



Metro®

ISDS PROJECT

INTEGRATED STATION DESIGN SOLUTIONS



Acoustics and Public Address White Paper

December 2021

Gensler

ARUP



STUDIO-MLA

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Kilograph



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1.0 Element Overview and Problem Statement

1.1 Description of Element

Station Public Address (PA) systems are essential to ensuring a safe and informed passenger experience for Metro customers. The overall acoustic environment of a station also contributes to the intelligibility of PA announcements and overall passenger comfort.

Enhancements in station design that can deliver a low noise environment with clear, intelligible announcements shall focus on three key areas: sound attenuation strategies for underground stations, sound wall barriers for at-grade and aerial stations adjacent to freeways and roadways where noise intrusion is a concern, and the design of the PA system.

1.2 Problem Statement

Acoustic and speech intelligibility targets are well defined in the Metro Rail Design Criteria (MRDC), but in practice are hard to achieve in current stations. Attenuation measures are needed to ensure MRDC targets are achieved. The table below shows the results of field recordings at the platform level of ten Metro stations, most of which exceed the MRDC Maximum Sound Level (Lmax dBA):

Station	MRDC Lmax (dBA)	Recorded Lmax (dBA)
Arcadia	75	92
Aviation/LAX	75	93
Cal State LA	75	89
Expo/Bundy	75	79
Harbor Freeway	75	89
Hollywood/Highland	85	85
North Hollywood	85	82
Pacific Coast Highway	75	79
Wilshire/Vermont	85	86
7th St/Metro Center	85	87

Please note, these ten field recordings are a sample, and there may be additional Metro rail stations that have even higher noise levels.

The MRDC requires that PA systems be seamlessly integrated with station architecture and system

technology. Existing station architecture and loudspeaker placement reduces speech intelligibility. Other sources of noise, both internal and external to the station, also diminish speech intelligibility. In addition, the intelligibility of the announcements affects passenger safety, if there is emergency information to be provided.

Underground stations tend to be highly reverberant spaces that can cause noise build-up, which can create an uncomfortable acoustic experience for the passenger. These stations would benefit from sound absorbing treatments, controlled noise sources, and resiliently-mounted tracks.

Platform conditions in at-grade and aerial stations adjacent to freeways routinely exceed maximum allowable noise levels as prescribed in the MRDC due to their proximity and direct line-of-sight to traffic noise. Any station where road noise intrusion is an issue would benefit from effective sound wall barriers.



Figure 1-1 Existing sound wall barriers that are effective. 37th St/USC Station, J (Silver) Line.



Figure 1-2 Existing sound wall barriers that are not effective. Harbor Freeway Station, C (Green) Line.



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2.0 Design Process and Principles

2.1 Design Process

The Project Design Team for this element was led by Arup's Acoustic team, and included Gensler and RAW.

Metro departments across the agency provided input throughout the design process. Beginning in May 2018, Working Group Members accompanied the Project Design Team on site visits to Metro stations to observe and document acoustic environments and existing conditions. In addition, the Acoustic team performed background noise level readings at these same stations in August 2018. The Project Design Team also conducted a series of interviews with representatives from a wide range of Metro departments, including:

- Arts + Design
- Asset Management
- Facilities Maintenance (including separate interviews with FM field staff and management)
- Fire and Life Safety
- Office of Civil Rights
- Operations Liaison and Planning
- Program Management
- Project Engineering
- System Security & Law Enforcement

Based on the analysis and the information provided during interviews with Metro staff, the Project Design Team developed initial design concepts, which were presented to the Working Group in July 2019.

Using the feedback provided by the Working Group members, the Project Design Team refined the initial design concepts into a Draft Concept Design, which was incorporated into this white paper. A Draft Design Documentation package was submitted thereafter, and the revised Final Design Documentation was completed in March 2020. For additional information, see "Table 2-1 Timeline of Design Process" on page 5.

2.2 Working Group Feedback

Working Group members provided the following feedback on acoustics, specifically at freeway stations:

- Provide transparent sound wall panels mounted on concrete barrier dividing tracks from traffic lanes to increase visibility and openness for safety. (Facilities Maintenance)
- Single sound barrier on platform will limit riders' access to train doors.
- Staggered sound barrier will clutter station platform impacting riders' free movement. Provide transparent sound wall panel mounted on traffic lane and trackwork concrete barrier. (Project Engineering)
- Install a transparent sound barrier wall along the platform edge for future stations to reduce noise and serve as fall protection. (System Security & Law Enforcement)
- Fully enclosed shelters on the platform or station will require heating, ventilation and air conditioning (HVAC), and limit rider access to train doors.
- Consider visibility of the operators and the security cameras with the on-platform sound walls. (System Security & Law Enforcement)
- Working with Caltrans to install sound barriers at existing stations is difficult, and they should instead be designed/built with the station itself for new or retrofit projects. (Project Engineering)



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2.3 Design Principles

Station acoustics should support low noise environments, attenuating common noise sources at underground stations. At-grade and aerial stations adjacent to freeways or major arterial roads should include barriers to maintain appropriately low background noise at station platforms. PA systems should be clear and intelligible, with consistent coverage throughout stations. The design principles listed below provide alternatives for station specific acoustic environments and PA intelligibility:

Sound Attenuation at Underground Stations

- Sound absorbing finishes should be strategically located to absorb sound from underground sources, such as train noise, rail squeal, and commuter conversation.
- Low noise HVAC systems should be employed.
- Strategic sound absorbing finishes should be incorporated near tracks.

Resilient Track Systems

- Resilient track systems can be considered at aerial stations to reduce radiation of noise from the support structure, and at underground stations with critical adjacencies to reduce vibrations transmitted to neighboring buildings.

Sound Wall Barriers

- Sound walls between the trackway and traffic/other noise sources are the only proposal at this time as it they are continuous barriers that will provide sufficient coverage and not create safety/visibility concerns.
- Sound walls may be used at freeway-adjacent stations and at stations above major arterials where road noise is an issue.
- Barriers should be placed directly between sound source and receiver (passenger).
- Critical height of barrier is based on the distance between sound source and receiver.
- Options for sound absorbing external barriers can take into account station specific architecture, design, and other requirements.
- Material selected should be as massive as is practical while balancing structural and security requirements (e.g. attachment limits and visual transparency). Denser and more massive barriers

will provide greater sound attenuation, however, continuity and height of barriers will have the largest impact on acoustic performance.

Public Address Systems

- Spacing, mounting height, and product specification should be coordinated throughout each phase of architectural design to achieve consistent coverage and MRDC-required speech intelligibility throughout stations.
- Loudspeaker distance to passengers will vary based on station architecture.
- Station acoustics and reverberation times will impact speech intelligibility of public announcement system. Public announcement system design should account for station reverberation times to achieve minimum MRDC-required speech intelligibility performance.
- Loudspeaker systems should have appropriate frequency response and directivity.

Station Design

During the station design process, a qualified acoustic engineering team should be engaged to evaluate the station architecture and calculate the expected noise levels within the space. Station architecture should consider the Acoustic team's findings in determining design changes and mitigation factors that would ensure compliance with MRDC standards, including the addition of sound wall barriers where deemed necessary.



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Table 2-1 Timeline of Design Process

May to June 2018	Project Design Team and Metro Working Group Members conducted site visits of existing stations, including: 7th Street/Metro Center, Arcadia, Aviation/LAX, Expo/Bundy, Cal State LA, Harbor Freeway, Hollywood/Highland, North Hollywood, Pacific Coast Highway, and Wilshire/Vermont.
August 2018	Arup Acoustic team conducted background noise level readings at Arcadia, Aviation LAX, Cal State LA, Expo/Bundy, Harbor Freeway, Hollywood/Highland, North Hollywood, Pacific Coast Highway, Wilshire/Vermont, 7th Street/Metro Center.
June to November 2018	Project Design Team conducted interviews with Metro departments, including: Arts + Design, Asset Management, Facilities Maintenance (including separate interviews with FM field staff and management), Fire and Life Safety, Office of Civil Rights, Operations Liaison and Planning, Program Management, Project Engineering, and System Security & Law Enforcement.
March to June 2019	Project Design Team developed initial design concepts.
July 2019	Project Design Team initial design concepts to the Working Group.
October 2019	Draft Concept Design Package submitted.
December 2019	Draft Design Documentation Package and White Paper submitted.
March 2020	Revised Design Documentation Package submitted.
March 2020	Final Design Documentation Package and White Paper submitted.
March 2020	Draft MRDC and Architectural Standard/Directive Drawings updates submitted.



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3.0 Design Solutions

3.1 Sound Attenuation at Underground Stations

Noise Build-Up in Reverberant Spaces

Metro stations have noise sources such as train noise, rail squeal, and commuter conversation, which all contribute to noise buildup in reverberant spaces. Sound absorbing treatments, such as acoustic lining or sound attenuation material at station ceilings and walls should be concealed by acoustically transparent finishes (e.g. perforated metal panels). While these materials are already part of Metro's standards, additional treatment may be required based on the site-specific evaluation of the station design by the acoustic engineer. See Figures 3-1 and 3-2.

Train Noise

Sound absorbing finishes (e.g. sound attenuation material) should be applied under the platform/area of refuge adjacent to the trackbed to reduce wheel-rail noise. See Figure 3-3.

Resilient track systems, such as the installation of a floating slab system with resilient rail fasteners and other design elements can be considered at aerial stations to reduce noise emanated from platforms and at undergrounds stations with vibration-sensitive adjacent properties (Figure 3-4). For resilient track applications, tracks should be decoupled from the track foundation. Specific solutions are dependent on noise sensitive adjacencies and structural considerations at each station, which should be determined by station-specific engineering studies.

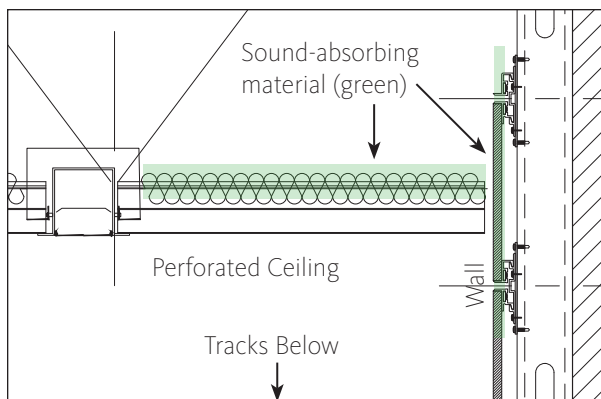


Figure 3-1 Cross-section of ceiling and track wall in underground station, with sound-absorbing material behind (in green).

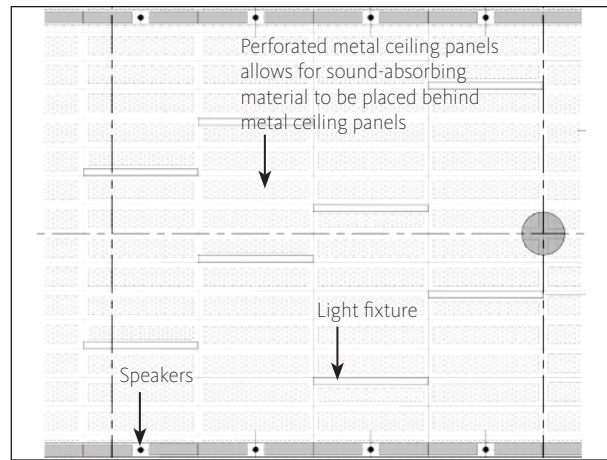


Figure 3-2 Plan view of ceiling in underground station, showing perforated metal panels with sound-absorbing material behind.

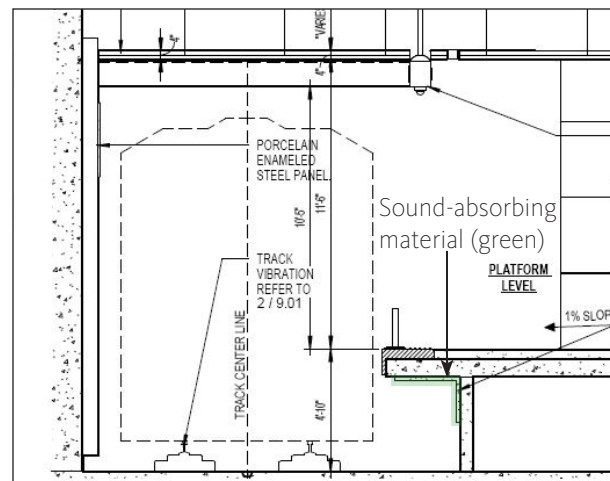


Figure 3-3 Cross-section of trackbed in underground station, with sound-absorbing material under platform/area of refuge (in green).

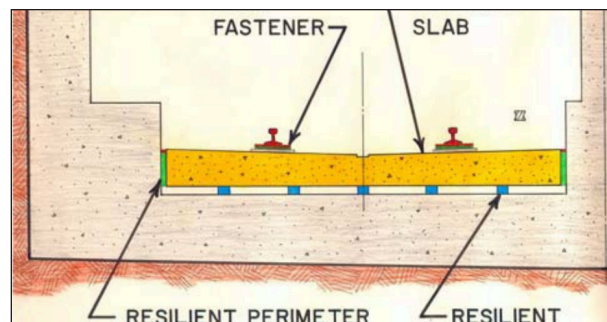


Figure 3-4 Cross-section of continuous floating slab design developed for WMATA.



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3.2 Sound Wall Barriers

Sound wall barriers should be considered at certain stations where noise intrusion can create unacceptable noise levels for passengers and negatively affect both intelligibility of PA announcements and the comfort of passengers. The examples and guidelines provided here are concept-level and for use only as a reference. Final design and placement will require further coordination within Metro and with external agencies such as Caltrans, among others, and be site-specific. Barrier placement, height, and design should be developed with the design team for each station.

Barrier design should take into consideration:

- Minimum effective barrier height requires blocking a line of sight between the noise source and the receiver.
- Barriers should be extended beyond the platform and station to mitigate as much noise as possible at pedestrian pathways (ramps, stairs, elevators, etc.) leading to the station/platform, especially from freeway/arterial cross-streets. This will ensure noise stays below maximum allowable sound levels at the platform as stated in the MRDC.
- Barriers should be installed at stations where noise intrusion is an issue, especially at stations adjacent to freeways or large arterial roads. Specific barrier dimensions are to be determined based on an acoustic study for each station.
- Barrier must be transparent/semi-transparent to ensure clear visibility to the platform.
- Artwork integration into barriers should be considered where possible.

See Figure 3-5 for a typical sound barrier layout at a freeway-adjacent station.

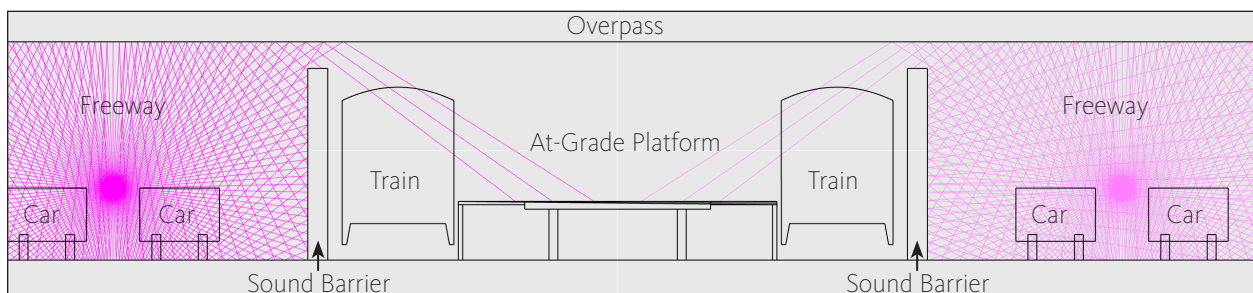


Figure 3-5 Cross-section view of an acoustic ray-tracing study to show sound barrier effectiveness at a freeway station platform located beneath an overpass. The purple lines represent the path of sound emitted from car traffic.

3.3 Public Address System Design

PA system layouts, distribution, and product specification should be carefully coordinated and integrated with the specific design of each station. PA systems should be designed to achieve MRDC Speech Transmission Index (a measure of speech transmission quality) targets based on the architecture and geometry of each station. See Figure 3-6.

PA system design should take into consideration the following speaker options to achieve stated MRDC levels of speech intelligibility at the platform:

- Point source loudspeakers direct sound in a wide arc, and are best suited for distributed systems in open, acoustically controlled areas.
- Beam steering loudspeakers may be required in highly reverberant areas (e.g. double-height spaces with limited sound absorbing finishes). The loudspeakers can be integrated into columns and ceilings.

Point source
loudspeaker



Beam steering
loudspeakers



For additional information, see “Tables 3-1, 3-2 and 3-3, Key Design Features” on pages 8-9.

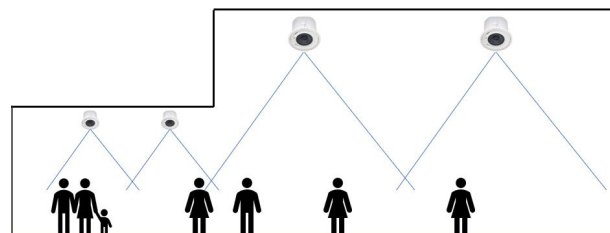


Figure 3-6 Example of variable PA loudspeaker spacing in response to station architecture.



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Table 3-1 Key Design Features for Sound Attenuation at Underground Stations

Design Feature	Rationale
1. Sound absorbing materials consist of acoustic concrete and/or duct liner.	Acoustic concrete and duct liner achieve high levels of acoustic absorption. When applied to ceilings and wall areas, these treatments will support greater speech intelligibility from PA systems and help reduce noise buildup in stations. Modular treatments like duct liner panels allow for materials to be swapped out and replaced over time.
2. Sound absorbing materials are concealed by acoustically transparent finishes (e.g. perforated metal).	Acoustically transparent finishes allow seamless integration of sound absorbing treatments with architectural design elements. Slats and perforated metals allow easy cleaning while protecting treatments from damage. Materials should be consistent with Metro's standard material pallet.

Note: This table provides a summary of key features only and is not an exhaustive list of all design features. Project design documentation provides complete details and requirements, and is available upon request.

Table 3-2 Key Design Features for Sound Wall Barriers

Design Feature	Rationale
1. Barriers extend beyond the length of station platforms.	Sound barriers must extend far enough alongside the roadway to attenuate sound from passing cars as they approach and leave the immediate area surrounding the platforms.
2. Barrier heights block line of sight between Metro passengers and any traffic lanes. Specific height requirements should be determined by an acoustic study of each station where barriers are to be installed.	Barrier heights must extend high enough to reduce sound diffracting (bending) over the top of the barrier. Acoustic barrier attenuation calculations shall be performed by an acoustical engineer to determine minimum effective barrier heights based on platform and adjacent roadway lane layouts.
3. Steel clad panels with perforated sections of sound absorbing materials help reduce noise buildup between parallel barrier walls.	In locations with particularly high noise intrusion from traffic, such as platforms located beneath overpasses, sound absorption facing the platforms will help to reduce reflected sound and therefore lower noise buildup at platform locations.
4. Where transparent barrier walls are used, alternating transparent sections with steel-clad perforated sections allows for attenuation of sound on the platform side of the barriers while still providing for the required visibility at the platform for safety.	Having two parallel transparent barrier walls on either side of the station will reinforce noise build-up between the barrier walls. By alternating sections of transparent barrier walls with sound absorbing ones, we can further attenuate sound at platforms. (Transparent barriers provide passive surveillance and increased visibility and security for passengers waiting on the platform).

Note: This table provides a summary of key features only and is not an exhaustive list of all design features. Project design documentation provides complete details and requirements, and is available upon request.



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Table 3-3 Key Design Features for Public Address Systems

Design Feature	Rationale
1. Loudspeaker locations are coordinated with loudspeaker spacing, based on an acoustic engineering study and station-specific designs.	Distributed loudspeaker systems in strategic layouts are key to achieving uniform coverage and speech intelligibility. Stations with lower ceilings may require more tightly spaced, lower power loudspeakers to ensure that passengers walking through a station are always within the coverage pattern of a loudspeaker and hear announcements at a consistent comfortable level.
2. Different technologies, such as beam steering column arrays, will be used as appropriate depending on station architecture and the results of an acoustic engineering study.	Distributed point source loudspeaker systems may not be appropriate in more reverberant spaces with limited ceiling locations available for loudspeakers. Beam steering column arrays can provide focused coverage at farther distances using fewer loudspeakers. Beam steering columns also avoid spilling sound to unnecessary locations, therefore reducing how much announcements excite reverberant spaces.

Note: This table provides a summary of key features only and is not an exhaustive list of all design features. Project design documentation provides complete details and requirements, and is available upon request.

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