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Memo

To:	Kathryn O'Brien		
From:	Tim Casey and Elliott B. Dick	Project:	Central Corridor Light Rail Transit
cc:			
Date:	November 6, 2008	Job No:	65891

Re: Transit train horns and bells simulation at Minnesota Public Radio

BACKGROUND

The building which houses *Minnesota Public Radio* (MPR) is located in downtown St. Paul, along the *Central Corridor Light Rail Transit* (CCLRT) route on Cedar Street. Some noise-sensitive interior spaces at MPR may be affected by the introduction of Light Rail Transit on Cedar Street. The *Light Rail Vehicles* (LRV) are expected to sound horns and bells under certain operational circumstances.

Minnesota Public Radio Interior Spaces

The main building occupied by MPR has several additions, each of different vintages. The original building was a two-story bank. One renovation added two stories atop the original bank and houses two studios of particular interest: *Studio M*, also known as Maud Moon Weyerhaeuser Studio, and *Studio P*, also known as the Atrium Studio.

The most recent renovation (2006) included an atrium and a new building to the north of the original bank. This new building houses several studio spaces including one assessed as part of the ESI simulation, *Studio 443*. This building also had several offices with windows onto Cedar Street, some of which were also assessed as part of the ESI simulation.

Studio M: Maud Moon Weyerhaeuser Studio

Studio M was assessed in both the ESI simulation and the HDR simulation. Studio M is a large shoebox-shaped recording studio. One of the long-dimension walls is the exterior wall adjacent to Cedar Street. There is a semicircle window in this wall, made up of two quarter-circle windows. The window in Studio M is just an ordinary window; it has an assembly of clear plastic half-cylinders placed over the windows, which do not appear to be acoustically designed for use in a recording studio. This half-cylinder surface is intended to increase the window isolation by adding mass and an airspace, and additionally to prevent reflections (echoes) by eliminating the flat window surface. There was internal ventilation at the top and bottom of the confined airspace, presumably to prevent condensation.

Studio P: The Atrium Studio

Studio P was assessed in the ESI simulation, but was not assessed as part of the HDR simulation. Studio P is quite a bit smaller than Studio M, and is located above the Northwest corner of the original bank building. It has two windows: a tall, narrow window looks out on Cedar Street, and a quarter-circle window looks out into the new atrium. The windows in Studio P are acoustically designed for use in recording studios, with a thick airspace between the panes of glass and absorption around the airspace perimeter.

Forum

The Forum was assessed in the HDR simulation. The Forum is a large room, half occupied by audience risers. There are two, two-story windows looking out onto a rooftop patio, with two separate doors in the window assembly. These windows, like the windows in Studio P, are designed for studio use, with a thick airspace between two thick layers of glass.

By the description of MPR personnel, the Forum does not have isolation normally associated with a recording studio, aside from the exterior windows. There are single-entry doors; there is no sound-lock arrangement of doors. The floor slab is reportedly not ‘floating’, a method of mechanically separating the floor with the rest of the building. It was also reported that bands playing in the forum could be heard elsewhere in the building, whereas most recording studios are acoustically isolated from the rest of the building in which they reside.

Fitzgerald Theatre

The Fitzgerald Theater is separate from the MPR building, located approximately a half-block away on Exchange Street. This is a theater, originally built in 1910; MPR purchased it in 1980 and subsequently renovated it to its current state. MPR uses this theater regularly for performances and broadcasts, such as, “A Prairie Home Companion.” The lobby is located on Exchange Street, and would have a clear view of LRV’s as they travel Cedar Street due to its glass doors. The stage door opens into an alley, but LRV's will pass by the end of the alley on Cedar Street.

Light Rail Vehicle Bells and Horns

According to Metro Transit standard operating procedures, current LRV horn and bell noise level standards are as follows.

Table 1

Metro Transit LRV Horn and Bell Noise Level Criteria

	Target Level	Measurement Distance
Bells	79 dBA	50 ft
Low-Horn	90 dBA	100 ft
High-Horn	95 dBA	100 ft

LRV horns and bells are currently calibrated when maintenance is performed on the LRV warning system. Metro Transit staff performs the calibration procedure inside the maintenance building, at the prescribed distance from the front of the train, and measures the noise level on a hand-held sound-level-meter.

Metro Transit has adopted standard operating procedures for the sounding of bells and horns, which are attached. Bells are sounded when entering and leaving an LRT station platform. High horns are sounded in emergency situations when operators believe a loud warning is required to alert persons outside the LRV to a hazard. The high horns (2 short blasts) are also sounded when two trains pass each other at a grade crossing. Low horns are typically used only at the Franklin yard and shops as part of LRV operations and maintenance occurring there.

LRT Airborne Noise Testing

On September 24, 2008, MPR's consultant, ESI Engineering conducted a simulation of LRT horn and bell use outside MPR in downtown St. Paul. This simulation was attended by an observer from HDR Engineering, which is a consultant under contract to the Central Corridor Project Office. On October 22, 2008, HDR conducted a second simulation, with a more accurate representation of horn and bell noise levels and audible signal use. An observation of the ESI testing and a summary of preliminary findings of the HDR testing follows.

ESI SIMULATION OBSERVATIONS

This test was conducted by Tony Baxter and Bret Peterson, both with ESI Engineering. Steve Griffith represented MPR. A sound engineer for MPR was also present at times during the simulation. ESI reported that this simulation was intended to investigate the potential of noise intrusion from light rail transit train horns and bells into the MPR building.

ESI Simulation Method

The transit horn and bell source was simulated with a DAT recording played with a TEAK RD130TE to a Mackie SRM450 two-way powered loudspeaker. The loudspeaker was lifted to 11 ft from the roadway (measured from the bottom of the loudspeaker). The loudspeaker faced down the road, so the loudspeaker axis was parallel with the centerline of the track. The environment at the simulation site was a typical urban canyon, except for a lawn across from the old portion of the building.

The recordings included a high-horn, a low-horn, and bells. The high-horn seemed to be similar in frequencies, but higher in level with the low horn. The recordings were made by ESI, outside the Hiawatha maintenance building. The recording environment would be free of buildings and the ground would be ties on ballast. Reference levels were also measured at the time of recording. Measurements by ESI were 80 dBA at 25 ft on-axis with the bell source, directly in front of the stationary train, and 78 dBA at 50 ft from the bell source.

The playback level was calibrated to match the measured reference levels. The reference recordings and measurements were made at 25 ft on-axis with the bell sound source, as were the calibration measurements. ESI reported that the high horn was 3 dB too low, but that increasing the level would introduce distortion in the loudspeaker. Calibration of the bells had to be delayed due to a lawnmower initially interfering with the measurement, but the bells were calibrated successfully once the engine noise ceased.

Measurement Equipment

Noise levels of the high-horn, low-horn, and bells were measured in each location with a Larson Davis 824 handheld analyzer. It was calibrated at the beginning and end of the measurement, and the background level was measured in each location.

A second measurement was made in some locations through a studio microphone belonging to MPR. This microphone signal was split; one signal was sent to a PC-based analyzer, also operated by ESI, while the other simultaneous signal was recorded by MPR and monitored by headphones. The available calibrator would not fit on this microphone, so the level on the PC-based analyzer was adjusted to match the level on the calibrated meter (the direct output of the meter was also sent into the PC-based analyzer).

The studio microphone signal recorded by MPR, was also monitored on headphones. The signal gain on the headphones was adjusted so inaudible signals became audible on the headphones. While this may not represent what a human ear hears within the studio space, it nonetheless reveals signals that would be captured on an audio recording. Such signals at or near the noise floor may or may not present a problem; it depends on the recording and mixing of an end-product.

ESI SIMULATION MEASUREMENTS

Measurements occurred within three studios, and several offices. This portion will describe and address each studio individually, and all the office measurements as a group.

Studio M: Maud Moon Weyerhaeuser Studio

There was studio equipment and furnishings stored around much of the room perimeter, but there was still a large area of free floor space in the studio. An isolation booth sat in the corner. The microphones were set up on an axis normal to the center of the exterior window. Subjective impressions of the HDR observer during the simulation of each source were:

- **High Horn:** filtered, but clearly audible.
- **Low Horn:** unmistakably audible, but very quiet.
- **Bells:** Nearly inaudible, but still distinctly present.

The window in this room was clearly the weak point in the overall acoustical isolation from the outside. The HDR observer could not discern if there was a specific sound leak, or if the sound was just passing though the window assembly.

Studio P: The Atrium Studio

There was studio equipment and furnishings stored around much of the room perimeter, constraining the free floor space to a relatively small area. A single microphone and desk were set up for voice recording in front of the control room window. The measurement microphones were set up in the middle of the studio, near the desk. Subjective impressions of the HDR observer during the simulation of each source were:

- **High Horn:** barely audible, but distinct. It could be localized to the narrow window looking out on Cedar Street.
- **Low Horn:** inaudible to the HDR observer, but the ESI test operator reported hearing it faintly.
- **Bells:** inaudible, even to the MPR observer listening on headphones with gain.

The MPR observer was listening on the headphones with gain while the test operator was in the studio, and reported stomach gurgling, picked-up on the studio microphone that was at least as loud as the horns.

Studio 443

Studio 443 is one of the most recently-built studios. Only the handheld meter was used to measure sound in this space. Nothing was audible from the outside of the studio, not the high horn or any other noise from the LRV. Even when a door closed in a wall adjoining the studio (outside the studio), the impact vibration was not transmitted into the studio space. Based on these observations, these studios seemed well-designed and the space seems acoustically isolated from the spaces outside of it.

Office Measurements

Only the handheld meter was used to measure the simulated sound in offices. HDR notes that offices are not assessed for potential noise impact according to FTA standards, although some offices are assessed for vibration. However, the HDR observer noted the following points somewhat relevant:

- The horns and bells alike were clearly audible in every office facing Cedar Street. The new building was not notably quieter than the old building.
- The walls between offices did not provide much privacy, but the horns and bells were still significantly louder than talking heard through the walls.
- At one office in the newest part of the building, the bells from Louis, King of France Church were clearly audible (they sound every quarter-hour). This event did not get measured.

ESI SIMULATION SUMMARY

The simulation of transit horns and bells was not a perfect simulation: ESI reported this was a preliminary investigation. The horns and bells simulation was clearly audible in the offices facing Cedar Street, however the regular church bells were also clearly audible. The simulation did not affect the background noise of the newest studios at MPR, but the simulation did affect two of the older studios facing Cedar Street.

The effect of the horns and bells simulation on Studio M was very apparent. Transit trains will be sounding bells at every passing through the grade-crossing at Seventh Street, and so will likely be audible on some recordings in Studio M. Transit train horns could be expected less frequently, but their occurrence will likely be noticeable.

Based on observations in Studio M, one might expect other sounds to be audible through the window. For instance, the lawnmower that interfered with calibrating the bell simulation, though this event was not measured, could be expected to be audible at some level in Studio M. Likewise any other sounds that are at least as loud as the transit train bells would intrude into the studio, including common traffic sounds (brake screech, honking horns, loud vehicles, emergency sirens, etc.). The church bells from down the street chime every 15 minutes but weren't quite as loud as the simulated transit train bells.

During ESI's simulation, LRV horn and bell noise was barely audible in Studio P. Some recordings in Studio P may exhibit low levels of transit horn noise, as simulated. Based on the observations during the simulation, Studio P is more effectively isolated than Studio M from the sounds of train horns and bells. While not conclusive, this suggests that Studio P has more effective acoustic isolation than Studio M.

HDR SIMULATION METHOD

The HDR simulation and measurement was lead by Tim Casey and Elliott Dick, both with HDR, and assisted by a team of four other attendants. Kathryn O'Brien of the Central Corridor Project Office, and Tony Baxter of ESI, were also present to observe the measurements. LRV horns and bells noise was measured by HDR staff during a series of simulated pass-bys of a Metro Transit vehicle operating horns, bells, or both. Measurements of the simulated horns and bells occurred at several locations: one inside Studio M, one inside the Forum, two locations inside the Fitzgerald Theater, and one location outside MPR. ESI did not perform measurements inside Studio P because ESI determined that Studio P has better acoustic isolation against the LRV horns and bells than Studio M. Studio M is the worst-case scenario for MPR's studios' acoustic isolation

Data collected during measurements allows HDR to assess the anticipated affect of the LRV horns and bells within these interior spaces. Ultimately, HDR intends to compare the interior noise levels without LRT horns or bells, against the noise levels in the studio with LRT horns, and the levels with LRT bells.

Data acquired by the sound level meters was stored in the meters, and later downloaded for post-measurement analysis of data. The time histories were examined to differentiate levels during LRV horns or bells sounds, versus during pauses between LRV sounds. Sounds of LRV horns and bells, at each measurement location, are compared to the measured natural ambient sound of the location (in the absence of simulated LRV horn and bell noise).

Characteristics of Sound Measurement Equipment

The measurement equipment HDR used included digital Sound Level Meters (SLM) with the capability to store analysis results, at least a 60-dB dynamic range; Type 1 as defined by ANSI S1.4. HDR used a Larson Davis (LD) 2900 analyzer to measure noise levels inside studios in MPR. HDR also used LD 824 analyzers at other monitoring locations. Sound pressure levels were measured in 1/3 octave bands inside MPR: at all other locations HDR measured broad-band sound pressure levels. The octave-band filters HDR used during the simulations meet the requirements of ANSI S1.11.1985. The microphones selected for the measurements have a nominal frequency response range that includes the range of frequencies from 10 Hz to 10 kHz. HDR used either a free-field or a diffuse-field microphone; the directional response is not significantly different below 10 kHz on either type of microphone. Nonetheless, directional response of microphones was selected appropriate to the measurement environment, identified below.

For measurements performed inside MPR, HDR configured the LD2900 analyzer to use A-weighting; octave band sound level weighting is set at FLAT. All LD824 SLM's were also configured to apply A-weighting. The measurement systems for interior spaces interior include the capability to measure fast-average sound level with exponential decay over consecutive time intervals, stored independently to produce a time history. The measurement systems for exterior locations include the capability to measure the time-average sound level (L_{eq}), simultaneously over one or more prescribed periods of time. The overall measurement duration is determined by a manual run/stop triggered by the operator. Each measurement is stored within each meter.

Calibration of Sound Measurement Equipment

HDR SLM's and analyzers are calibrated on an annual basis by an independent laboratory using standards traceable to the National Institute of Standards and Technology. Rented equipment is likewise calibrated annually. Calibration certificates of HDR equipment and rented equipment are available to the client upon request.

The sound measurement equipment is adjusted to a reference level traceable to the National Institute of Standards and Technology, using a battery-operated precision microphone calibrator meeting ANSI S1.40 and IEC 60942, Class 1 Sound Calibrators. Sound measurement equipment is calibrated and adjusted in HDR's office prior to transportation to the measurement site. Calibration checks are performed in the field before the first measurement and after completion of the series of measurements.

Testing of mock-up equipment and validation

Metro Transit operations and maintenance personnel arranged a mock-up to simulate LRV horns and bells. HDR staff were present along with Metro Transit personnel at the Franklin yards and shop to test and validate the mock-up to ensure consistency with actual HLRT bells and horns. This validation was conducted by setting up the mock-up equipment and an actual Hiawatha LRV side-by-side. The levels of bells and horns were measured for the mock-up and the actual ligh rail vehicle.

The first audible warning simulation device tested in the manner described above was inconsistent with the actual LRV. Specifically the noise levels matched reasonably well, but the horn pitch sounded somewhat different, and the measured spectrum content was notably different. HDR observed a slight frequency shift between the two signal sources which may present a minor problem, but more concerning was that the mock-up's horn emitted a narrow-band tone compared with the actual horn in use, which spans at least two whole octaves. The explanation was that the mock-up was originally made before Metro Transit bought any trains for HLRT, and it used a signal generator for another transit system. Consequently the signal generator in the mock-up was different from the ones in trains. This mock-up was rejected and Metro Transit staff set about the task of building a second mock-up using actual HLRT components.

The second mock-up used a spare signal generator for the vehicles in service on the HLRT line and the actual horn device currently in use on the HLRT fleet. Noise levels emitted by this mock-up measured much more consistently with the measured LRV. The following table shows measured SPL's at 50 ft from the LRV and the mock-up. Data in the table shows close agreement between the audible signal on the LRV and the mock-up. This second mock-up was accepted for use in testing at MPR.

Table 2

LRV Horn and Bell Noise Level Validation Data

	Light Rail Vehicle	**Mock-Up**
Bells	78.9 dBA	79.8 dBA
Low-Horn	88.3 dBA	88.5 dBA
High-Horn	94.8 dBA	94.3 dBA

One measurement of the LRV high horn demonstrates the directivity of the horn and bell source; it is 19.2 dBA down at 90° from on-axis.

HDR previously obtained reference levels of LRV bells sounding during a pass-by event, by measuring several actual LRV pass-by events at locations between Bloomington Central Station and the Mall of America. Compared to the on-axis measurements performed in the Franklin Yard, the HDR reference measurements differed in that the train was moving, and the measurement was 50ft perpendicular from the track centerline, 90° off-axis from the bell source. The HDR reference measurement results ranged from 73 dBA to 78 dBA, and averaged 76 dBA. Given the difference in measurement conditions, the measurements of the transit bells are reasonably comparable.

LRV Horn and Bell Pass-by Simulation Measurement

The accepted mock-up was constructed from spare parts of actual LRV audible warning devices, including a signal source box with adjustable levels, normally located behind a locked access panel in the LRV, and an Atlas-brand “wide-dispersion” horn, normally mounted atop the vehicle. The mock-up was mounted on a truck, and driven down Cedar Street along the planned CCLRT track alignment. A Hiawatha LRV operation trainer sat in the truck cab to trigger the sounding of horns, bells, or both, appropriate to standard operation of the vehicles. The photograph below shows the Metro Transit vehicle with the LRV horn; the horn control unit was in the back seat of the truck cab.

Figure 1

Metro Transit LRV Horn and Bell Simulation Vehicle

HDR measured horn and bell noise levels during pass-by events outdoors: these SLM's were located on the east side of Cedar Street. This placed microphones in proximity to acoustically reflective surfaces (the buildings). Any reflections present in the measurement represent the acoustic environment of that locale, specifically urban canyons. The SLM microphones were placed at a point that is away from any such non-normal acoustically reflective surface by at least 0.75 m (2.5 ft), to meet guidance in ASTM standards.

HDR positioned the microphone between 4 ft and 6 ft above the ground, mounted on a mast sufficiently strong to support the weight of the microphone and protective equipment mounted on it, and which is resistant to being upset by the wind or other disturbances.

Table 3

Equipment for Exterior Locations

Microphone	PCB Type 377B41 free-field microphone
Measurement Equipment	Larson Davis Type 824 analyzer
Microphone Protection	Environmental microphone mounting assembly

The directional response of the exterior microphone locations are free-field. The self-noise of the microphones is less than 30 dBA (re. 20 μPa) to ensure adequate signal-to-noise when the signal is the ambient sound level of the outdoor soundscape. An environmental microphone protection kit was utilized for outdoor microphones, consisting of a microphone rain shield, windscreen, bird deterrent accessory, and desiccant system, compatible with the microphone system.

Studio M measurement

The low-noise microphone was located in line with the window facing Cedar Street, close to the middle of the room, but not in the exact center of the room.

The measurement environment inside the studio at MPR is very quiet. Operator-generated noise may constitute an interference of the measurement of sound levels, including operator movement or even breathing. An extension cable allowed the test operator and observers to work away from the low-noise microphone system, so the operator and other observers do not influence the measurement with movement, breathing, or other operator-generated noise.

Within the interior studio space, the level in some frequency bands of interest may be less than 10 dB above the electrical self-noise of the microphone and measurement system. The self-noise of the measurement system (including the microphone and microphone preamplifier system) including each band of interest, was measured by covering the microphone with a calibrator with a tight seal.

Table 4

Equipment for Interior Studio Location

Microphone	Brüel & Kjær Type 4955 low noise free-field microphone
Measurement Equipment	Larson Davis Type 2900B analyzer
Microphone Protection	None
Accessories	Brüel & Kjær Nexus conditioning amplifier
	BNC to Switchcraft adapter
	100ft BNC extension cable

The measurement environment inside the studio at MPR was very quiet. To avoid microphone self-noise as interference in the measurement of sound levels, the self-noise of the low-noise microphones was less than 10 dBA (re. 20 μPa) to ensure adequate signal-to-noise when the signal is the ambient sound level of the studio. The low reverberation of the MPR studio suggests use of an interior free-field microphone, oriented to face the incident noise (the window), where the orientation vector is normal to the microphone diaphragm.

Forum/Fitzgerald measurement

The Forum, although quite dry (low reverberation), is more or less a typical large-volume space with a diffuse field; The Fitzgerald Theatre measurement locations were typical interior spaces with diffuse field characteristics. Analyzers and microphones were mounted on tripods, or handheld by experienced operators.

Table 5

Equipment for Forum and Fitzgerald Locations

Microphone	Larson Davis Type 2560 diffuse-field microphone
Measurement Equipment	Larson Davis Type 824 analyzer
Microphone Protection	Windscreen

A diffuse-field microphone was utilized in a vertical orientation (straight up), customary for typical interior spaces. The self-noise of the microphones was less than 30 dBA (re. 20 μPa) to ensure adequate signal-to-noise when the signal is the ambient sound level of the interior spaces. Environmental protection of interior tripod-mounted microphones was an interior windscreen to prevent interference from air movement.

HDR SIMULATION RESULTS

Preliminary results and some on-site observations are reported here. Full analysis of measurement data is forthcoming.

Studio M

The background noise level of the room, using the low-noise microphone, is 20-22 dBA. The noise of the high-horn is as high as 30 dBA inside the studio.

HDR performed an experiment to determine the highest level of horn noise that is inaudible in Studio M, and therefore also has least potential to interfere with recordings inside studio M. The mock-up was positioned stationary and at a position north of the centerline of the window, along the Cedar Street alignment and facing south. Metro Transit staff reduced the horn volume level three times, and after the third adjustment, the horn noise was inaudible in studio M. According to this experiment, a high-horn maximum sound pressure level of 79 to 80 dBA at 25 ft is not audible or detectable in Studio M (Tony Baxter of ESI confirmed this SPL and also that at this level the horn noise was inaudible in Studio M). This horn noise level was also only faintly heard on the recording equipment. It was difficult for the studio engineer to discern while listening with high gain on the signal, but he thought he could barely distinguish it from the background noise.

This experiment was not repeated with the LRV bells. The bell sound pressure level specification (extrapolated from 50 ft using a typical point-source 6 dB decrease per distance doubled) is 85 dBA at 25 ft, higher than the maximum horn sound pressure level determined in the experiment. Based on the horn noise level experiment results, the volume level of the LRV bells needs to be similarly reduced to a level that is comparable to the horn maximum sound pressure level of 79 to 80 dBA at 25 ft.

These experiment results also apply to Studio P due to its higher acoustic isolation. The high horn was less audible and less detectable in Studio P during the ESI simulation. Therefore it is likely that the maximum horn sound pressure level determined in the experiment (79 to 80 dBA at 25 ft) will be less detectable in Studio P than the already barely detectable signal in Studio M.

Forum

The background level in the forum is around 30 dBA. The level of the horn, after adjustment to a level acceptable in studio M, is as high as 35 dBA.

Fitzgerald

HDR measured noise levels during two pass-bys with high-horns, one northbound and one southbound, simultaneously in two locations, the lobby area and the stage. The measurement location in the theatre lobby area was separated from the street by an enclosed glass entryway. Horns were audible in the lobby, but barely measurable. The ambient background noise level without the horns is around 50 dBA, and the A-weighted level of the horn pass-by measurements did not increase from the ambient more than one-half of a decibel.

The horn was not measurable and barely audible on the stage, if audible at all. The door between the 2nd lobby and the house seating was open during these measurements, but it was not possible to localize the very faint signal by ear to determine if it came through the lobby door, or the stage door or wall. This despite the northbound passby was a constant-running high-horn as it passed by the alley, a very unlikely situation.

MITIGATION

Metropolitan Council has two categories of options to mitigate LRT horn and bell noise in this portion of the project area. The first mitigation category is administrative, which refers to adjustments to operational practices. The second mitigation category is structural, which refers to physically implementing a mitigation measure (like constructing a noise wall next to a highway). Potential options within each category are discussed below.

Administrative Mitigation Measures

Following are potential administrative mitigation measures available to Metropolitan Council.

- Reduce the level of the high-horn for the entire fleet. Results of these activities determined that a high-horn maximum sound pressure level of 79 to 80 dBA at 25 ft was not audible or detectable in Studio M and Studio P. This sound pressure level is much lower than current standard operating procedures. Metropolitan Council should consider surveying LRT systems in other cities and determining their horn and bell sound pressure level: reducing high-horn noise levels throughout the LRT fleet should also be considered.

- Institute a more rigorous calibration standard/procedure to ensure consistency of horn and bell sound pressure level throughout the fleet. The uniformity this provides will ensure that LRT horn and bell noise to not interfere with activities in the most noise-sensitive portions of the project area. HDR recommends Metro Transit hire an acoustical consultant to perform these measurements, to ensure they are performed correctly.

Structural Mitigation Measures

Following are potential structural mitigation measures available to Metropolitan Council.

- Acoustically isolate Studio M from Cedar Street. The isolation of the exterior wall can be improved by constructing a new wall inside the existing exterior wall along Cedar Street. The new wall should be acoustically isolated from the floor, ceiling and walls, to minimize the transmission of acoustic energy from Cedar Street into the recording space. The new wall should be designed to with adequate transmission loss to ensure that traffic noise (including emergency sirens) does not leak into the recording space. Compared to the rest of the exterior wall of Studio M, the window is the weakest point of isolation and it must be improved to realize any other isolation improvement. The existing window can be left in place, however a new acoustically designed window should be incorporated into the new wall partition to maintain ambiance and allow natural light into the space. The Studio M window is semicircular; if the new window is also semicircular, it may have to be a custom window order.

- Similar measures could be constructed into Studio P.

- According to information on Minnesota Public Radio's Web site (www.mpr.org), the UBS Forum is a "public space dedicated to exploration and dialogue concerning our society's most pressing public policy and cultural issue…[I]t hosts community discussions, public debates and live program recordings." The Forum was designed to provide an amount of outdoor to indoor noise reduction commensurate with this purpose. As such, mitigation measures recommended for critical listening / critical recording studios (e.g., Studios M and P) would not be appropriate for the Forum. With the potential institution of administrative mitigation measures, as described above, the Forum would experience lessened LRT-related noise intrusion.