MTA Construction & Development

NEWYORK CITY TRANSIT NOISE REDUCTION REPORT

Prepared Pursuant to the Rapid Transit Noise Code and Public Authorities Law 1204-a

Abstract

This report shall include, but not be limited to an itemized summary of all monies spent, bids requested and received, contracts let, and actual work done on noise abatement programs during the previous period. Any and all subway noise measurements made during the previous period shall be included, with, whenever possible, analyses of such measurements. Such annual reports shall include a detailed analysis of all future noise abatement activities planned for the upcoming twelve months. Following the first twelve-month interval these reports shall also include comprehensive statements of progress made on all planned noise abatement activities included in the previous annual report.

Introduction

MTA New York City Transit (NYCT) has investigated noise issues that may affect the health, safety, or quality of life of our customers and employees and the communities we serve, and has expedited any necessary mitigation actions, for many decades. Noise abatement efforts have been undertaken by technical experts from the Departments of Subways, Stations, Buses, Office of System Safety and MTA Construction & Development (C&D). Beginning in 2015, annual noise reduction reports have been posted on the MTA website and this effort has been continued by MTA C&D since then.

This annual report, prepared pursuant to the requirements of Public Authorities Law 1204-a, provides an update for the previous year on capital investments and improved maintenance that contribute most to reducing subway system noise. All subway noise measurements made during the previous period shall be included, with, whenever possible, analyses of such measurements. The annual report shall also include a detailed analysis of all future noise abatement activities planned for the next twelve months.

Noise Abatement Program

MTA NYCT's ongoing noise abatement program was begun in 1974. It calls for noise related improvements where appropriate as part of other important capital and operating programs. This has included such major programs as track reconstruction (welded rail and resilient rail fastener installation), station reconstruction (station acoustic treatments), car overhauls (traction motor retrofit, air conditioning retrofit/overhaul) and Scheduled Maintenance System work (ring damped wheels and wheel truing machines). This policy was adopted, and continues to be favorably implemented, because it is most efficient to undertake treatments which contribute to noise reduction in concert with other activities. By including noise abatement activities as integral parts of other vital NYCT programs, such as track replacement, they will not take a back seat to other high priority projects which may otherwise fail to contribute to noise abatement efforts.

There have been several MTA NYCT programs which were designed to exclusively address noise abatement. Many projects have also provided noise abatement benefits indirectly. Examples of the abatement treatments have included traction motor noise reduction (5-7 dBA noise reduction), resilient rail fastener installation on steel elevated structures (3-5 dBA noise reduction), ring damped wheel installation (15-20dBA screech noise reduction). Programs which provide benefits in addition to noise abatement have included new car purchases, rail welding (9-10 dBA noise reduction, while at the same time decreasing the wear on wheels and rails, and providing a smoother ride), car air conditioning and rail lubrication (reduces wheel and rail wear on curved track).

MTA NYCT's noise abatement programs are summarized below. These initiatives are organized by the four specific categories in which noise occurs. They are: 1) in-car, 2) elevated structures, 3) curve and brake screech and 4) stations. These represent the areas which are most significantly affected by a particular treatment, although many treatments provide benefits which overlap environments.

In-Car Environment

By purchasing new subway cars and overhauling older cars, MTA NYCT has provided significant reductions to in-car noise, while reducing the amount of noise which emanates from cars. MTA NYCT's existing fleet consists of two Divisions, namely Division A and Division B. The lines that are represented in Division A include all the numbered lines as well as the Times Square Shuttle; Division B consists of all the lettered lines as well as the Rockaway and Franklin Avenue Shuttles.

For each of these Divisions, new cars are being introduced into the fleet for each line. For Division A, older R62 and R62A models were replaced by R142 and R142A. With this changeover, one could see a measurable reduction in noise. A 2010 systemwide noise study indicated that the R62 model, manufactured in 1983-85, had an average sound level of 73.2 dBA. This is in comparison to the newer model R142A that had an average sound level of 69.7 dBA. This satisfies the suggested goal of 80 decibels for new cars cited in the Rapid Transit Noise Code. The results of Division B were even clearer that MTA NYCT is continually improving its fleet when it comes to noise reduction in passenger cars. For instance, the average sound level was found to be 80 dBA for a R32A versus 63.9 dBA for a newer R160B; this is a 16.1 dBA reduction in interior noise level.

Many older cars also meet the 80dBA noise level goal, including over 1,000 cars purchased in the 1970's. Currently, the newer R211 subway car models are being phased in and will replace all R44 cars on the Staten Island Railway and all R46 subway cars.

Other improvements have been made which reduce in-car noise. The use of controllers that more closely synchronize acceleration and deceleration of individual cars in a train reduces the incidence of locked wheels, thereby reducing a major cause of flat wheels. The use of improved door and window components provides better seals to insulate the car interior from outside noise. Some cars also have noise abating material installed under the floor.

The installation of welded rail and resilient rail fasteners has had a significant impact on in-car noise levels. Resilient rail fasteners are installed on reconstructed tangent (straight) track and unguarded (gentle) curves on subway concrete track (Type II) and elevated track (Type III). Welded rail is installed only on tangent track and unguarded curves in the subway, open-cut and at-grade sections of the track system.

Elevated Structure Environment

There are several treatments which can contribute to noise abatement on elevated structures. These treatments include the installation of resilient rail fasteners, wheel dampeners, wheel truing and the use of rail lubricants to reduce curve screech. Resilient rail fasteners with improved noise reducing characteristics now replace steel tie plates placed between the rail and the ties during elevated structure track replacement. Prefabricated track panels are constructed with resilient rail fasteners in place. NYCT installs resilient rail fasteners in Type III track installations at all tangent track and unguarded curve locations.

The occurrence of flat wheels can significantly contribute to an increase in the noise level of a train. In some cases, the increase can be as great as 10 dBA. Flat wheels generally occur because of poor controller operation, which causes unsynchronized acceleration and deceleration from car to car within the train. This in turn results in wheels dragging rather than rolling evenly on the rails. There are two related strategies for reducing flat wheels. One is to prevent them before they occur. Car controllers replaced as part of the completed car overhaul program have significantly reduced the incidence of flat wheels. The improvements made in controller maintenance and increased track testing of cars are also factors in assuring that controllers do not contribute to wheels flattening. The second strategy is to true wheels after they become flat. Wheel truing, a procedure in which the surface of the wheel is ground to correct flats, is an important part of MTA NYCT operations. Wheel truing also eliminates other imperfections created by irregular wheel wear which may cause them to generate excessive noise.

Curve and Brake Screech

Screech noise is generated by friction between wheels and rails, usually on tight curves. It can also be caused by friction from braking. The primary ways to reduce screech noise are through ring damped wheels, rail lubrication and composition brake shoes. Resilient rail fasteners may also reduce rail screech to some extent, but their effectiveness on reducing noise is better addressed in the sections covering elevated structures, stations, and in-car environments.

Ring damped wheels have shown to be an effective means to reduce wheel screech on curves. Rail lubrication of curves is used by MTA NYCT to reduce curve screech. All guarded curves with a radius of less than 1500 feet are equipped with lubricators with Maintenance of Way (MOW) personnel working year-round to keep the lubricators operational and in a good state of repair.

Old cast iron brake shoes have been replaced by new composition brake shoes that lower the screech associated with braking. Composition brake shoes provide a more constant level of friction and, to some extent, sound damping.

Station Environment

The station environment benefits from almost all noise treatments. This includes station acoustical treatments such as noise absorbing barriers installed between tracks and acoustic material installed over and under subway platforms and on ceilings over tracks. The other noise abatement treatments which lower noise in stations are the installation of welded rail with resilient rail fasteners, running trains with quieter traction motors and equipping cars with composition brake shoes and ring damped wheels. In addition, if the station is adjacent to a curve, rail lubrication of that curve will decrease screech noise as trains enter or leave the station.

The Station Reconstruction and Rehabilitation Programs such as the Enhanced Station Initiative are designed to reconstruct or refurbish all elements of a station. Noise reduction is one of the many types of improvements these programs produce. MTA NYCT has instituted a policy to include station acoustical treatments where appropriate as part of these programs.

2024 Noise Abatement Program Progress

Resilient Rail Fasteners

Resilient rail fasteners reduce noise by absorbing vibration from wheel-rail interaction and is the best method to reduce vibration and vibration-generated noise in supporting structures. Resilient fasteners can reduce noise by 3 to 5 dBA underground and 6 to 8 dBA on elevated tracks. NYCT installed 31,632 regular resilient rail fasteners in 2024, plus 12,756 super resilient rail fasteners in 2024. In 2025, 31,605 regular resilient rail fasteners are planned for installation, and 9,464 super resilient rail fasteners are planned.

New Low Vibration Track (LVT)

A new type of LVT is being installed throughout the NYCT System to determine its cost effectiveness. Several locations have been completed, and preliminary results show a marked improvement in vibration-generated noise. The Culver Viaduct LVT installation, which ended in 2013, was for 18,000 track-feet. The #7 Line Extension LVT track installation, completed in 2014, was for 13,600 track-feet. In 2016, 23,006 track-feet LVT was added when the 2nd Avenue Subway Line opened for business. In 2017, 13,629 track-feet LVT was added, in 2018, 656 track-feet LVT was added throughout the System, 2019, 2020 and 2021 did not include any LVT. A total of 41,649 track-feet of regular track was replaced in 2019, none was replaced in 2020 but a total of 33,739 track-feet was replaced in 2021. In 2022, 2023, and 2024 zero track-feet of low vibration track was added, and none is projected for 2025.

Continuous Welded Rail (CWR)

A proven noise reduction technique, welded rail continues to be installed with approximately 28,319 track-feet added throughout the system in 2020 which is approximately 56,638 feet of CWR. This includes continuous welded rail where rails are welded together to form one uninterrupted rail that may be several miles long. Because there are few joints, this form of track is very strong, gives a smooth ride, and needs less maintenance; trains can travel on it at higher speeds and with less friction. This technique can result in up to 8 to 10 dBA of noise reduction when used with resilient fasteners. CWR is installed on tracks underground and at-grade, but not on elevated track due to thermal expansion issues and need to modify structure and rail fixation. In 2024, 16,698 feet of CWR were installed and 21,000 track feet of CWR installation is planned for 2025.

Top of Rail Friction Modifiers

This is a technique that lubricates contact surfaces of the rail to reduce squeal, which can be very effective under certain circumstances: 4 units of top-of-rail friction modifiers were added in 2024 and 16 are planned for installation in 2025.

A new state of the art lubrication delivery technology called the DropsA Lubrication System is being installed throughout the system.

DropsA Lubrication System: IoT-Enabled Precision for Rail Maintenance

DropsA specializes in centralized lubrication systems and has developed an advanced, computerized rail lubrication system designed to reduce wear and tear on both rails and wheels. This state-of-the-art system precisely applies a programmed amount of lubricant to the rails, ensuring optimal performance, longevity, and efficiency in railway operations.

A key feature of the DropsA system is its IoT integration, which provides real-time monitoring, and automated alerts in the event of system malfunctions or maintenance needs. This smart technology significantly reduces the need for manual inspections, improves operational efficiency, and enhances safety.

Key Capabilities of the DropsA Lubrication System

- **Automated, Computer-Controlled Lubrication**: Ensures precise and consistent lubricant application, minimizing waste and maximizing effectiveness.
- **IoT Integration & Remote Monitoring**: The system continuously transmits data, allowing operators to monitor lubrication levels, track performance.
- **Fail-Safe Operation with Instant Alerts**: The system provides automatic notifications in case of malfunctions or errors, reducing response time and enhancing reliability.
- **Modular & Scalable Design**: Can be implemented across various rail networks, from small-scale installations to extensive railway systems.
- **Environmental Adaptability**: Adjusts lubrication based on real-time weather conditions, track usage, and environmental factors to ensure optimal application.
- **Wireless Connectivity**: Uses secure Wi-Fi or cellular networks for seamless communication between components and the main control system.
- **Weather-Resistant & Durable Design**: Built to withstand extreme environmental conditions for long-term reliability.

Benefits of the DropA System for Rails and Wheels

1. **Extends Equipment Lifespan**: Reduces friction between wheels and rails, minimizing wear and tear.
2. **Improves Safety**: Ensures consistent lubrication, preventing rail failures.
3. **Reduces Maintenance Costs**: Lowers the need for frequent manual inspections and repairs.
4. **Boosts Operational Efficiency**: Eliminates downtime caused by lubrication failures, ensuring uninterrupted railway operations.
5. **Environmentally Sustainable**: Optimized application minimizes excess lubricant usage, reducing environmental impact.

Installed Locations

DropsA Sumo Pump with Zone Box System

- West 8th St (BMT Brighton, A3, A4 Tracks)
- 21st St Van Alst
- 57th St
- 121st St on the BMT J Line
- Westchester Sq on the Lex
- Hoyt-Schermerhorn

DropsA Electric Barrel Pump System

- 14th St (Lexington Line, N/B Track Lube House)
- 14th St (Lexington Line, S/B Track Lube House)
- 18th Ave (West End Line, Lube House)
- 4th Ave/9th St (IND Prospect Line)
- Sheepshead Bay (BMT Brighton Line)
- 9th Ave (BMT West End)
- Simpson St (IRT White Plains)
- Hoyt-Schermerhorn
- Cortlandt

Projected Installation

Currently, the only projected installation is Hammel Wye on the A Line. While we aim to implement this system throughout the network, current budget constraints limit expansion.

Ring-Damped Wheels

All NYCT revenue subway car wheels continue to be outfitted with ring-damped wheels, which reduces bell-like ringing of wheels. Ring-Damped Wheels are economical and achieve between 15 to 20dBA screech noise reduction (both level and duration).

Wheel Truing

Flat wheels sometimes develop over time and can cause extreme noise conditions, in addition to potentially causing damage to rail and or the subway car itself. When it is ascertained through inspection that flat wheels exist the wheels are removed from the truck of the subway car and sent for wheel truing. Wheel truing machines are in 8 of our 15 Maintenance shops (239th Street, Corona, 207th Street, Jamaica, Concourse, East NY, Coney Island Overhaul Shop, 207th Street Overhaul Shop) and 1850 cars wheels were trued in 2022; 2,273 cars wheels were trued in 2023; 2,428 cars wheels were trued in 2024.

Fan Plants and Electric Substations

In addition to incorporating noise reduction techniques for new fan plants and substations, MTA NYCT has added silencers and vibration isolators to several existing above-ground fan plants to reduce emergency ventilation fan noise and ground-borne vibration to adjacent structures. In addition, in September 2022 a noise study was conducted at Maspeth Substation in Brooklyn to better ascertain noise levels in underground stations and what mitigation measures can be taken to minimize noise impacts for future installations. No noise complaints originating from operation of fan plants and electric substations were made in 2023 or 2024.

Buses

All recent, current, and future bus purchases require sustainable design incorporating the latest noise reduction methods available, such as through the use of state-of-the-art mufflers, to reduce the noise level exposure of passengers and bus operators as well as adjacent pedestrians, vehicles, housing, and businesses. Future studies may be performed to ascertain the effectiveness of current operations in regard to noise mitigation.

Annual and Projected Noise Abatement Financials

Noise Abatement Financials 2024			
Regular Resilient Rail Fasteners (feet)	31,632 Each/Total	2024 Construction Cost	$1,196,954.88
Super Resilient Rail Fasteners (feet)	12,756 Each/Total	2024 Construction Cost	$5,402,166.00
Track-feet of LVT installed (feet)	0 Feet/Total	2024 Construction Cost	$0.00
Track Feet replaced (feet)	25,200 Feet/Total	2024 Construction Cost	$13,834,800.00
Feet of Welded rail installed	33,396 Feet/Total	2024 Construction Cost	$856,165.90
Number top-of-rail friction modifiers	4 Each/Total	2024 Lubrication Cost	$175,000.00
2024 Material Cost			**$21,482,086.78**
2024 Labor Cost			**$124,800,000.00**

Noise Abatement Projected Financials 2025			
Regular Resilient Rail Fasteners (feet)	31,605 Each/Total	2025 Construction Cost	$1,195,933.20
Super Resilient Rail Fasteners (feet)	9464 Each/Total	2025 Construction Cost	$4,008,004.00
Track-feet of LVT installed (feet)	0 Feet/Total	2025 Construction Cost	$0.00
Track Feet replaced	37,116 Feet/Total	2025 Construction Cost	$20,375,570.52
Feet of Welded rail installed	12,231 Feet/Total	2025 Construction Cost	$462,821.04
Number top-of-rail friction modifiers	16 Each/Total	2025 Lubrication Cost	$249,600.00
2025 Projected Material Cost			**$26,291,928.76**
2025 Projected Labor Cost			**$162,240,000.00**

Response to Noise Complaints

MTA C&D measures and quantifies noise on transit equipment/structures for maintenance and troubleshooting purposes, but also in residences impacted by the operation of the subway system, critical infrastructure, and construction activity from NYCT capital projects. In 2024, Environmental Services responded to four new noise and vibration complaints from residents located throughout Brooklyn and Manhattan.

One noise study alleging harmful levels of noise in the subway system was submitted to the president of New York City Transit from Dr. Friedan, former Commissioner of the NYC Department of Health and Mental Hygiene and Dr. Juan P. Bello, Director of the Music and Audio Research Laboratory at NYU. The MTA's response involved multiple noise tests conducted at 10 stations identified in the report (Bleecker Street, Union Square, Herald Square, Columbus Circle, Rockefeller, Bleecker Street, Chambers Street, Times Square, Atlantic Avenue, Nevins Street, Grand Central, and Union Square); these tests did not corroborate the absolute peak noise levels reported by the NYU team. Two noise tests were conducted side by side with the NYU field team at Bleecker Street and Union Square and those tests likewise did not reproduce the absolute peak values reported by the NYU field team.

Eight repeat/follow up noise measurements were done that were related to noise testing conducted in the DUMBO section of Brooklyn that began in 2023. Two noise measurements were done in Coney Island related to pre-existing noise complaints made in previous years about train noise on elevated structures for the F&Q lines; progress is being made towards installing newer top-of-rail friction modifiers. Memorandums sent to various NYCT departments are included in the appendix of this report.

Conclusion

MTA NYCT has continued to make substantial progress in abating noise in the system. Transit's fleet is now entirely composed of new and overhauled cars, and new subway cars that are in the process of being phased in, such as the new R211 trains on the A line. Based on noise studies conducted by the MTA, it has been established that the noise exposure of the riding public is substantially less than the maximum acceptable dose established by OSHA for 8 hours continuous exposure (85 dBA, 8-hour time weighted average).

In the area of track MTA NYCT continues its capital program to improve its inventory of mainline track. Through the installation of welded rail, resilient rail fasteners and rail lubricators, substantial progress has been made in reducing noise. Rail welding and the installation of resilient rail fasteners is continuing in the next program as part of the normal replacement track program. Car equipment maintenance is also being undertaken to ensure that noise emissions are minimal by means of ring damped wheels and wheel truing. A total cost of $21,482,086.78 was spent on materials and $124,800,000.00 was spent on labor for noise mitigation efforts; a projected material cost of $26,291,928.76 and a projected labor cost of $162,240,000.00 is expected for 2025.

2 Broadway, 8th Fl.
New York, NY 10004-2207

Memorandum

Construction & Development

Date: October 2, 2024

To: Tony DiRuggiero, Assistant Chief Officer, Infrastructure Engineering, MoW Engineering

From: Stacy Konstantellis, Principal Environmental Specialist, Environmental Services, C&D

Re: Vibration Measurements, 250 Church Street Manhattan

Environmental Services conducted vibration measurements in a second-floor space and basement at the subject address between September 25-26, 2024. The highest vibration level measured that is attributable to passing subway trains is 0.0844 in/sec PPV in the apartment and 0.1179 in/sec PPV in the basement.

Noise measurements were also taken at the same locations; the highest noise level attributable to passing subway trains was 64.3 dB(A) on the second floor and 58.9 dB(A) in the basement.

The vibration levels measured at both locations are highly perceptible. According to published criteria, such vibration levels are approximately equivalent to vibration sources such as bulldozers and other heavy tracked construction equipment and are well beyond the upper range for commuter rails. Environmental Services strongly recommends a track inspection immediately.

If any further information is needed, please contact Gideon Dunkley of my staff at 646-316-9224.

cc:
G. Dunkley
M. Dawson
M. Qadri

2 Broadway, 8th Fl.
New York, NY 10004-2207

Memorandum

MTA Construction & Development

Date:	July 8, 2024
To:	Pierre Syldor, P.E., Asst. Chief Officer, Track Engineering Design & Specification, DOS
From:	Stacy Konstantellis, Principal Environmental Specialist, Environmental Services, C&D
Re:	Noise and Vibration Measurements, 181 18th Street, Brooklyn

Environmental Services conducted vibration measurements in a second-floor apartment and basement at the subject address between July 1 to July 2, 2024. The highest vibration level measured that is attributable to passing subway trains is 0.0835 in/sec Peak Particle Velocity (PPV) in the basement and 0.0348 in/sec PPV in the apartment. Noise measurements were also conducted at both measurement points. The highest noise level attributable to passing subway trains was 61.8 dB(A) in the basement against a baseline (L_{90}) of 39.0 dB(A); the highest noise level measured in the apartment was 51.4 dB(A) against a baseline (L_{90}) of 42.0 dB(A).

The noise and vibration levels measured in the apartment show a significant increase from February 2023, as no vibrations were detected on the seismometer at that time. The highest vibration level measured the year before in February 2022 measured 0.0248 in/sec for reference. The vibration levels in the basement show no improvement and are approximately the same in 2023 and 2024, and both years are higher than the max 0.0660 in/sec PPV measured in February 2022.

The vibration levels in the basement are highly perceptible. According to published criteria, such vibration levels are approximately equivalent to vibration sources such as bulldozers and other heavy tracked construction equipment and are well beyond the upper range for commuter rails. Environmental Services strongly recommends a track inspection immediately.

If any further information is needed, please contact Gideon Dunkley of my staff at 646-316-9224.

cc: G. Dunkley
M. Dawson
M. Qadri
R. Sarno
T. DiRuggiero

2 Broadway, 8th Fl.
New York, NY 10004-2207

Memorandum

Construction & Development

Date: **January 18, 2024**

To: **Vladimir Jean, Project Manager, Mechanical Engineering, Stations Business Unit**

From: **Stacy Konstantellis, Principal Environmental Specialist, Environmental Services**

Re: **Noise Measurements, 2nd Avenue 72nd Street Station Roof Cooling Equipment**

In response to complaints from residents about noise levels from cooling equipment on top of the 72nd street station roof, Environmental Services was requested to take noise readings with the cooling equipment operating in December 2023. The background sound level without the equipment running was measured at 61.6 dB(A); with the equipment on and running at 50% capacity, noise measurements taken around the perimeter of the roof and on the cooling tower catwalk measured noise levels between 56.4 dB(A) to 60.7 dB(A). These noise levels are indistinguishable from the background noise level as corroborated by playback of the sound recordings. Because the noise impact of the cooling system could not be determined when the system runs at 50% capacity, approval was obtained to run the system at 100% capacity.

Follow up measurements were taken on January 17, 2024, with the system running at 100% capacity closest to the two nearby sensitive receptors on the northeast and northwest side of the roof. On the northeast corner of the roof, the cooling system noise level was measured at 66.0 dB(A), and on the northwest corner of the roof, the noise level was measured at 58.9 dB(A). The northwest corner of the roof is more representative of the noise impact solely from the fan since traffic noise impacts the readings on the northeast side. For reference, the ambient sound level was measured at 60.8 dB(A) on the east side of the roof. Noise levels from the cooling system would be substantially less when measured inside a receiving property with the window open, because of sound level attenuation with distance and because the system will be running at 50% capacity, per the system Standard Operating Procedures.

If any further information is needed, please contact Gideon Dunkley of my staff at 646-316-9224.

cc: G. Dunkley
J. Pajarito
M. Qadri
K. Schnur

2 Broadway, 8th Fl.
New York, NY 10004-2207

Memorandum

Construction & Development

Date: **July 11, 2024**

To: **Vladimir Jean, Project Manager, Mechanical Engineering, Stations**

From: **Stacy Konstantellis, Principal Environmental Specialist, Environmental Services** SKonstantellis

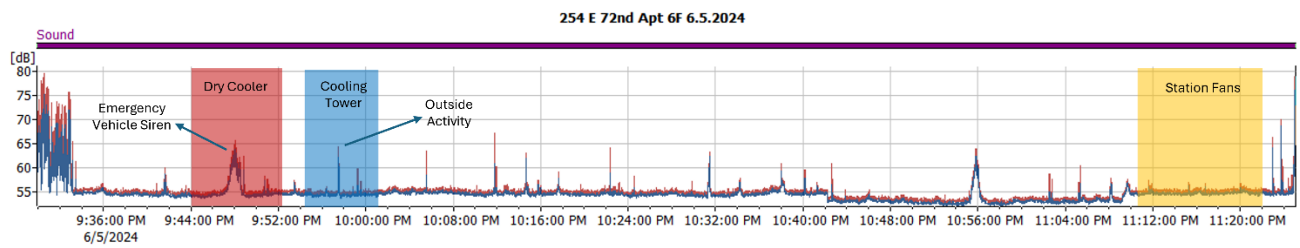
Re: **Noise Measurements, 2nd Avenue 72nd Street Station Roof Cooling Equipment**

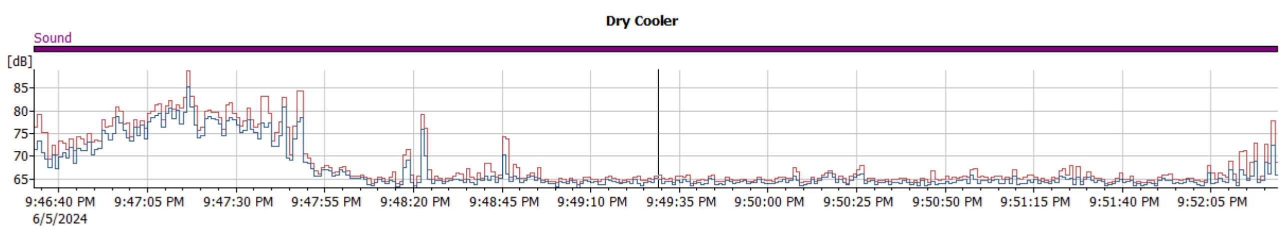
In response to complaints from residents about noise levels from MTA owned and operated cooling equipment on top of the 72nd street station roof, Environmental Services was requested to take noise readings with the cooling equipment operating. This equipment consisted of the rooftop dry cooler, cooling tower, and the noise emanating from the vent shaft coming from operation of the station and tunnel fan plants.

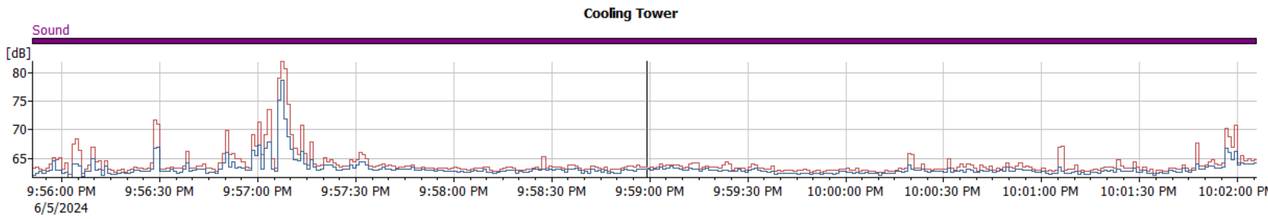
Noise measurements were collected on June 5, 2024 and June 26, 2024. On June 5, 2024 the dry cooler, cooling tower, and station fan plant fans were manually operated with noise levels being measured on the roof and simultaneously at 254 E. 72nd Street apartment 6F, a source of some of the noise complaints.

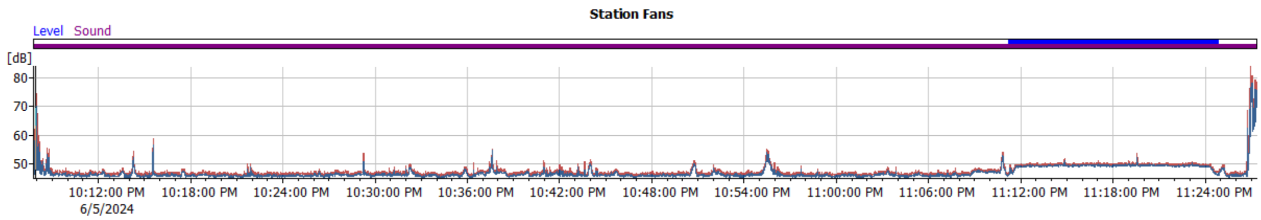
Side by side comparison of the two meters shows no increase in noise levels with manual operation of the cooling tower and dry cooler.

Below are graphs showing the times of operation of each cooling system superimposed onto a graph of the sound level in the resident's apartment on June 5, 2024.





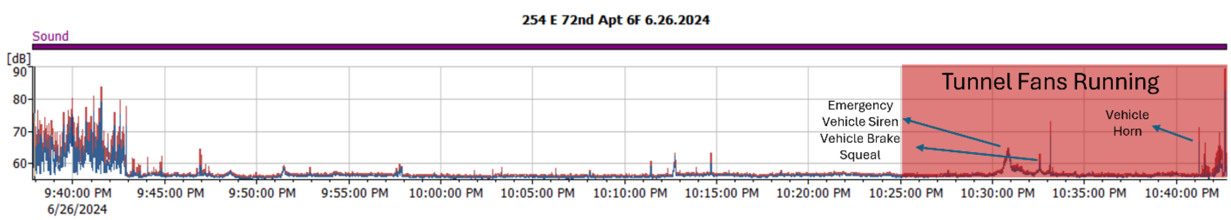


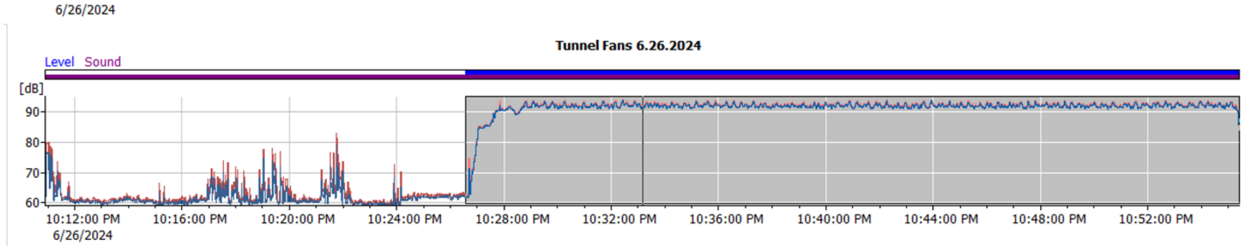


Extraneous noise unrelated to the operation of each cooling system was identified by means of playback of the sound recording of the meter in the resident's apartment. Permission was obtained from the resident to allow the instruments to record interior noise.

On June 26, 2024 the 72nd Street station tunnel fans were manually operated. Side by side comparison of the meter in the fan chamber and in the resident's apartment shows no increase in interior noise with the tunnel fan plant running.

The following graph shows the time of operation of the tunnel fan superimposed onto the graph of sound levels measured in the resident's apartment with extraneous noise similarly identified.





The above graphs show no increase in interior noise occurring with the onset of MTA owned cooling system operation.

If any further information is needed, please contact Gideon Dunkley of my staff at 646-316-9224.

cc: G. Dunkley
J. Fisher
M. Qadri
T. Abdallah

Richard Davey
President
New York City Transit
2 Broadway
New York, NY 10004

October 17, 2023

Re: Request for a meeting to discuss monitoring and mitigation of harmful levels of noise pollution in New York City subway stations

Dear President Davey:

Avoidable levels of noise in the subway system are creating an imminent health hazard for millions of New Yorkers. The attached draft report documents that sound levels created by MTA subway cars are resulting in substantial health harms to riders. We request a meeting with you and/or your team to discuss these findings and means to monitor and mitigate harmful noise pollution in subway stations.

Attached is a draft report of what is, to our knowledge, the most rigorous analysis of noise pollution of the New York City subway system. With philanthropic support, we were able to field a team of investigators with state-of-the-art sound recording equipment and event tracking systems to measure levels of ambient noise in 32 stations, with nearly 100 hours of thorough recording.

The results indicate a significant public health hazard:

- Intense and prolonged exposures to harmful noise levels with absolute peak dBA levels above 110 dBA and peak average dBA levels above 90, with one station reaching 113.6 and 98.6 respectively.
- Five stations among those tested were notable for harmful noise levels and large proportions of the time with elevated noise levels: Lafayette Avenue, Union Square, 23rd Street, Bleecker, and Lexington Ave/51st.
- Three factors were associated with higher peak and average levels: (1) express tracks, (2) a large number of tracks, and (3) stations with both numbered and lettered subway lines. Express tracks mainly affect peak values and exposure, while many tracks from multiple divisions drive high average levels during events. For some stations the difference between average values during sound events and background is more than 10dBA (10 times louder). Further, the absolute peak levels during events can increase by another 10dBA or more, i.e. they are 100 times louder than background.
- More than a third of the stations sampled had sound events occurring 70% or more of the measurement time, e.g., 7 minutes of loud noise during a 10-minute wait.

Proven negative health impacts of excess noise include irreversible hearing loss, increased risk of heart disease and stroke, lower sleep quality and other sleep disturbances, as well as impaired focus, memory, and academic performance. In addition to these proven negative impacts, there is growing evidence for other negative health impacts including increased risk of preterm birth and impaired cognitive and emotional development in children.

Although some rider behaviors (e.g., volume of headphone-delivered sound) will influence the ototoxicity of the subway system, the MTA can substantially reduce health harms by remediating "loud spots". Your staff would be best placed to identify remediation, which might include track alignment, subway car wheel and brake maintenance and operation, and other design, operation, maintenance, and mitigation strategies. An intensified program by the MTA to monitor and remediate dBA exceedances would protect rider and staff health.

We request a meeting with you and/or your representatives in the coming weeks, either virtually or in person. At this meeting, we look forward to providing further information on the methodology and results of our analysis and learning what the MTA is doing and will do to reduce this harm to your customers.

We are eager to share data and to help in any way we can to improve noise monitoring and mitigation in the subway system. We plan to write a scientific publication with these results, and it would be great if we could include discussion of positive engagement with the MTA in this report.

We are strong supporters of public transportation. We firmly believe that a collaborative approach would be the best way to address this important issue.

Sincerely,

Thomas R. Frieden, MD, MPH[1]   Juan Pablo Bello, PhD[2]

Copies to:

Janno Lieber, Chair and CEO, Metropolitan Transportation Authority
Demetrius Crichlow, Senior Vice President, Department of Subways
Jon Kaufman, Chief of Strategic Initiatives
John McCarthy, Chief of External Relations
Patrick Warren, Chief Safety and Security Officer

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[2] *Dr. Bello is Professor, Music Technology, Computer Science and Engineering, Center for Urban Science and Progress, and Electrical and Computer Engineering; and is the Director of the Music and Audio Research Laboratory (MARL) at New York University. His noise pollution work has been profiled in the New Yorker, New York Times, and many other news outlets.*

Technical Report: Noise levels across the NYC subway system
Music and Audio Research Lab, New York University
Contact: jpbello@nyu.edu; tfrieden@gmail.com

Executive summary:
A scoping study on noise levels in the NYC subway system found that millions of passengers are regularly exposed to sound levels that pose a significant health hazard. Prior studies have shown that average noise levels in the NYC subway system potentially exceed the community exposure limits recommended by the EPA and WHO. We expand on these results by investigating the effect of division, station features (number of tracks, express tracks) and occupancy on noise levels.

We collected approximately 90 hours of calibrated sound pressure level (SPL, measured in dBA) data and manual annotations at 183 train tracks across 32 stations in Manhattan and Brooklyn, including some of the busiest stations in the network. We separated this data into sound event and background segments, computed peak and average SPL across tracks for all conditions and stations, and analyzed it to understand the effect of division, number of tracks per station, presence of express tracks and approximate ridership numbers per station as a proxy for occupancy. We found that occupancy, especially in large station complexes, is the main driver of high background (non-event) SPL values. However sound events, which are noisiest and most harmful, are driven by station features. Important findings include:

- Intense and prolonged exposures to harmful noise levels with absolute peak dBA levels above 110 dBA and peak average dBA levels above 90, with one station reaching 113.6 and 98.6 respectively.
- Five stations among those tested were notable for harmful noise levels and large proportions of the time with elevated noise levels: Lafayette Av (Brooklyn), Union Square, 23rd Street, Bleecker, and Lexington Ave/51st.
- Three factors result in higher peak and average SPL values: (1) express tracks, (2) a high number of tracks, and (3) the combination of divisions AB (i.e., stations with both numbered and lettered subway lines). Express tracks mainly affect peak values and exposure, while many tracks from multiple divisions drive high average SPL values during events. For some stations the difference between average SPL values during sound events and background is over 10dBA (10 times louder).
- More than a third of the stations sampled had sound events occurring 70% or more of the measurement time, e.g., 7 minutes of loud noise during a 10-minute wait.
- The combination of these factors can be used to identify high-priority stations for intervention, such as Union Square, the 4th busiest station in the system, for which we observed a 10.72 dBA increase in the presence of sound events, including the second-highest average peak level at 94.32 dBA and sound events occurring over 75% of the measuring time.

Sound levels created by MTA subway cars on platforms are resulting in substantial health harms to riders. Scientific evidence documents that the cumulative burden of excess noise includes

hearing loss, which contributes to loss of cognitive capacity with aging; increased stress; higher blood pressures contributing to heart attack and stroke; disturbed sleep; and more. Although some rider behaviors (e.g., volume of headphone-delivered sound) will affect the ototoxicity of the subway system, the MTA can substantially reduce health harms by remediating “loud spots”, possibly related to track alignment, subway wheel and brake maintenance and operation, and other design, operation, maintenance, and mitigation strategies. An intensified program by the MTA to monitor and remediate dBA exceedances would improve rider and staff health.

Contributions:
Conceptualization: Juan P. Bello, Tom Frieden, Iran R. Roman and Charlie Mydlarz
Analysis: Chuyang Chen, Iran R. Roman, Juan P. Bello
Methods: Chuyang Chen, Adelaide Zhang, Iran R. Roman, Charlie Mydlarz, Juan P. Bello
Writing: Chuyang Chen, Iran R. Roman, Juan P. Bello
Data Collection: Adelaide Zhang, Mridula Anandhakrishnan, Chuyang Chen, Nancy Rico-Mineros, Jacob Li, Jesse Chang-Frieden and Charlie Mydlarz

1. Introduction

The New York City subway system is a rapid transportation system comprising the largest network of stations (472) in the world. It is also the oldest such system and one of the busiest, with an annual ridership of over 1 billion in 2022.[1] These numbers remain lower than the 1.6-1.7B yearly passengers registered pre-pandemic, but have been increasing since 2021. Due to its vast ridership, regular exposure to loud noise in subway stations has the potential to affect millions of people.[2] Excessive noise is a significant public health hazard, with negative effects including increased risk of hearing loss, cardiovascular disease, stress, anxiety and other physical and mental health conditions. Thus the monitoring of sound levels in the subway system is necessary to understand levels of exposure, identify structural issues causing said exposure and plan accordingly to prevent the resulting health risks and losses.

Proven negative health impacts of excess noise include:
1. Irreversible hearing loss
2. Increased risk of high blood pressure, heart disease, and stroke
3. Lower sleep quality and other sleep disturbance.
4. Elevated cortisol levels
5. Cognitive Impairment with impaired focus, memory, and academic performance.

In addition to these proven negative impacts, there is growing evidence for other negative health impacts including increased risk of preterm birth and impaired cognitive and emotional development in children.[3,4,5]

Prior research has shown that noise levels in the NYC subway and bus systems exceed exposure guidelines from the Environment Protection Agency (EPA) and World Health Organization (WHO).[6] Also that noise levels in NYC subway platforms are significantly louder in comparison to other mass transit systems including buses, ferries, commuter railways, and tramways.[7] However, these works were limited by technology that could not record long series of sound pressure level (SPL) measurements, and thus did not evaluate the temporal variations of noise as a function of transient events (e.g., train arrivals, tannoy announcements, etc). In most cases, these studies were performed on a small subset of train tracks and stations.

In this study, we collected time series of SPL measurements across 183 tracks in 32 stations of the NYC subway system. We used a combination of annotations and algorithmic analysis to

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[1] Metropolitan Transit Authority. https://new.mta.info/. Accessed July 13, 2023
[2] Gershon, R. R., Qureshi, K. A., Barrera, M. A., Erwin, M. J., & Goldsmith, F. (2005). Health and safety hazards associated with subways: a review. *Journal of Urban Health*, *82*, 10-20.
[3] Auditory and non-auditory effects of noise on health - PMC
[4] Cardiovascular effects of environmental noise exposure
[5] Occupational and Environmental Noise Exposure and Extra-Auditory Effects on Humans: A Systematic Literature Review
[6] Gershon, R. R., Neitzel, R., Barrera, M. A., & Akram, M. (2006). Pilot survey of subway and bus stop noise levels. *Journal of Urban Health*, *83*, 802-812.
[7] Neitzel, R., Gershon, R. R., Zeltser, M., Canton, A., & Akram, M. (2009). Noise levels associated with New York City's mass transit systems. *American journal of public health*, *99*(8), 1393-1399.

temporally segment this data into sound events and background. Using these segments we computed peak and average SPL across tracks for conditions and stations and analyzed them to understand the effect of station features and occupancy on noise levels. To the best of our knowledge we are the first to do this.

2. Methodology

2.1. Sample

We measured SPL at 183 tracks across 32 subway station complexes in the Manhattan and Brooklyn boroughs of the NYC subway system. The selected complexes consisted of major transfer points as well as local stations. Thirty of these stations were selected to create visualizations, as their layouts are available online,[8] with 2 more stations added for completion. For each station we collected metadata from the Metropolitan Transportation Authority (MTA) official website, namely ridership ranking, division, express track presence, and number of tracks in the station:

(a) *Ridership ranking* is measured by calculating the number of passengers entering the subway system. We obtained the rankings of the target stations from the 2021 subway ridership data and divided them into four quartiles.[9] Thus the first quartile consists of station complexes that have the highest volume of passengers (high), with the second to fourth quartiles representing, respectively, mid-high, mid-low and low levels of ridership.

(b) *Division* refers to the A and B divisions of the NYC subway system, each representing a group of operating lines. The A division consists of services designated by numbers, whereas the B division consists of lettered lines. A division cars are lighter and narrower than B division cars. Some station complexes include both divisions and are thus represented as AB.

(c) *Express track presence* indicates whether express trains pass through the station.

(d) The *number of tracks* in a station is easily obtained from the station layout.

A complete list of stations and their characteristics, as relevant for this study, can be found in Appendix A. We consider these stations to be representative of the diverse characteristics of the NYC subway system.

2.2. Data Collection

Data collection took place from November 16, 2022 to March 28, 2023. It was completed by five team members at assigned times and locations. All recordings were done between 10 am and 4 pm from Mondays to Thursdays. We restricted the recording schedule to minimize the influence of factors such as increase of ridership during rush hours and on weekends.

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[8] http://www.projectsubwaynyc.com/gallery

[9] Subway And Bus Ridership For 2021. https://new.mta.info/agency/new-york-city-transit/subway-bus-ridership-2021. Accessed July 13, 2023.

We used two devices for data collection: 1) a sound level meter (SLM) to measure sound pressure levels (SPL), and 2) a mobile phone into which data collectors annotated events in real time. We used the industrial-grade Reed Instruments R8070SD Data logging Sound Level Meter[10] to measure SPL. It was set to use the A-weighting system and sample SPLs at a rate of 1 Hz for up to 30 minutes per session (1,800 measurements). The SLM microphone is detachable (but wired) by design. This allowed us to attach it on top of a wearable baseball cap that data collection participants wore on their head when recording SPL. Wind screens were used to protect the microphones from potential gusts of air, such as subway trains passing nearby. We used the Neukadye mobile app[11] to record timestamped observations in real time (i.e. annotations). The app allows team members to click on preset text labels and automatically saves the timestamps when a label is clicked. Appendix B lists all preset text labels used. The researchers also had the opportunity to enter timestamped free-form text at any given time. SPL measurements and text annotations were aligned post-hoc for each session.

At the beginning of each recording day, the data collectors gathered all equipment and calibrated the SLM with a 94 dB sound level decibel calibrator in our lab. They also synchronized the clocks on the SLM, which are lost every time batteries are changed, so the measurements align with the field note timestamps. For each recording session, a researcher stood at a fixed location at the middle section of the platform, approximately 1.5 feet away from the edge of the track. A recording session starts as the researcher enables the logging function of the SLM to save its readings to an SD card. All recording sessions had a target duration of 30 minutes. At the same time, the data collection participants annotated train activities and other perceptually loud noises using the phone app Field Notes. Train arrivals and departures were systematically annotated with the preset keywords, while any other loud events were individually and manually typed. A data collection participant normally completed two to five recording sessions on each recording day. One unique recording was made for all 183 train tracks in our target stations.

2.3. Event Detection

For the purpose of this study, we identified time intervals in our SPL recordings that correspond to discrete sound events, such as train activities, station announcements, or noise from other platforms, etc. We partially achieve this by using the annotations produced during data collection. However there are limitations. Although the annotations indicate the presence of loud sound events, the timestamps associated with each label may fail to fully represent the beginning and ending of an event. In addition, it is unavoidable that some events are missed or mislabeled, especially when multiple events occur simultaneously or out of the field of vision of the researcher. Note that the mobility of the researchers during data collection is restricted to preserve the validity and consistency of the SPL measurements. To consistently extract periods of loud events from the raw SPL recordings, we developed an event detection algorithm which was optimized using the event annotations. As a result, we obtained time intervals that delimit discrete sound events within the recording of each track.

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[10] https://www.reedinstruments.com/product/reed-r8070sd-data-logging-sound-level-meter
[11] https://www.neukadye.com/mobile-applications/timestamped-field-notes/

After applying our event detection algorithm, we then proceeded to segment each recording into event and background segments, allowing us to differentiate noise behavior in SPL in the presence or absence of train activity. We use these segments to compute five metrics per station:

(a) Average Level: the arithmetic mean of all SPL readings across tracks.
(b) Average Level (events): the arithmetic mean of SPL values during sound event segments across tracks.
(c) Average Level (background): the arithmetic mean of SPL values during background segments across tracks.
(d) Average Peak: the arithmetic mean of the maximum SPL value per sound event segment across tracks.
(e) Event Exposure: the ratio between the temporal duration of sound events and the total duration across tracks.

3. Analysis and Results

The following subsections correspond to each of the five metrics described above. For each metric we rank all stations from high to low and present (a) a table with the top-10 stations for a given metric, and (b) a set of figures comparing the distribution of top-10 stations as a function of station features: ridership ranking, division, number of tracks, and presence of express trains, as retrieved from the metadata. In each of these figures we show an orange bar corresponding to the number of top-10 stations for a given feature value, and a blue bar showing the number of stations that would correspond to a given feature value if the stations were sampled at random. The intuition behind these figures is that if the orange bar is higher than the blue bar, then that station feature is overrepresented in the top-10 and is likely a driving factor behind the metric being analyzed. For example, in a random sample of 10 stations, we expect 2-3 stations to correspond to the high ridership quartile. If for average level we see 5 stations in our top-10 in the high ridership quartile, that might be an indication that high ridership drives average noise levels. With this in mind, below are the results.

3.1. Average Level

We first investigate the top ten stations with the highest average level. Table 1 shows these results. UnionSq is the highest ranked station followed by GrandCentral, with average levels over 76 dbA. This is remarkable if we consider that these stations add to 18 tracks, so these are average dBA values over 9 hours of recordings. Figure 1 shows that the top stations show overrepresentation of the high ridership quartile, with twice as much as random. Same for large station complexes with 4 tracks or more (notably 10 or more), and those featuring both divisions (AB). Conversely, mid to low ridership stations are undersampled, same as those with division B and less than 4 tracks. The presence of express tracks seems to have no effect. These results indicate, unsurprisingly, that major station complexes with high ridership are noisiest. Note that the top-4 busiest subway stations: TimesSq42, HeraldSq, GrandCentral and UnionSq, are in

Table 1, albeit not in the same order. Also that the high number of tracks and the presence of both divisions co-occur with high ridership. Yet there is no exact correlation between ridership and average noise, otherwise TimesSq42, with twice as much ridership as UnionSq, should be at the top, and certainly not below a small station like Nevins. To understand these patterns better, the following subsections look at average levels segmented by event and background.

Rank	Station	Average Level (dBA)	Ridership Ranking	Division	Express Track	Number of Tracks in the Station
1	UnionSq	78.64	1	AB	None	10
2	GrandCentral	76.85	1	AB	None	8
3	Rockefeller	75.73	2	B	None	4
4	ColumbusCir	74.54	1	AB	23	6
5	BwayBleecker	74.36	3	AB	45	6
6	HeraldSq	74.11	1	B	None	8
7	CityHallChambers	74.03	3	AB	None	6
8	Nevins	73.72	4	A	None	4
9	TimesSq42	73.53	1	AB	None	16
10	AtlanticBarclays	73.44	2	AB	None	10

Table 1: Top ten stations with the highest average level

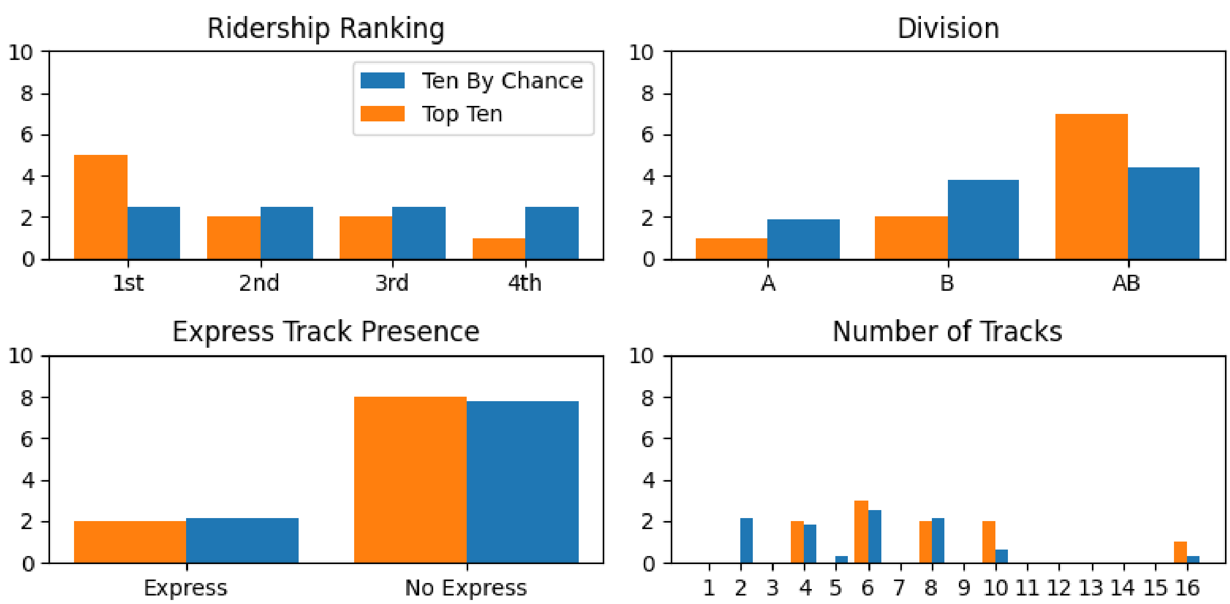

Figure 1: Comparison of feature distributions for average level

3.2. Average Level (background)

This metric measures the mean SPL in the absence of sound events. As shown in Figure 2, 7 of the top stations are in the 1st quartile of ridership ranking, which is nearly thrice as much as random. Thus, when compared with average levels, background average levels seem to be even more highly correlated with high ridership. 6 out of the 7 high ridership stations in the table feature both divisions, with the number of tracks ranging between 6-16 and averaging 8.85. Thus we can see clearly that the high average levels in section 3.1 are to a large extent explained by the occupancy of busy stations in multi-track halls, even in the absence of train events. This could be caused by a combination of activities including passenger movements, conversations, and reverberation in the stations.

Rank	Station	Average Level (no events) (dBA)	Ridership Ranking	Division	Express Track	Number of Tracks in the Station
1	GrandCentral	70.63	1	AB	None	8
2	UnionSq	70.54	1	AB	None	10
3	ColumbusCir	69.51	1	AB	23	6
4	Rockefeller	68.59	2	B	None	4
5	TimesSq42	66.65	1	AB	None	16
6	Lexington59	66.58	1	AB	None	6
7	Nevins	66.0	4	A	None	4
8	FultonMan	65.87	1	AB	None	8
9	HeraldSq	65.16	1	B	None	8
10	DelanceyEssex	64.81	3	B	None	5

Table 2: Top ten stations with the highest average level (no events)

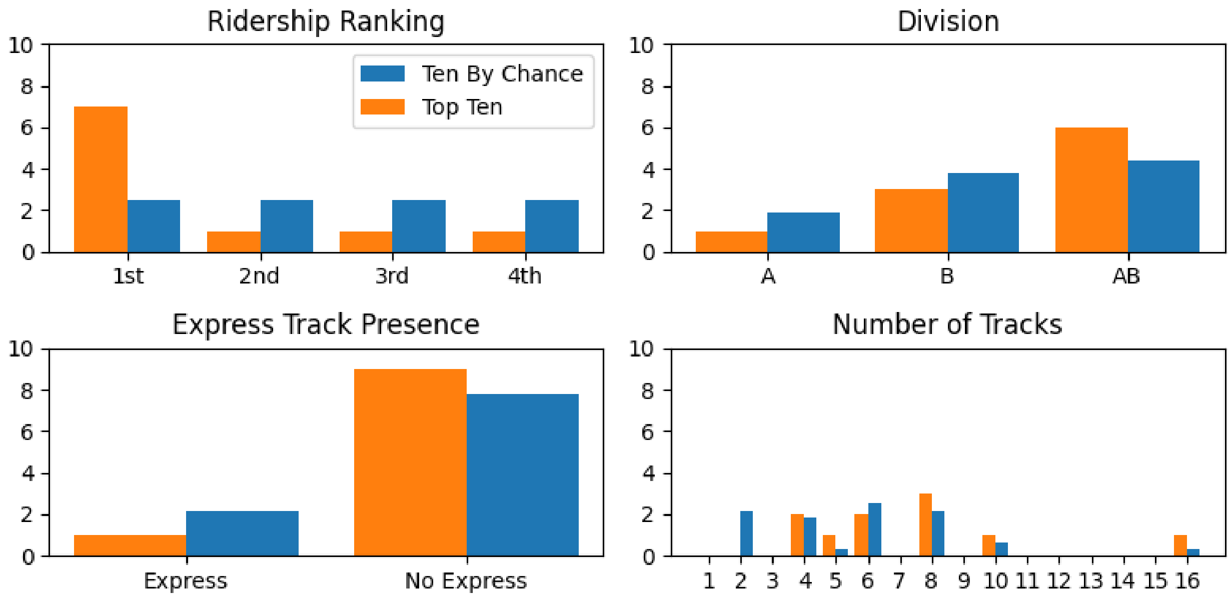

Figure 2: Comparison of feature distributions for average level (no events)

In contrast to the background average level, this metric measures SPL averages across sound events. In Table 3 we can see that average SPL levels are significantly higher than in Table 2. The top ranked station (UnionSq) has an average SPL of 81.26 dBA during events, which is 10.63 dBA higher than the top station during background segments. In fact, for UnionSq the increase due to sound events is 10.54 dBA, more than 10 times as loud. Overall, while several high ridership stations remain, some of the busiest ones are no longer in the list (notably TimesSq42, and HeraldSq, the top-2 in ridership). Further, the table now includes 4 stations from the bottom 2 ridership quartiles, indicating that more than ridership is at play. This is intuitive since in the presence of loud acoustic events, noise from human activity is largely masked (e.g. when having a conversation while a train arrives). Mechanical noise, from the train and its friction with tracks and platforms, plus amplification from the acoustics of the station hall, take over. Figure 3, shows that division AB, stations with 6 tracks and the presence of express tracks make an outsize appearance in the table as well. Much of this is correlated with high ridership, like in UnionSq and GrandCentral, but notably two mid-low ridership stations, CityHallChambers and BwayBleecker, with 6 tracks and AB divisions, also appear in the table, indicating that these factors might be drivers of high SPL during sound events across stations of varying occupancy. This trend is broken by two mid to low ridership stations, with a single division and 2 tracks each: Lafayette and 23rd street, indicating that the presence of express tracks is an independent factor contributing to high SPL values. BwayBleecker, also in the list, is the only station combining AB divisions, 6 tracks and an express track. All of these stations show more than a 10-fold increase in loudness during sound events.

Rank	Station	Average Level (events)	Ridership Ranking	Division	Express Track	Number of Tracks in the Station

		(dBA)				
1	UnionSq	81.26	1	AB	None	10
2	CityHallChambers	79.34	3	AB	None	6
3	Lafayette	78.74	4	B	A	2
4	Rockefeller	78.67	2	B	None	4
5	GrandCentral	78.66	1	AB	None	8
6	FultonMan	77.62	1	AB	None	8
7	Lexington59	77.62	1	AB	None	6
8	BwayBleecker	77.59	3	AB	45	6
9	23St	77.28	3	A	45	2
10	JaySt	77.21	2	B	None	6

Table 3: Top ten stations with the highest average level (events)

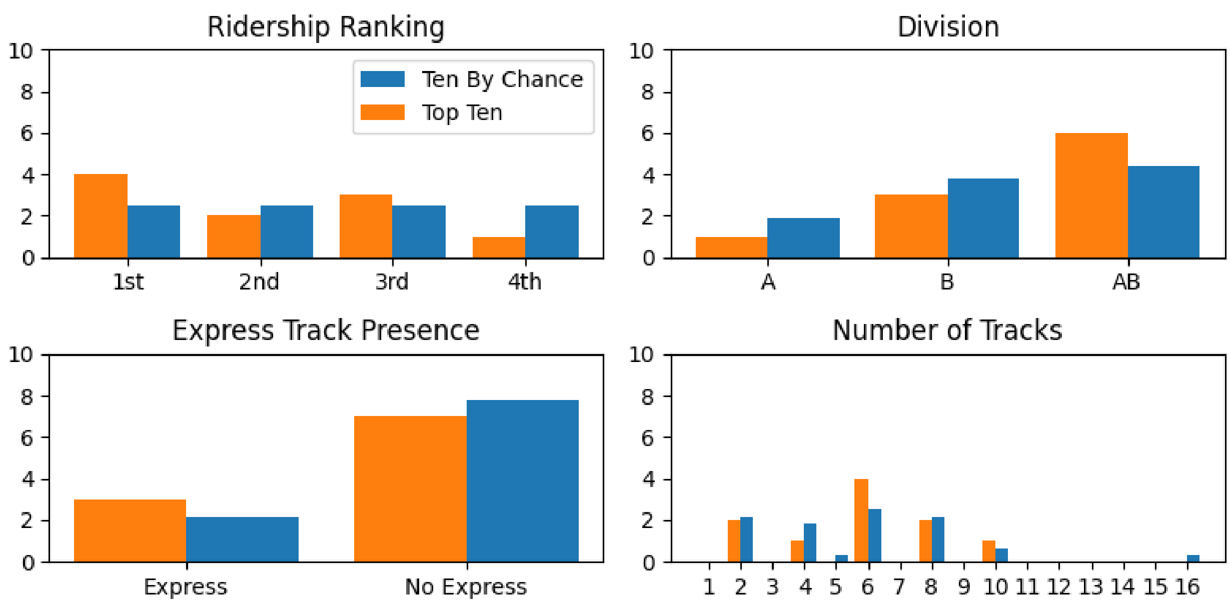

Figure 3: Comparison of feature distributions for average level (events)

<u>3.4. Average Peak</u>

To complement the results from the previous section we look at average peak rankings in Table 4 and Figure 4. Mid to low ridership stations like Lafayette, 23St and BwayBleecker appear now at the top, with Lafayette showing significantly higher peak values (+4.29 dBA) than any other station. The common factor for these stations is the presence of an express track. Figure 4 shows that 5 of the top stations have express lines, which is more than twice as likely as random. Since express lines have no apparent effect on background or overall average SPLs, and their effect on average event SPL is more moderate, we can conclude that they are the main driver of the loudest events in the network. The figure also shows that stations with 6-10 tracks, and the presence of division AB and, for the first time, A, also have an effect. Finally, while we use average peak levels to characterize noise exposure during events, the last column of Table 4 also reports the absolute peak values measured at each one of those stations. The highest peak value registered across the network is 113.6 dBA at Lafayette Avenue station, well over the level of harmful noise exposure. Six of the 10 stations in the table report absolute peak levels over 110 dBA, with 14 stations overall reporting absolute peaks over 100 dBA.

Rank	Station	Average Peak (dBA)	Ridership Ranking	Division	Express Track	Number of Tracks in the Station	Absolute Peak (dBA)
1	Lafayette	98.6	4	B	A	2	113.6
2	UnionSq	94.31	1	AB	None	10	112.9
3	23St	93.5	3	A	45	2	97.7
4	BwayBleecker	93.31	3	AB	45	6	113.4
5	Lexington51	92.84	2	AB	None	4	113.4
6	WTCCortlandt	92.22	4	A	None	2	99.3
7	Canal	92.21	2	AB	45	8	110.1
8	ColumbusCir	91.55	1	AB	23	6	110.5
9	Lexington59	90.74	1	AB	None	6	98.6
10	Rockefeller	90.69	2	B	None	4	97.6

Table 4: Top ten stations with the highest average peak

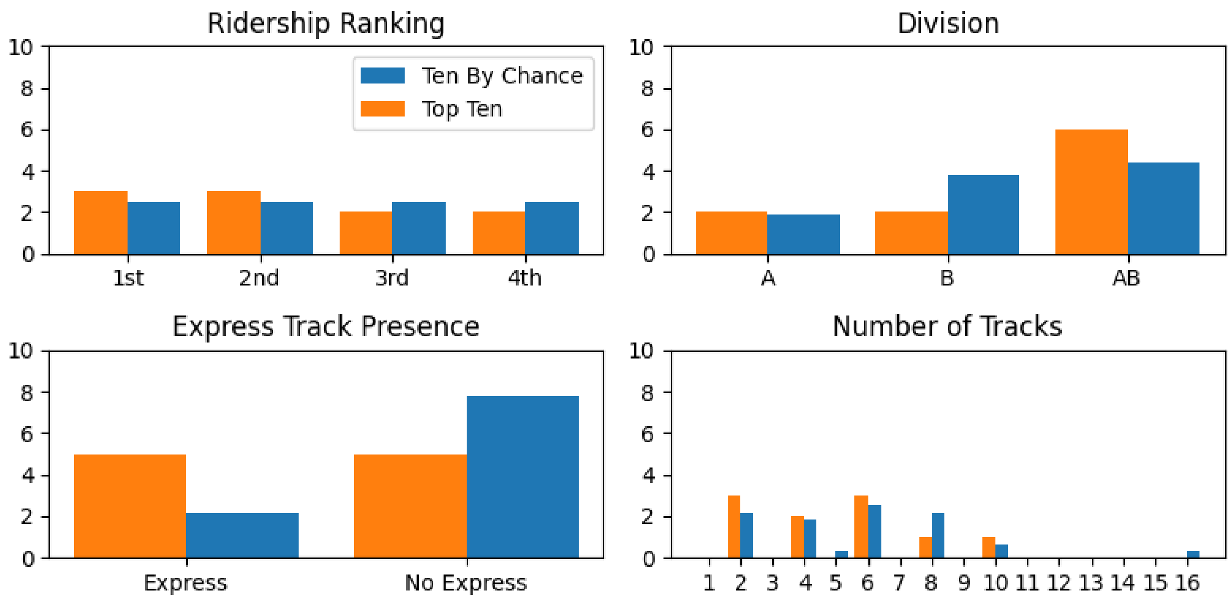

Figure 4: Comparison of feature distributions for average peak

3.5. Event Exposure

Finally, we look at how station features affect event exposure, that is, the percentage of measured time that sound events were occurring. Table 5 shows that the top stations have event exposure ranging from 70.57% to 82.06%. These are unexpectedly high levels, meaning that during a 10-minute wait at these stations, passengers can expect 7-8 minutes of activity related noise. As we have seen, these can result in noise exposure 10 times as loud than at background levels in those stations. In Figure 5 we can see that the presence of express tracks seems to have an impact on exposure, in other words, express trains not only raise SPL in the stations as they pass, but they can also contribute to long periods of exposure to noise. Less intuitively, this is the same for having 4 or 10 tracks in the station. One potential interpretation is that 4-track halls drive exposure, with station complexes rarely, if ever, having bigger halls. Yet the trends are nowhere as significant as for the other metrics, and are mostly marginal. For most feature values, the sample simply fluctuates around random.

Rank	Station	Exposure Prevalence (%)	Ridership Ranking	Division	Express Track	Number of Tracks in the Station
1	Hoyt	82.06	4	A	45	2
2	Nevins	79.11	4	A	None	4
3	GrandCentral	77.17	1	AB	None	8
4	UnionSq	75.25	1	AB	None	10
5	BwayBleecker	74.98	3	AB	45	6

6	HeraldSq	74.42	1	B	None	8
7	BryantPark	73.5	2	AB	None	6
8	DeKalbAv	71.13	3	B	DN	4
9	Rockefeller	70.83	2	B	None	4
10	AtlanticBarclays	70.57	2	AB	None	10

Table 5: Top ten stations with the highest exposure prevalence

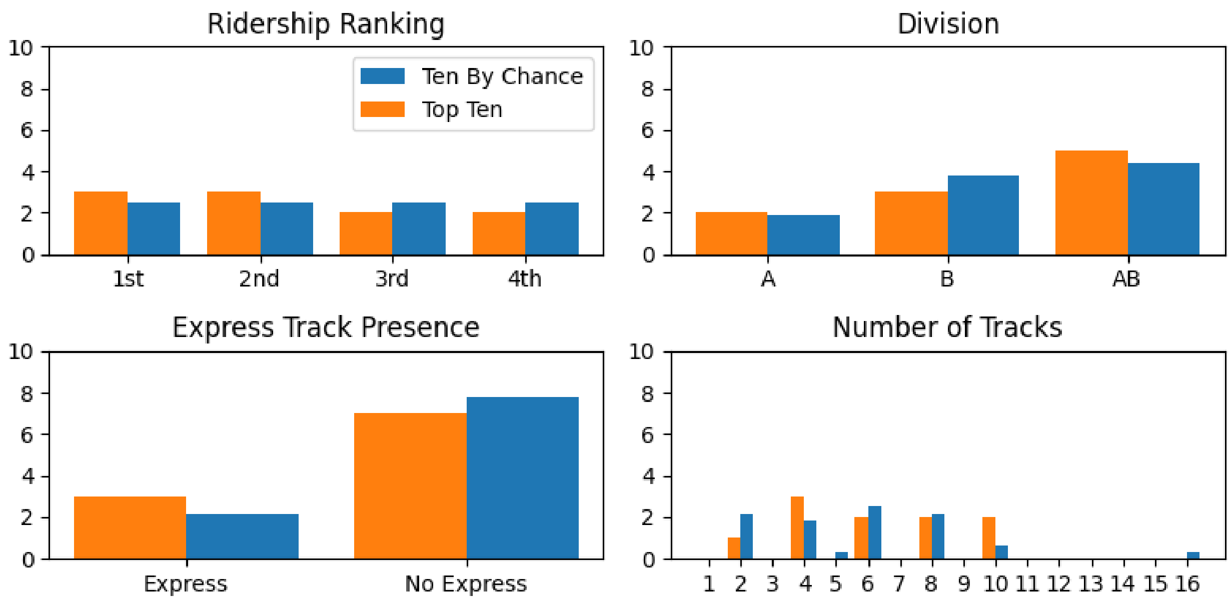

Figure 5: Comparison of feature distributions for exposure prevalence

4. Discussion

In summary, our results show that noise levels in the NYC subway system are partly driven by occupancy (as approximated via ridership ranking) and partly driven by station features including division, express trains, and the number of tracks in the station. What is novel in our study is that, by splitting the data into events (mainly trains arriving, departing and passing) and background conditions, we can better discern the effect that different features have on noise levels.

Station complexes with high ridership are likely to experience high levels of average background noise in the absence of sound events. This means that human activities within subway stations naturally raise the noise floor, and that the acoustics of a station play a role, especially in large, multi-platform station complexes with large reverberant halls. This is unsurprising and intuitive, but hard to mitigate. Further, background levels are significantly lower than average levels, indicating that background conditions are less of a priority in tackling exposure to noise events – arriving, departing, and passing trains.

The situation is markedly different during sound events, especially train events. The average noise levels during these events can increase by 10 dBA or more, i.e. are 10 times louder than background. Further, the average peak levels during events can increase by another 10dBA or more, i.e. they are 100 times louder than background. Note that these are average and not actual peak levels, which are likely much higher. Concerningly, for a third of the stations in our study, sound events occurred for more than 70% of total measurement time, indicating that sustained, high noise exposure is not rare amongst these stations.

Our analysis suggests that SPL averages during sound events are driven by a combination of a high number of tracks, the presence of both divisions, and express tracks. However not all stations ranking high have the same combination of features. We can identify two main types of layouts involved: (a) large, 6+ tracks stations with both AB divisions; and (b) small 2-4 tracks stations with express tracks. The common thread is increased train activity due to neighboring tracks for (a) and passing express trains for (b). In most large stations ranked high there is at least one level with 4 adjacent tracks, and in a few cases two (e.g. UnionSq). The high traffic of trains in a 4-track level increases both SPL and the event exposure of passengers standing in any of the 2-3 platforms servicing that level. In small stations ranked high the overwhelming driving factor is the increase of SPL and exposure caused by passing express trains. In fact, our study shows that express trains are the main factor behind the highest peak levels across all stations.

Several stations are ranked in the top ten for two or more of the calculated metrics. The most salient cases are UnionSq, GrandCentral and Rockefeller, which are the 3 loudest overall, with high background and event SPLs, and event exposures of approximately 75, 77 and 71% respectively. Both UnionSq and GrandCentral are consistently in the top-4 of the busiest stations in the city, with high noise levels regularly affecting hundreds of thousands of people. UnionSq is an especially egregious case as it has the highest sound event average value, the second highest average peak and average backgrounds values amongst our sample, and the 4th highest level of event exposure and ridership. It is likely fertile ground for pilot interventions, such as track, wheel, and brake mitigation, analysis of operator and train variability, sound barriers between neighboring tracks, and/or the testing of low-friction track/train components to address some of the noise produced by track curvatures.

Finally, although our data collection is more extensive than for most subway noise studies we are aware of, it is still limited in the number of stations and conditions measured. It is also circumscribed to platform measurements, and thus cannot characterize the exposure of passengers while on trains. Many other potential factors are yet to be studied, including platform curvatures, speed of arrival, the acoustic response of stations, the interaction of various levels in station complexes, and track/train components, to name a few. Further, our analysis is preliminary with rigorous statistical testing still pending, not to mention the potential to expand the analysis to measure effect at the track, rather than the station, level – something that is possible with the data already collected. Despite these limitations, our results clearly indicate structural factors affecting noise exposure that are addressable, while providing information that can help prioritize interventions across stations in the system.

Appendix A: List of Station Complexes and Metadata

Station	Ridership rank	Division	Express Lines	Number of Tracks
14St6	2	AB	None	8
14St8	2	B	None	6
23St	3	A	45	2
5Av53	4	B	None	2
7Av53	4	B	None	4
AtlanticBarclays	2	AB	None	10
BryantPark5	2	AB	None	6
BwayBleecker	3	AB	45	6
Canal	2	AB	45	8
ChambersCortlandt	1	AB	None	8
CityHallChambers	3	AB	None	6
ColumbusCir	1	AB	23	6
CourtBorough	3	AB	None	6
DeKalbAv	3	B	DN	4
DelanceyEssex	3	B	None	5
FultonBk	4	B	None	2
FultonMan	1	AB	None	8
GrandCentral	1	AB	None	8
HeraldSq	1	B	None	8
Hoyt	4	A	45	2
HoytSchermerhorn	4	B	None	4
HudsonYards	3	AB	None	2
JaySt	2	B	None	6
Lafayette	4	B	A	2
Lexington51	2	AB	None	4
Lexington59	1	AB	None	6
Nevins	4	A	None	4
Rockefeller	2	B	None	4
TimesSq42	1	AB	None	16
UnionSq	1	AB	None	10
WTCCortlandt	4	A	None	2
West4	3	B	None	8

Appendix B: Field Notes Keywords

<table>
<tr><th>Label</th><th>Description</th></tr>
<tr><td colspan="2">For current track/train</td></tr>
<tr><td>Snap</td><td>Indication for aligning timestamps/SLM</td></tr>
<tr><td>First seen</td><td>Train first enters platform</td></tr>
<tr><td>Stopping</td><td>Train comes to a full stop</td></tr>
<tr><td>Starting</td><td>0Train starts moving</td></tr>
<tr><td>Doors open</td><td></td></tr>
<tr><td>Doors close</td><td></td></tr>
<tr><td>Braking</td><td>If particularly loud</td></tr>
<tr><td>AC</td><td>If particularly loud</td></tr>
<tr><td colspan="2">Other tracks</td></tr>
<tr><td>Arriving + (LABEL)</td><td rowspan="2">Behind 1: Train/track directly behind recording location
Behind x: Consecutively further tracks behind

Ahead 1: Train/track immediately on the other side of the current train/track
Ahead x: Consecutively further tracks</td></tr>
<tr><td>Departing + (LABEL)</td></tr>
<tr><td>Braking + (LABEL)</td><td rowspan="2">Behind or Ahead</td></tr>
<tr><td>Express train + (LABEL)</td></tr>
<tr><td colspan="2">Other notes</td></tr>
<tr><td>Bg noise</td><td></td></tr>
<tr><td>Announcement</td><td></td></tr>
<tr><td>Construction</td><td></td></tr>
<tr><td>Other platform</td><td></td></tr>
</table>

Appendix C: Event Detection Algorithm

Definitions

Individual time segments containing local maximas in our SPL time series are referred to as peaks. A peak has several properties including height, which is its maximum value; left valley, which is the starting location; and right valley, which is the ending location. For each peak, we denote the first preceding peak with higher height as the left reference peak. We calculate a peak's left prominence as the difference between its height and the lowest SPL value that occurred starting from the left valley of the left reference peak. The location of the lowest value is denoted as the left prominence base. The right prominence and right prominence base could be computed in the same manner but using subsequent peaks instead. A peak's general prominence is whichever value is lowest between the left and right prominence. We further define peaks with general prominences above a set threshold as major peaks and all other peaks with either left or right prominence above the threshold as minor peaks.

Algorithm

To allow more accurate and robust peak detection, we first apply a low pass filter to the SPL recordings with a cutoff frequency of 0.1 Hz. Our algorithm works by filtering out peaks that fall under a threshold P_1. Then we use a second threshold P_2 to segregate peaks into major or minor peaks. After retrieving a set of qualifying major and minor peaks, we examine the minor peaks between two major peaks. Minors peaks that have the same left prominence base as the second major peak are clustered together with the second major peak. Similarly, minor peaks that have the same right prominence base as the first major peak are clustered together with the first major peak. Each major peak grouped with its corresponding minor peaks then constitutes a sound event.

The P_1 and P_2 thresholds are optimized for each recording, as one recording may have different levels of background noise in a given station. These background noise characteristics may affect both height and prominence of peaks. Therefore, we use the annotations in our dataset that indicate train arrivals and departures times to optimize the two parameters of our algorithm. For each track, we identify all train arrival and departure periods and the corresponding highest peak within each period. Then we calculate the average height and general prominence of these peaks, denoted as H_{avg} and P_{avg}. We also find the minimum SPL of the track, which we denote as SPL_{min}. For each track, we set $P_1 = 0.6(H_{avg} - SPL_{min}) + SPL_{min}$, and $P_2 = 0.6(P_{avg})$.

From:	Dunkley, Gideon
To:	Konstantellis, Stavroula
Subject:	10 Stations Noise Measurements
Date:	Friday, May 3, 2024 1:01:00 PM
Attachments:	image001.png

Hello, Stacy

In October 2023 Environmental Services received a technical report on noise levels in the NYC subway system that states passengers are regularly exposed to sound levels that pose a health hazard. Several stations were identified in the report as having very high average sound levels, and others with peak sound levels in excess of 100 dB(A), with some reporting peaks in excess of 110 dB(A).

Measurements were taken April 30th through May 2nd with two Bruel & Kjaer type 2270 class 1 sound level meters. The meters were calibrated prior to measurement, and measurements were taken for a minimum of one hour at each location.

Please see below the noise measurements for the ten stations referenced in the report.

Station	Absolute Peak	Average Sound Level	Baseline
Union Square	102.5 dB(A)	86.0 dB(A)	67.9 dB(A)
Broadway Bleecker	98.5 dB(A)	86.5 dB(A)	56.8 dB(A)
Columbus Circle	101.9 dB(A)	88.1 dB(A)	62.6 dB(A)
Rockefeller	99.1 dB(A)	82.7 dB(A)	62.0 dB(A)
Atlantic Avenue	97.5 dB(A)	84.6 dB(A)	62.9 dB(A)
Nevins	92.2 dB(A)	80.6 dB(A)	60.9 dB(A)
Times Square	99.0 dB(A)	81.9 dB(A)	70.2 dB(A)
Grand Central	98.3 dB(A)	83.6 dB(A)	66.3 dB(A)
Chambers	92.1 dB(A)	82.2 dB(A)	69.5 dB(A)
Herald Square	94.7 dB(A)	80.9 dB(A)	57.9 dB(A)

For direct comparisons with some of the data reported in the NYU report, see the following table:

Station	Absolute Peak Reported	Absolute Peak Measured by ES

Union Square	112.9 dB(A)	102.5 dB(A)
Broadway Bleecker	113.4 dB(A)	98.5 dB(A)
Columbus Circle	110.5 dB(A)	101.9 dB(A)
Rockefeller	97.6 dB(A)	99.1 dB(A)

Let me know if you have any questions

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MTA Construction & Development

From:	Dunkley, Gideon
To:	Abdallah, Thomas
Cc:	Konstantellis, Stavroula; Qadri, Muhammad
Subject:	Update on NYU/MTA C&D Noise Data Collection at Broadway/Bleecker and Union Square stations
Date:	Friday, August 2, 2024 10:29:00 AM
Attachments:	image001.png

Hello, Tom good morning

I reviewed the data from the NYU team. Brief Summary:

Broadway Bleecker NYU: Highest Measurement was 105.2 dB(A)
Broadway Bleecker MTA C&D: Highest Measurement was 98.3 dB(A)
Percent Difference: 7%

Union Square NYU: Highest Measurement was 98.1 dB(A)
Union Square MTA C&D: Highest Measurement was 93.8 dB(A)
Percent Difference: 4.6%

None of the data measured side by side by either team, NYU or MTA C&D, corroborates the absolute peak values reported by the NYU team for both locations, which was 113.4 dB(A) for Broadway Bleecker and 112.9 dB(A) for Union Square

Given that the NYU team has a makeshift sound level meter that does not appear to conform to the requirements for a class1 or class 2 microphone and did not do any field calibrations before or after the measurement with an acoustic calibrator, we should assume any data they collect may be subject to major inaccuracies. If we assume their microphone is Class 2, then the maximum percentage difference between our measurements (with a Class 1 microphone) and theirs should roughly be between half a percent to 1 percent.... not 4.6/7%

Thank you for your support

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