ACOUSTICAL PEER REVIEW
CONCEPT DESIGN REPORT-NOISE ANALYSIS
112th Avenue Light Rail Options (B2M)

PREPARED FOR

CITY OF BELLEVUE
Department of Transportation

PREPARED BY

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1.0 INTRODUCTION

The intent of this peer review is to analyze the noise study and resulting conclusions presented in the Concept Design Report for six Options for the B2M Alternative, East Link Light Rail project. This peer review summarizes Sound Transit's study process in a comprehensive report, which includes our evaluation of the following elements:

- Location of sound measurements to establish the pre-project ambient sound conditions along the alignment.
- Sources of potential noise associated with the project.
- Methodology used in the prediction of project noise.
- Elements included in the predicted project noise levels.
- Potential mitigation proposed.
- Resulting mitigated noise levels for each of the proposed alignments.

Additional questions and concerns brought forward by the Mayor and City Council members were also considered in the peer review process. Responses to these questions are presented in this document.

Our evaluation also included several conversations with Sound Transit (ST) and their Noise Expert, Michael Minor (MM) to clarify study assumptions and approaches. It should be noted that the Concept Design Report is intended as a screening document to provide the ST Board, the City of Bellevue (COB) and members of the public with information regarding the predicted impact and potential mitigation for each of the six Options. It is intended as an abbreviated evaluation of the six Options along the B2M alignment to assist in the selection process. Once the preferred Option is selected, a more in-depth evaluation of the selected alignment will be included in the Supplemental Draft EIS (SDEIS) and the Final EIS (FEIS).

The evaluation of issues surrounding the noise study for the B7 alignment will be postponed until the Final EIS. Additional analysis is needed to reflect current conditions along this alignment.

2.0 EXECUTIVE SUMMARY

The Concept Design Report is intended to be a screening evaluation of the six Options under consideration for the B2M alignment. Areas potentially impacted by the project are identified, the level of impact is predicted and various mitigation approaches are evaluated. The study concludes that mitigated sound levels will be within Federal Transit Authority (FTA) criteria for No Impact for each Option.

- Methodology used in the predictions appears to be in line with industry standards and best practices for the evaluation of the airborne transit sound.
- Sound Transit is applying the knowledge gained through Central Link issues to the design of East Link. Following are elements of the design:
  - Wheel skirts on all trains.
  - Lowered bell sound pressure levels.
  - Lubricators will be installed on curves where wheel squeal is identified.
  - Track grinding and wheel truing are now capabilities of ST and are included as regular maintenance.
- Sound levels associated with bells and the impact sound of wheels crossing the rail gaps in the crossover switches have been included in the noise model to define impact along the East Link alignments (these elements were not included at Central Link).

3.0 NOMENCLATURE

Decibel, dB

The most common measure of sound level is expressed in decibels. The auditory response to sound is a complex process, which occurs over a wide range of frequencies and intensities. Decibel levels, or “dB”, are a form of shorthand that compresses this broad range of intensities into a convenient numerical scale.

The decibel scale is logarithmic, and as such, a doubling or halving of energy causes the sound level to change by 3 dB; it does not double or halve the sound level as might be expected. The minimum sound level variation perceptible to a human observer is generally around 3 dB. A 5-dB change is clearly perceptible, and an 8 to 10 dB change is associated with a perceived doubling or halving of loudness.

A-weighted Decibel, dBA

The human ear has a unique response to sound pressure. It is less sensitive to those sounds falling outside the speech frequency range. Sound level meters and monitors utilize a filtering system to approximate human perception of sound. Measurements made utilizing this filtering system are referred to as “A weighted” and are called “dBA”.

Ambient Sound Level

A sound pressure level that describes the sound environment at a specified location during a specified time period including contributions from all sound sources, both local and distant, excluding specific sources of interest or under investigation.

Day-Night Sound Level, L_{dn}

L_{dn} is the L_{eq} measured over a 24 hour interval, with sound levels occurring between 10:00 PM and 7:00 AM penalized by 10 dBA to reflect greater potential for disturbance. The nighttime penalty is imposed where sleep interference is a consideration. The L_{dn} has been found to have a close correlation with community response to noise. The L_{dn} is the descriptor upon which FTA bases their impact criteria.

Equivalent Sound Level, L_{eq}

L_{eq} is the A-weighted level of a constant sound having the same energy content as the actual time-varying level during a specified interval. The L_{eq} is used to characterize complex, fluctuating sound levels with a single number. Typical intervals for L_{eq} are hourly, daily and annually.

Maximum Sound Level, L_{max}

L_{max} is the maximum recorded root mean square (rms) A-weighted sound level for a given time interval or event. L_{max} “fast” is defined as a 125-millisecond time-weighted maximum, while L_{max} “slow” corresponds to a 1-second time-weighted maximum. L_{max} “slow” is used in the FTA evaluation.

4.0 REGULATORY CRITERIA

4.1 FTA

The FTA evaluation considers ambient conditions in setting Noise Impact Criteria for public transit systems. Both existing ambient and the cumulative effect of the predicted project sound are used to determine the criteria for impact. The quieter the ambient condition, the greater exposure above ambient is allowed. Table 1 below outlines the FTA criteria.

Table 1. FTA Noise Impact Criteria and Project Cumulative Noise Levels

Noise Levels Defining Impact for Transit Projects-Residential Sites				
Existing (Ambient) Noise Exposure L_{dn}	***Project Noise Impact Exposure L_{dn}***			***Allowable Increase Over Ambient, No Impact***
	No Impact	***Moderate Impact***	***Severe Impact***	
<43	<Ambient + 10	Ambient +10 to 15	>Ambient +15	<10
43	51	52-58	59	9
44	51	52-58	59	8
45	51	52-58	59	7
46	52	53-59	60	7
47	52	53-59	60	6
48	52	53-59	60	5
49	53	54-59	60	5
50	53	54-59	60	5
51	53	54-60	61	4
52	54	55-60	61	4
53	54	55-60	61	4
54	54	55-61	62	3
55	55	56-61	62	3
56	55	56-62	63	3
57	56	57-62	63	3
58	56	57-62	63	2
59	57	58-63	64	2
60	57	58-63	64	2
61	58	59-64	65	2
62	58	59-64	65	1
63	59	60-65	66	1
64	60	61-65	66	1
65	60	61-66	67	1
66	61	62-67	68	1
67	62	63-67	68	1
68	62	63-68	69	1
69	63	64-69	70	1
70	64	65-69	70	1
71	65	66-70	71	1
72	65	66-71	72	1
73	65	66-71	72	1
74	65	66-72	73	1
75	65	66-73	74	0
76	65	66-74	75	0
77	65	66-74	75	0
>77	65	66-75	76	0

Source: Table 3.1 Noise Impact Criteria: Effect on Cumulative Noise Exposure FTA Transit Noise and Vibration Impact Assessment, May 2006

Given that the ambient noise levels in this area are in the higher range, L_{dn} 59-70, the allowable increase above ambient is only 1-2 dBA. This is usually not a noticeable increase, although the light rail system may be audible even if the overall noise is lower than the FTA L_{dn} criteria due to the different character of the light rail sounds.

4.2 FHWA

The Federal Highway Administration (FHWA) impact criteria[1] for highway projects are based on a “level not to be exceeded” basis. The threshold for FHWA noise abatement criteria (NAC) for Residential is L_{eq} 66 dBA and 71 dBA for Commercial.

Not all of the options for B2M require modification along the traffic corridor. Therefore, traffic noise was not evaluated in the Concept Design Report. Based on a review of the DEIS, there is a 1-2 dBA difference between L_{eq} and L_{dn} along the B2M alignment. Much of the alignment is L_{dn} 64 or higher. Assuming an L_{eq} of 62 if the road is widened, bringing the traffic nearer to a residential area, the FHWA criteria of L_{eq} 66 would allow as much as a 4 dBA increase over existing conditions. This would be perceived as a slight increase in overall sound level from traffic.

5.0 B7 PEER REVIEW

An evaluation of the DEIS noise study for the B7 alignment is not included in this review. Elements included in the original DEIS do not reflect current conditions.

Construction occurring after the completion of the DEIS has revised the configuration of I-405. The modified alignment has changed the proximity of the highway to receivers. Elevation changes have also altered aspects of direct line-of-sight and shielding which will affect noise levels at receiver locations. The changes may alter the ambient noise conditions significantly in some locations along the corridor. The change in ambient conditions could modify the evaluation of impact along the B7 alignment. Additional noise measurements have been conducted and will update and replace measurements previously collected along this alignment in the SDEIS and FEIS.

The opening of the Central Link alignment has revealed that noise levels associated with the Sound Transit light rail trains are higher than anticipated. Noise measurements of the operational trains along the Central Link corridor are around 4 dBA louder than originally predicted. The DEIS model assumed the lower train sound levels in the study. The higher train sound levels will affect the predicted sound levels along the alignment. Sound Transit has developed specifications for vehicle procurement that includes limits on the noise emissions to ensure that low noise vehicles are purchased. Current measurements of Sound Transit’s fleet of vehicles are reported to be within 1 dBA of reference noise levels provided in the FTA manual[2].

Unanticipated noise issues along Central Link are currently being addressed. Issues such as sound from bells, wheel clank at the crossings and switches, and wheel squeal at various locations along the alignment are currently under investigation. Mitigation is being developed to address these issues. The SDEIS and FEIS for East Link will reflect the insight gained at Central Link as noise issues are resolved.

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[1] Transit Noise and Vibration Impact Assessment, Federal Transit Administration, 2006, Table 3-4

[2] Transit Noise and Vibration Impact Assessment, Federal Transit Administration, 2006, Table 6-3

Based on B2M peer review and review of the DEIS methodology, changes to study methodology and additional analysis to fully capture the community experience associated with the East Link Light Rail are being suggested. These will apply to the B7 alignment as well as the selected B2M alignment. The peer review for this alignment option will be postponed until the study is revised and updated. It will also be suggested that community concerns (as voiced by the Mayor and City Council) be addressed in this revision.

6.0 B2M PEER REVIEW

6.1 Study Methodology

The Study was intended to be a screening of six Options within the B2M alignment, rather than a full SDEIS level evaluation. The evaluation predicted noise levels, proposed mitigation and re-evaluated noise levels with the mitigation in place. The study was done quickly, but appears to be in line with industry standards and best practices for the evaluation of the airborne transit sound.

Noise monitoring sites selected are appropriate. Recent data collected were in good agreement with data collected in 2007. Therefore re-use of data collection point MC-6 (2007) for M-1 is appropriate.

Sounds associated with crossing bells and train horns have been included in the study. However, the sound levels associated with these short-term sources are averaged over a 24-hour period, similar to the train events. While this is in keeping with FTA methodology, it does not fully reveal the noise level the community experiences. Given that the bells/horns are shorter in duration, averaging the sound over an extended period tends to bury the “impact” of each event. The warning devices are also more intrusive due to their very nature of being designed to attract attention.

Wheel impact was considered at crossover switches and other discontinuous sections of track. Correction factors of +5 dBA were implemented by MM in the evaluation, which is consistent with the FTA manual. Again, this source of sound was averaged over 24 hours. This type of impact noise is more irritating on an event level, rather than a project average. It is recommended that this source also be evaluated on an event basis, rather than an average.

Sound reflected off of barriers (noise walls), retained cut retaining walls, bridges for access, etc. has not been included in the evaluation. We recommend that the SDEIS be expanded to include the effect of the reflected sound in the community.

Traffic impacts (FHWA), transit vibration (FTA) and construction noise and vibration (FTA) were not evaluated in the Concept Design Report. We expect that a full analysis of these elements will be performed once the preferred option is selected and will be included in the SDEIS.

The Concept Design Report identifies curves with the potential for wheel squeal in each option. Central Link has demonstrated that, at least during the “breaking in” period for a new system, retrofit mitigation of a squeal can take time to perfect. Given that Michael

Minor has recently collected sound data for Central Link wheel squeal, we suggest that a predicted sound level be established at nearby residences for areas identified as having a potential for wheel squeal (near tight radius curves, etc.) for that worst case “breaking in” period.

6.2 Study Accuracy and Recommendations

The full environmental evaluation required by FTA is not yet complete. The Concept Design process is intended to be a screening study to provide stakeholders with an abbreviated analysis of all six Options. The process provides preliminary analysis information to identify deficiencies or benefits of each Option. Once the selection of the preferred Option is complete, a more in depth study will be completed.

Light Rail

- The Concept Design did not include a vibration evaluation for B2M operational vibration. We expect to see this analysis for the selected Option in the SDEIS.
- In many of the Options, the modeled average sound levels for the bells alone equal or exceed the average sound levels predicted for the train. We are concerned that the impact of the bells is under evaluated with the sound averaged over 24 hours. Sound Transit will provide the L_{max} noise levels from bells and also indicate those residences near crossings that may experience an increase in noise due to the bells. While ST has agreed to present data for the bells and wheel clack on an L_{max} event level, in order to receive funding from the Federal Transit Administration, the noise analysis must use the FTA defined impact criteria, L_{dn}.
- Data was collected at Central Link for reference noise levels for the trains. The Concept Design Report reflects the higher train sound levels in the predicted levels.
- Wheel squeal is acknowledged as a potential impact along the curved track for all options. The tunnel is expected to mitigate the sound for Option 4.

Traffic

- No evaluation of traffic noise based on the FHWA model was included. The center running alignments for Options 1, 3 and 5, may require 112th to be widened to accommodate both train and traffic lanes. This will bring the traffic closer to the receivers. We expect to see this analysis for the selected Option in the SDEIS, if the preferred Option modifies the traffic corridor.

Construction

- No evaluation of Construction Noise/Vibration impact was included in the Concept Design Report. We expect to see this evaluation for the selected Option in the SDEIS.

- The DEIS document cites WAC 173-60 regulations for Construction noise. Bellevue City Code[1] also places restrictions on construction noise. These Code limits should be acknowledged in the SDEIS.

6.3 Review of Options

All six Options proceed along 112th Ave SE from the "Y" at Bellevue Way and connect with one of the preferred Downtown Bellevue Options. Basic configurations for each Option are outlined in Table 2 below.

Table 2. B2M Alignment Options

B2M Alignment	***South Zone***	***Middle Zone***	***North Zone***
Option 1 Center to Main St Tunnel	Center running with at grade-gated crossing near SE 15th	Center running at grade station north of SE 8th.	Crosses southbound lanes of 112th w/ gated crossing, curves west in retained cut to Main Street Tunnel to underground Bellevue Transit Center Station
Option 2 Westside to Main St Tunnel	East side running at grade-gated crossings at SE 8th and SE 15th.	Eastside running at grade station north of SE 8th.	West side running w/ at grade-gated crossing at SE 6th to Main Street Tunnel along 110th NE to underground Bellevue Transit Center.
Option 3 Center to 2nd St Tunnel	Center running initially in a retained cut and then at grade	Center running at grade, with a station north of SE 8th.	Center running at grade crossing to NE 2ndth Tunnel to underground Bellevue Transit Center Station.
Option 4 Eastside to 2nd St Tunnel	Eastside running with at grade-gated crossing at SE 15th and SE 8th.	Eastside at grade to station north of SE 8th to retained cut w/ SE 6th & Main St bridges.	Eastside retained cut into NE 2nd Tunnel under 110th Ave NE to underground Bellevue Transit Center Station.
Option 5 Center At Grade	Center running initially in a retained cut and then at grade	North of SE 4th to elevated structure, to station on Main Street	South side Main St to at grade station between 110th NE & 108th NE to at grade Bellevue Transit Center Station at NE 6th.
Option 6 Westside at Grade	Center running with at grade-gated crossing near SE 15th	Crosses to westside running at SE 6th and transitions to elevated structure at SE 4th St.	South side Main St to at grade station between 110th NE & 108th NE to at grade Bellevue Transit Center Station at NE 6th.

Source: City of Bellevue Department of Transportation

For electric trains, such as those in operation along the ST Link Light Rail corridors, wheel noise will dominate the sound signature of the trains. This will increase with speed. The noise is created by:

- Continuous rolling contact between wheel and rail.
- The impact of the wheel on discontinuous track (crossovers and switching).
- Squeal or flanging caused by wheel slipping or skidding on tight curves.

Auxiliary sounds such as bells on the moving train vehicles and bells at the crossings also contribute to the overall operational sound of a light rail system.

[1] Bellevue City Code 9.18.020C

At grade alignments are generally at street level. Crossings along at grade alignments are gated with signal bells.

Elevated alignments are along a structure above street level. Light rail track passes over street intersections so gates and signals are not needed. However, the source is elevated, potentially increasing the number of properties that have lines of site to the train.

Alignments with retained cuts are profiles below grade level. The “trench” can have a retaining wall on one or both sides. Streets and driveways cross over the light rail eliminating the need for gated crossings or signaled intersections.

Tunnels allow the alignment to run underneath the streets or other land uses. Tunnels offer the greatest amount of noise mitigation as no crossings or gates are needed and line of site to the source is eliminated.

Noise impacts for all six Options are predicted to be eliminated with mitigation. Mitigation proposals are very preliminary, intended to be used for comparison between Options only. We expect to see complete impact analysis and mitigation strategies presented in the SDEIS and FEIS for the preferred Option. Potential mitigation identified in the Concept Design Report includes sound walls, special track configurations and residential sound insulation. Residential sound insulation packages are considered as a last resort option when exterior mitigation is not feasible or insufficient. In these cases, the interior noise levels due to the project are mitigated, but residual, exterior impacts remain for outdoor living spaces.

Each Option is also identified with the potential for wheel squeal due to the tight radii on the track curves. Lubrication is offered as the mitigation for this noise source.

Of the six Options, Option 4 has the least number of noise impacted properties due to the retained cut along the alignment. The predicted project noise levels result in 1 severe impact at the Bellevue Club pool and 31 moderate impacts; 15 single-family homes and 16 multifamily homes at Bellefields Residential Park. This alignment also has the fewest crossings and any potential wheel squeal would occur at the curve within the tunnel, significantly reducing any impact at residential properties.

6.4 Light Rail Noise Mitigation

Sound Transit Mitigation Policy[1] directs Sound Transit to comply with applicable Federal/State and/or Local law and relevant guidelines for evaluating noise impacts and determining appropriate mitigation. The FTA guidelines published in the Transit Noise and Vibration Assessment[2] are the governing authority by which Sound Transit abides.

[1] Sound Transit Board Motion M2004-08, 2004

[2] Transit Noise and Vibration Impact Assessment, Federal Transit Administration, 2006

FTA does not have a specific noise mitigation policy embodied in a regulation. In conjunction with FHWA, FTA has adopted the general policy of the National Environmental Policy Act (NEPA) for environmental mitigation. This policy includes requirements for "…measures necessary to mitigate adverse impacts are to be incorporated into the projects…". FTA identifies two levels of impact; Moderate and Severe. The requirements for Moderate impacts are less stringent than for Severe impacts. ST mitigates all Moderate impacts. Further, "…such measures are eligible for Federal funding when FTA determines that the proposed mitigation represents a reasonable public expenditure after considering the impacts of the actions and benefits of the proposed mitigation measures".

In order to meet the test for Federal project funding, FTA must demonstrate the following prior to project approval:

- The project design elements have endeavored to preserve and enhance the environment and interests of the community.
- Mitigation is included, where practical, to address adverse environmental effects as a result of the project.
- Options are analyzed to ensure that no feasible, prudent alternative exists and all reasonable steps have been taken to minimize the effect of the project. "Feasible" is determined objectively by quantitative elements such as engineering considerations, safety, maintenance and achieving a sound reduction of at least 5 dBA. "Reasonable" is more subjective and considers community desires, aesthetics, views, and evaluates whether the overall mitigation outweighs adverse social, economic and environmental effects and cost

In order to evaluate the noise impact of a project and the extent of mitigation, FTA and project planners need to determine:

- Number of affected properties.
- Increase in sound level over ambient conditions.
- Noise sensitivity of the property.
- Effectiveness of the mitigation.
- Neighborhoods already impacted with high noise are eligible for more mitigation so as not to increase above existing high levels.
- Community views (i.e. view obstructed by noise wall).
- Protected Historic sites, Parks, Wildlife refuge.
- Cost per benefited residence.

Sound can be treated with mitigation at the *source* (train or rails) along the *path* between source and receiver (barriers) and at the *receiver* (residence or other noise sensitive property). It is preferable to treat the noise at the source whenever possible.

Source mitigation approaches include:

- Quiet train purchase.
- Wheel skirts.
- Rail grinding.

- Wheel truing.
- Lubrication or friction modifiers between rail and wheel.
- Quieter train bells or crossing bells.

Path mitigation includes:

- Sound walls.
- Earth berms.
- Alignment modifications.
- Buffer zones.

Mitigation at the residential receiver (where required) is typically a sound insulation package, which includes:

- Acoustically rated windows.
- Mechanical ventilation.
- Seals along doors.

Sound insulation package will effectively reduce sound levels at the interior of a residence. However, exterior sound levels on decks and other outdoor living areas will remain intrusive. Sound insulation is typically considered as a last option for mitigation.

A table is enclosed as an Appendix expanding the various mitigation options and associated issues with each.

7.0 RESPONSE TO COUNCIL QUESTIONS

The Mayor and City Council have raised several questions about light rail noise. The questions are addressed in no particular order

7.1 What is best profile for noise?

The best profile for noise reduction is a tunnel, as the source of sound (train) is not exposed to the community.

The retained cut options offer some natural shielding for the trains. At grade options expose the first row of structures to the train noise. These structures often become a barrier for homes further from the alignment. Elevated tracks locate the noise source higher into the community and create the potential for increased line of sight to the train and therefore an increase in potential noise.

7.2 How to minimize/eliminate likely noise problems through design?

The process starts with the purchase of the trains. It is our understanding that all ST trains are equipped with wheel skirts which reduce the rolling wheel noise.

The design of the alignment is also critical. To minimize the impact, routing the alignment in areas with a higher existing ambient sound is one approach, as the sounds from the train are partially masked by ambient sounds.

Minimizing crossovers and gated crossings reduces the occurrence of bells. The FTA guidelines cite that “bells can be extremely annoying to nearby residents.”

The track design and construction is critical. Embedded track is fully encased in the supporting structure and can result in slightly higher noise and vibration levels. Ballasted track, typically with crushed stone beneath the track bed, can reduce noise and vibration.

Track curves need to be gentle enough to not encourage wheel squeal. FTA cites a design consideration of 1,000 foot radius or 100 times the truck wheelbase, whichever is less. It is our understanding that the wheelbase on the Sound Transit Kinkisharyo trains is about 6 feet. This would indicate that a turning radius closer to 600 feet might be the threshold for potential squeal for the ST light rail system. However, ST has indicated that Central Link curves with radii of 500 to 750 feet have resulted in squeal issues. ST is committed to addressing curves in this range or tighter for potential squeal issues on East Link.

7.3 What is the nature and quality of light rail noise?

The sound of the trains will be dominated by the wheel noise. Generally this will be a broadband sound, with energy from a wide range of frequencies. This type of sound is generally less annoying.

The impact sound of wheels over a discontinuous track will result in a “clunk” sound, which has a more transient quality and is more noticeable. ST is addressing this type of sound in the design.

Wheel flats, the flattening of a wheel surface due to the skidding at braking, will result in a “thunk, thunk” sound along the entire corridor. Again this sound is more transient in character and will be noticeable. ST has a policy of regular wheel truing to repair wheel flats.

Wheel squeal is a result of wheel slipping or skidding at track curves. This is extremely tonal, usually around 2 to 4 kHz. The human ear is most sensitive at these frequencies as they correlate with speech frequencies. The wheel squeal would be audible above the ambient sounds, even if the overall dBA level is below ambient, due to the tonal character of the sound.

Flanging is caused by friction from the wheel rubbing against the track flange. This is a more broadband sound, but would likely be audible above ambient.

Bells are a tonal and transient noise source and are designed to command attention. Sound levels for the bells can be reduced but must remain audible above the ambient at the crossings in order to serve as a warning device. it is likely that bells will be audible for some residents.

7.4 Will "click-clack" noise be a problem for East Link?

In theory, no. The light rail track is continuously welded except at crossovers or other special track work. Measures are being taken to install a special track at the crossover switches to minimize the impact of the wheels at the gap in the track.

Wheel truing will also reduce the click clack type of sound, through regular maintenance.

7.5 How can screeching and clacking be prevented? What are approaches to addressing wheel squeal?

Screeching can be reduced with larger radii curves in the track design, lubrication at the curves or top of rail friction modifiers.

Wheel clack can be reduced with track designs, which minimize the section of track with gaps, and through regular maintenance to keep the wheels in round.

7.6 How is ST accounting for the noise issues discovered in the opening of the Link Light Rail line? What specific efforts are being made to make certain these noises are mitigated? [in Central Link]

ST is committed to mitigating any noise impacts exceeding the FTA criteria for system operation.

Following are ST responses to the issues discovered at Central Link:

- Trains: It was discovered that train noise was actually higher than used in the predictions to determine impact at Central Link. Predictions for East Link are being revised based upon this new data. Trackside sound barriers are being added in some locations at Central Link.
- Bells: It is ST policy to ring the bells at pedestrian and vehicle crossings and entering and exiting the stations. The sound levels of these bells have been reduced to a minimum consistent with other agencies. Train bells were not included in the noise predictions for Central Link. This element will be included in the East Link studies.
- Crossovers: Crossovers in the Rainier Valley do not have noise reduction design features. Track switches are currently being modified at Central Link to reduce noise levels. Crossovers will be included in the East Link noise model and special tracks will be used where impacts are predicted.
- Wheel Squeal: Lubricators have been installed on curves where there is wheel squeal along Central Link. ST is still making adjustments to the location of the lubricators and the quantity of lubrication dispensed. Lubricators will be included in the design at East Link where potential for wheel squeal is identified.
- Sound Insulation: Additional residential insulation may be added in some areas along Central Link corridor where noise levels exceed those predicted.

7.7 Provide a comparison of decibel levels for a variety of modes of transportation?

Given that the train is a transient source, it is often measured during a passby as a maximum level. Michael Minor included the following values as he documented sound levels associated with the Central Link trains. Note the distance from the various sources when comparing the sound levels. For example, comparing the three transportation sources from Table 3, all normalized to 50 feet, would result in levels of 84 dBA a heavy truck, 75-79 dBA for light rail and 64 dBA for a passenger car. Most residences will be located at a distance greater than 50 feet from the light rail, further reducing the level.

Table 3. Typical Maximum A-weighted Noise Levels

Sound	***Sound Level (dBA)***	***Approximate Relative Loudness[3]***
Heavy Truck or Motorcycle (25 feet)	90[1]	2
Garbage disposal (2 feet)	80[1]	1
Typical at grade light rail vehicle (50 feet)	75-79[2]	1/2 – 1
Passenger car at 65 mph (25 feet)	70[2]	1/2
Moderately Busy Department Store	60[1]	1/4
Typical Television Show (10 feet)	50[1]	1/8
Bedroom or Quiet Living Room	40[1]	1/16

1. Source: Noise Impact Analysis Test Results and Recommendations Rainier Valley Segment, November 2009, Michael Minor & Associates
2. Source: Michael Minor & Associates
3. As compared to a garbage disposal at 2 feet

7.8 Will noise reflection be a problem for B2M retained cut option?

There is a potential for sound reflected off of the cut to increase neighborhood noise levels. We have asked for this to be included in the final analysis once the preferred Option is selected.

7.9 Bellevue has a provision in the Noise Code for 40 dBA inside residential facilities. Will this be factored into the evaluation.

We would not expect ST to consider this in their evaluation. Bellevue City Code[1] outlines a restriction for residential development in high noise areas (above L_{dn} 65). This section requires facility designs to achieve interior noise levels of L_{dn} 40 in bedrooms and L_{dn} 45 in non-sleeping areas. All study receptors are existing, not new construction.

7.10 Can the City of Bellevue opt not to have the bells?

This question is best answered by your legal counsel. Based upon our research, we have discovered the following:

[1] Bellevue City Code 9.18.045B

Sound Transit's Link Noise Mitigation Policy[1] directs ST to comply with applicable Federal State and Local laws. Federal Law[2] states that Standards for rail safety are established by "each state oversight agency" within FTA standard guidelines. Sound Transit has indicated that it is their understanding that WSDOT is the designated oversight agency for the State. FTA does not regulate the use of bells in their standard guidelines.

ST has a policy of ringing the bells at pedestrian and vehicle crossings and entering and exiting the stations. It is our understanding that ST intends to apply the same policy to all jurisdictions.

The Federal Railroad Administration (FRA) has stringent policies on warning devices and provisions for establishing "quiet zones"[3] where these warning devices are not sounded. However, this applies only to commuter and freight corridors, not to light rail.

8.0 MISCELLANEOUS INFORMATION

We acknowledge that the current design is not advanced enough to develop specific mitigation. ST has completed the screening process and, in general, identified appropriate types of mitigation. A more in-depth evaluation will occur when the SDEIS has been completed for the preferred option.

Michael Minor has included the following in his evaluation:

- All ST trains have sound reducing wheel skirts.
- ST will include lubrication devices on all curves with identified wheel squeal.
- Sound walls.
- "Special" noise reducing trackwork at the crossovers.
- Retained cuts will provide natural berming.
- Sound Insulation (last resort).

The Study states that all interior "impacts" will be mitigated. Sound walls are limited in their effectiveness to properties where the line of sight to the rail is blocked by the wall. Very little effect is gained for properties that look over the top of a sound wall. Sound Insulation (acoustical windows, added insulation, ventilation, etc.) is an appropriate approach for these units and is listed as the mitigation for several upper floor units on multi-family dwellings. However, exterior impact will not be mitigated for these units. The exterior sound level will not be reduced for:

- Exterior decks facing the alignment or roof decks.
- Open windows/doors facing the alignment.
- Potential infiltration through stove hood vents/dryer vents, etc.

[1] Sound Transit Board Motion M2004-08, 2004

[2] CFR Title 49, Chapter 6, Part 659 – Rail fixed guideway systems; State safety oversight; 2009

[3] CFR Title 49, Chapter 2, Parts 222 and 229 – Use of Locomotive Horns at Highway-Rail Grade Crossings; Final Rule, 2006

APPENDIX A

Appendix A1 Light Rail Noise Mitigation Evaluation

Mitigation Approach	Description	Operational or Capital measure	Effectiveness (most effective for certain types of noise, applications)	Visual impacts	Ease of implementation (relatively more of less difficult to construct?)	Maintenance considerations (for agencies or home owners)	Timeline for identification or implementation (i.e. does it need to be determined early in design process, or can it be implemented after the fact)	Other considerations	Comments from Sound Transit's Noise Consultant Team
Low Noise Vehicles	State of the Art quiet rolling stock is being developed.	Capital measure	Potentially effective but many features are in research and not yet available.	None	Many features in development not readily available	Similar to other trains	Must be considered as capital purchase.		The specifications that Sound Transit uses for vehicle procurements include limits on the noise emissions to ensure that low-noise vehicles are purchased. Current measurements of Sound Transit's fleet of vehicles are within 1 dBA of the reference noise levels provided in table 6-3 of the FTA manual. Experience is that it is rare to achieve noise levels lower than what is included in the Sound Transit procurement specification.
Wheel Skirts	A solid extension attached to the train creating a barrier very near to the wheel	Capital measure	Effective for the reduction of wheel noise.	Mitigation becomes part of the train body	Trains can be purchased with this feature. Retrofitting the train is possible but more difficult to implement.	Minimal to Agency	Best early in design.	6-10 dBA	Sound Transit vehicles already have wheel skirts.
Undercar absorption	Absorptive material applied to the under carriage of the train.	Capital measure	Effective for reducing wheel noise.	None	Trains purchased with this feature. Can be added as a retrofit.	Minimal to Agency	Best early in design.	5 dBA	While reductions of this magnitude have been achieved on some light rail systems and are stated in the FTA manual, they have not been achieved on modern light rail vehicles. Tests of absorptive insulated skirts on existing Sound Transit light rail vehicles showed a reduction less than 1 dBA Lmax.
Resilient or damped wheels	Two steel parts; a wheel body and a tire structurally isolated with an elastomeric element.	Capital measure	Reduce transmission of vibration and sound radiation due to wheels.	None	Similar to standard wheels	Regular Agency maintenance	Can be implemented at any time.	5 dBA 10-20 dBA for wheel squeal	All Sound Transit vehicles have resilient wheels, as do virtually all modern light rail vehicles in North America.
Wheel truing and replacement	Wheels develop flat spots due to braking and use. Flats cause a "thunk" sound as the wheels roll. Wheel truing restores the wheels to round.	Operational	Eliminates thunk of wheel flats.	None	Train is out of service.	Regular Agency maintenance.	After operation of Train.	5 dBA	Sound Transit has a state-of-the-art wheel truing program. The reduction of 5 dBA only occurs when a specific wheel has a noticeable wheel flat. It is Sound Transit's policy to inspect wheels on a regular basis and true any wheel with a substantial flat. .

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Rail grinding and replacement	Smoothing and polishing of rail to reduce rail corrugations.	Operational	Reduce impact of wheel on discontinuous surface.	None	Train is out of service on rail receiving procedure.	Regular Agency maintenance.	Quality control during construction.	5 dBA	Sound Transit is currently testing this mitigation.
Turning radii	1000 feet or 100 X truck wheelbase which ever is less	Capital measure	Very effective at reducing wheel squeal	Increased footprint for alignment.	Larger project area	Minimal additional effort to Agency	Must be included at design level.	Avoids squeal	Sound Transit has installed rail lubricators to mitigate wheel squeal.
Vehicle maintenance	Regular maintenance of fans, ducts compressors and valves.	Operational	Reduce wayside noise.	None	Train is temporarily out of service	Regular Agency maintenance.	After operation of train		Sound Transit vehicles are inspected on a regular basis. Sound Transit has tested the vehicles for noise and equipment on the vehicle has not been found to contribute to the noise issues.
Operator training	Operator training regarding procedures which can reduce noise such as braking and speed at turns.	Operational	Can be effective in reducing wheel squeal and wheel flats	None		Sustained Operator training program	Can be implemented at any time	Relies on Operator following Agency guidelines.	Sound Transit has an operator training program to educate operators regarding emergency braking procedures Emergency braking is one of the causes of wheel flats. The operators are also instructed to report any vehicle related issues, including wheel flats, to vehicle maintenance so the problem can be addressed.
Trackway type	Ballast at grade Ballast at Guideway	Capital measure	Effective at reducing wheel vibration and radiation of sound.	Minimal	Difficult to change after initial track construction.		Best early in design	3-5 dBA	Track type depends on a number of factors that must be balanced with the noise issue, including urban design and emergency vehicle access across the tracks.
Rail Face Lubrication	Gel to reduce friction between wheels and rail	Capital measure	Reduces wheel squeal	None			Can be implemented at any time	Reduces squeal	Sound Transit has installed rail lubricators to mitigate wheel squeal
Top of rail Friction Modifier	Thin film to control wheel-rail interface	Capital measure	Reduces wheel squeal and flanging noise. Reduce corrugation development.	None			Can be implemented at any time	Reduces squeal	Sound Transit has installed rail lubricators to mitigate wheel squeal

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Special track at Crossing and switches	Wheels hitting gaps in track	Capital measure	Reduces click clack sound of wheels over discontinuous track	Slight	Additional effort at construction of track	Regular maintenance required	Best early in design can be added as a retrofit but takes train out of service at point of construction work.	Reduces impact noise	Sound Transit is evaluating crossover noise as part of the East Link project and will install noise reducing trackwork where the crossover creates noise impacts.
Speed	Wheel noise increases with speed	Operational	Can reduce operation noise and wheel squeal and click at crossings and switches.	None					Although reducing speed will reduce noise levels, the detrimental effects of longer travel times, reduced capacity, and lower ridership usually outweigh the benefits of slightly reducing speed. For speeds of less than 35 to 40 mph, reducing speed will rarely provide more than 1 to 2 decibels, which would be a marginal benefit.
Bells on moving vehicles	Adjust bell Volume	Operational	Reduced sound levels in community	None	Less difficult, after establishing safety threshold	Safety	Can be implemented at any time		Bells are an audible warning safety device. The sound level of the bells must be loud enough to be heard above background sound levels.
Crossing and Gate Bells-stationary	Adjust Bell Volume	Operational	Reduced sound levels in community	None	Less difficult, after establishing safety threshold	Safety	Can be implemented at any time		
Public Address System at Station	Adjust volume and turn off at night	Operational	Reduced sound levels at night.	None	Less difficult.		Can be implemented at any time		Sound Transit has turned off PA systems at some stations at night to reduce noise.
Sound walls along trackway	Sound barriers are most effective close to the source of noise. Sound walls along the trackway can have a much lower profile with a height of 3 to 4 feet.	Capital measure	Effective for operational noise of the train.	Minimal due to low profile	Standard products available, many modular for ease of installation.	Minimal cleaning	Always best to identify prior to construction but can be installed after operation.	6-10 dBA	Sound Transit has sound walls installed along at-grade and elevated segments where impacts were identified during the project design. Sound Transit walls on elevated structures are as low as 3-feet.

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Sound walls separate from trackway	Sound barriers farther from the trackway need to be taller	Capital measure	Effective for receivers that have line of sight blocked by barrier. Not effective for upper story residences or homes on elevated topography	Significant visual impact in the community. Walls are 8 to 12 feet in height, typically	Major construction effort	Minimal	Best in design, can be added later.	3-5 dBA	
Alignment modifications	Design alignments in areas already impacted with other noise sources, through non-noise sensitive areas.	Capital measure	Effective to reduce overall noise in community	Varies			Early in design.		The light rail alignment depends on a number of factors that must be considered in addition to potential noise impacts.
Buffer Zones	Design alignments in areas with significant distance and topography etc from residential areas.	Capital measure	Effective to reduce overall noise in community	Varies			Early in design.		
Residential Sound Insulation Program, RSIP	Acoustical windows, mechanical ventilation, door seals etc.	Capital measure	Effective for the reduction of interior noise. Exterior noise at decks and other outdoor living areas is not affected by mitigation.	None	Homeowners temporarily impacted by construction at home.		Towards the end of design or later.	5-20 dBA	Sound Transit has provided sound insulation to many homes along the Central Link line and will continue to use insulation in areas where other options are not practical.