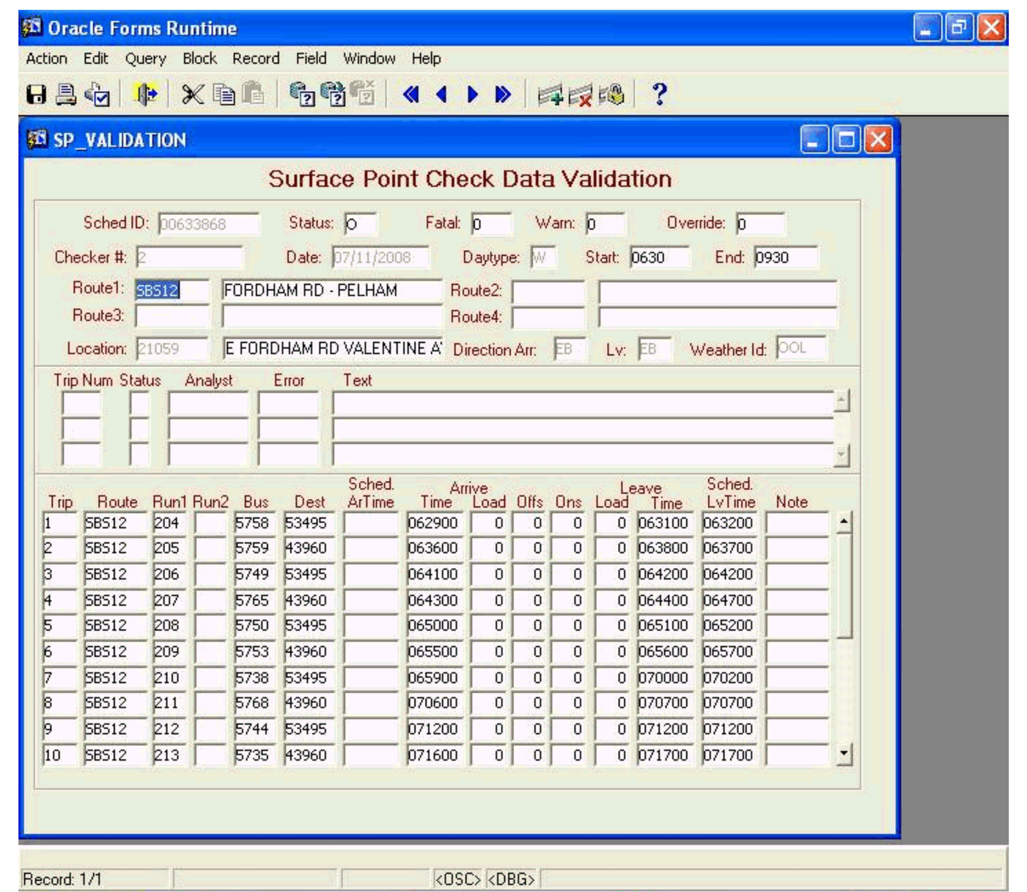
Sample Design

- 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 path locations



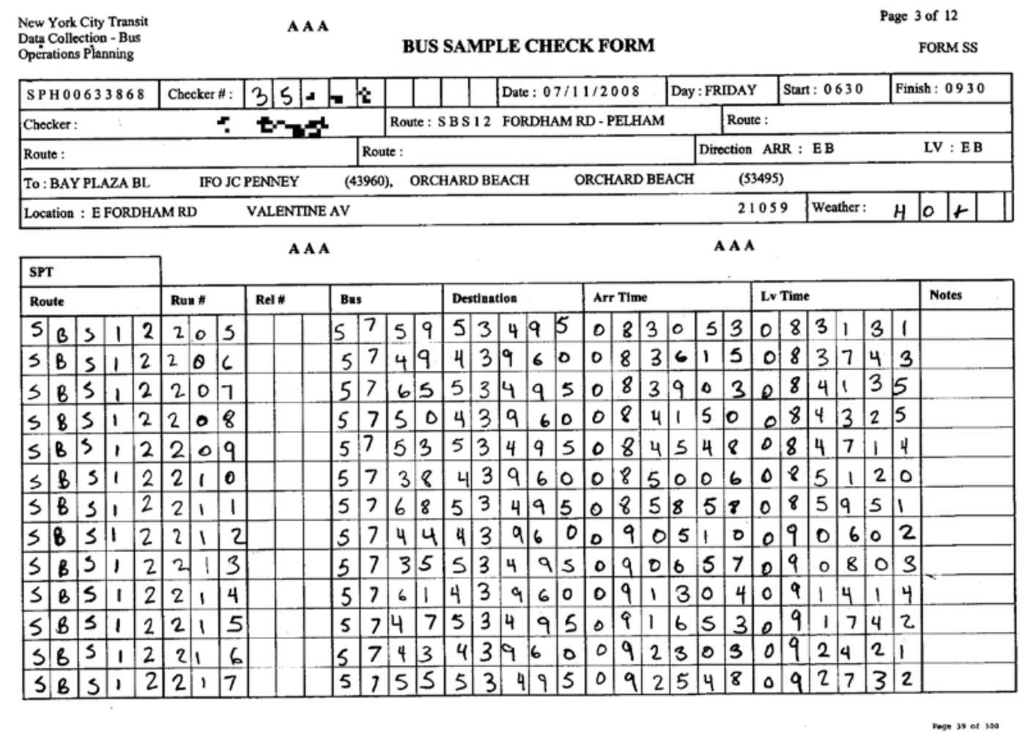
4 Data Processing

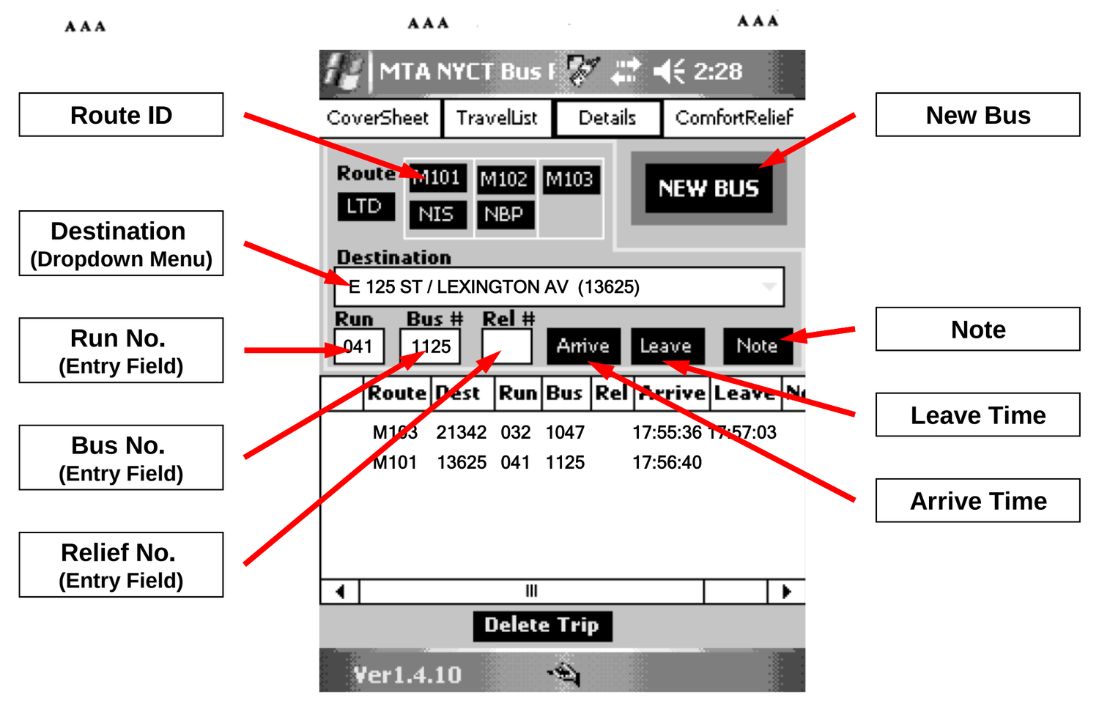
- The backend engine for collecting, analyzing, and reporting bus data is the Automated Traffic Clerking (ATC) client-server system
- The ATC application matches actual and scheduled departure times for each trip and each run for further analysis and reporting
- Subway cars must be matched to manually input dispatcher Train Register sheets prior to automated analysis



Data Collection

- PI data was traditionally collected manually by field surveyors using pre-printed data collection forms
- Paper forms for bus data collection were replaced in 2008 with a Personal Digital Assistant (PDA) application



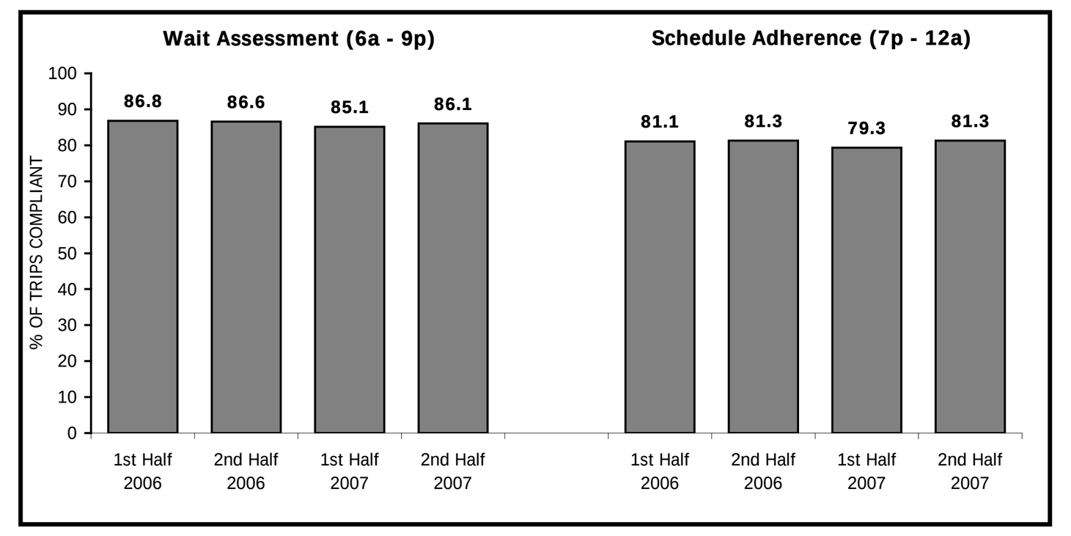


5 Reporting

Public Reporting

- PI Program's main purpose is to monitor NYCT's service delivery to the public
- The PI reporting process serves as the public trust in the performance audit infrastructure
- Reporting results are routinely used by rider advocacy groups for their ratings

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:

Wait Assessment		Schedule Adherence	
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%

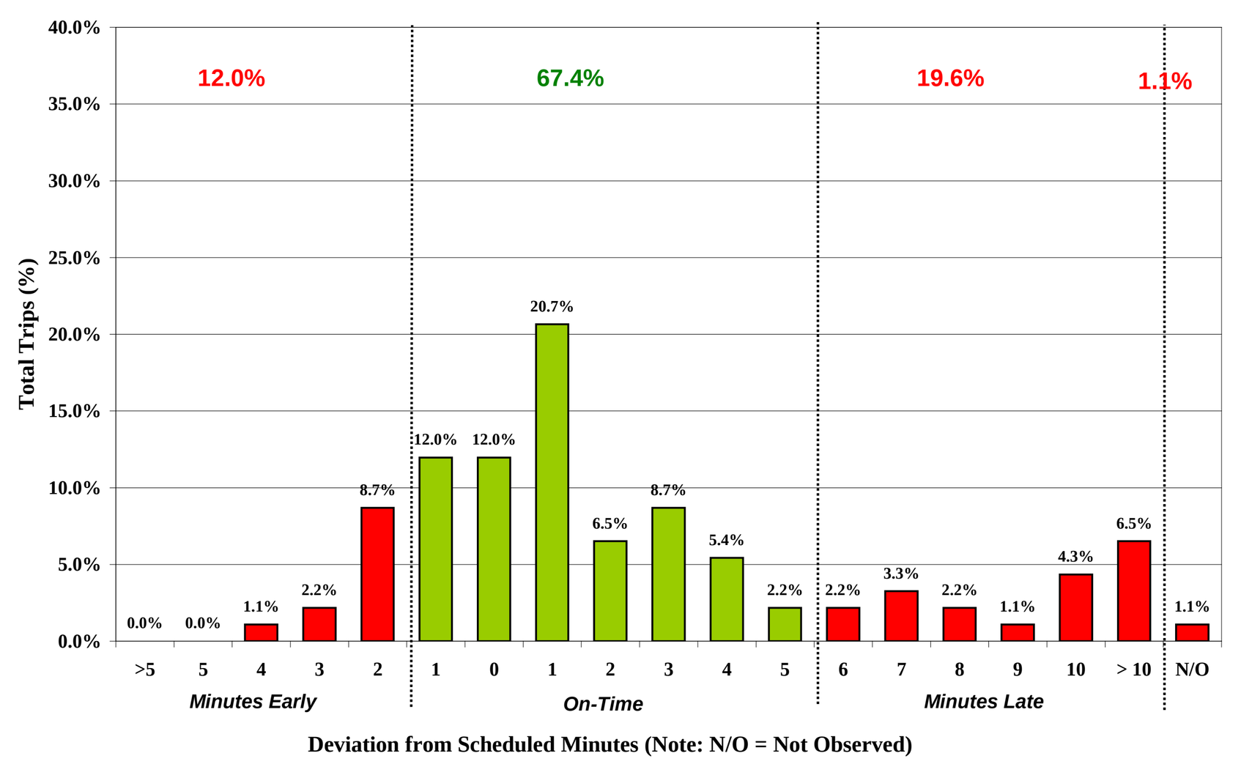
Discussion of Results: an increase/decrease of less than 1% is statistically unchanged.

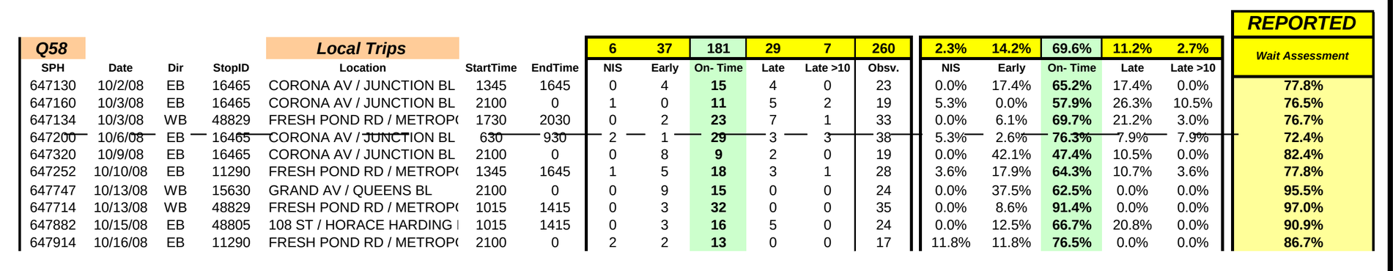
2nd Half 2007 vs. 2nd Half 2006: The differences in "Wait Assessment" and "Schedule Adherence" are less than 1%.

Internal Supplemental Reporting

- Developed in partnership with NYCT operating departments to facilitate corrective actions
- Per minute distribution of timepoint location performance enables operations management to troubleshoot consistently early or late problems

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





6 Operational Uses of Performance Indicators

PI program gives operations management the diagnostic tools to improve service quality and to set consistent and attainable goals

Schedule Recalibration

Schedules require periodic adjustments to reflect current traffic and environmental conditions

Dispatcher Programs

Initiated in response to steep declines in performance indicators, or by community concerns about service reliability

Pilot Program Monitoring

Evaluating initiatives sponsored by community leaders, line managers, and the capital program, such as the new BX12 +selectbusservice, NYCT's first BRT service

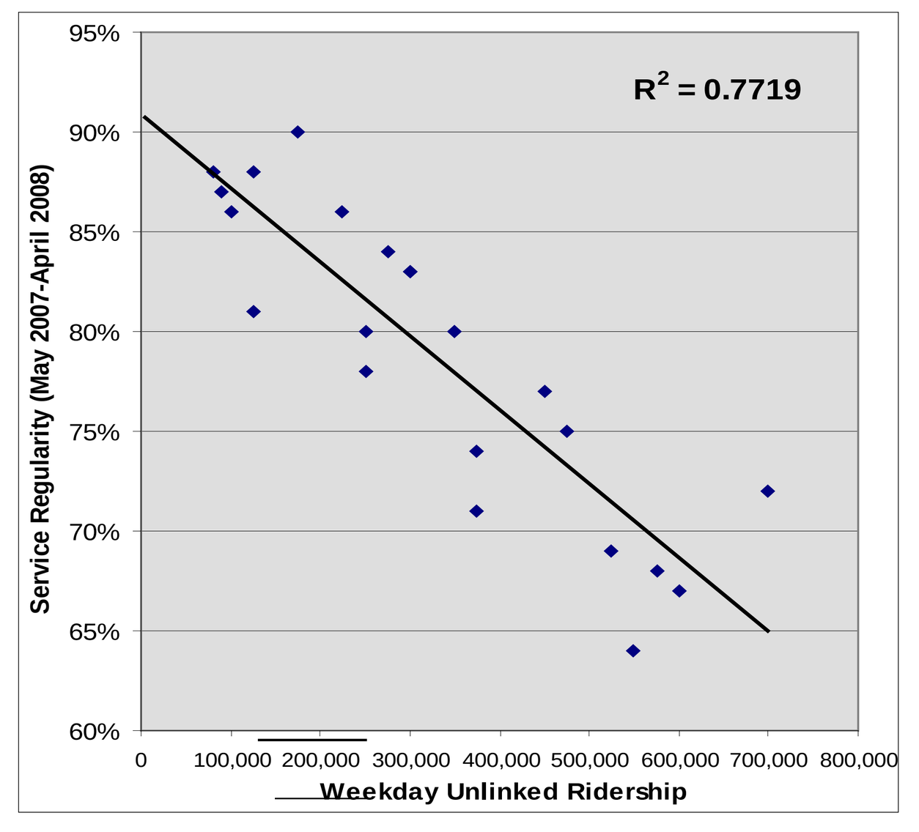
Dispatching Strategy Evaluation

Enabling line managers to change dispatching strategies to improve service provision to the public

Data Mining & Research

Attempting to locate answers in the data for pressing problems

"…providing sufficient transportation capacity by using efficient design and dispatching techniques can alleviate overcrowding."



Correlation Between Unlinked Ridership (Train Embarkations) and Headway Regularity

7 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

Future Work

- Expanding use of Automatically Collected Data
  - Automatic Train Supervision
  - 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