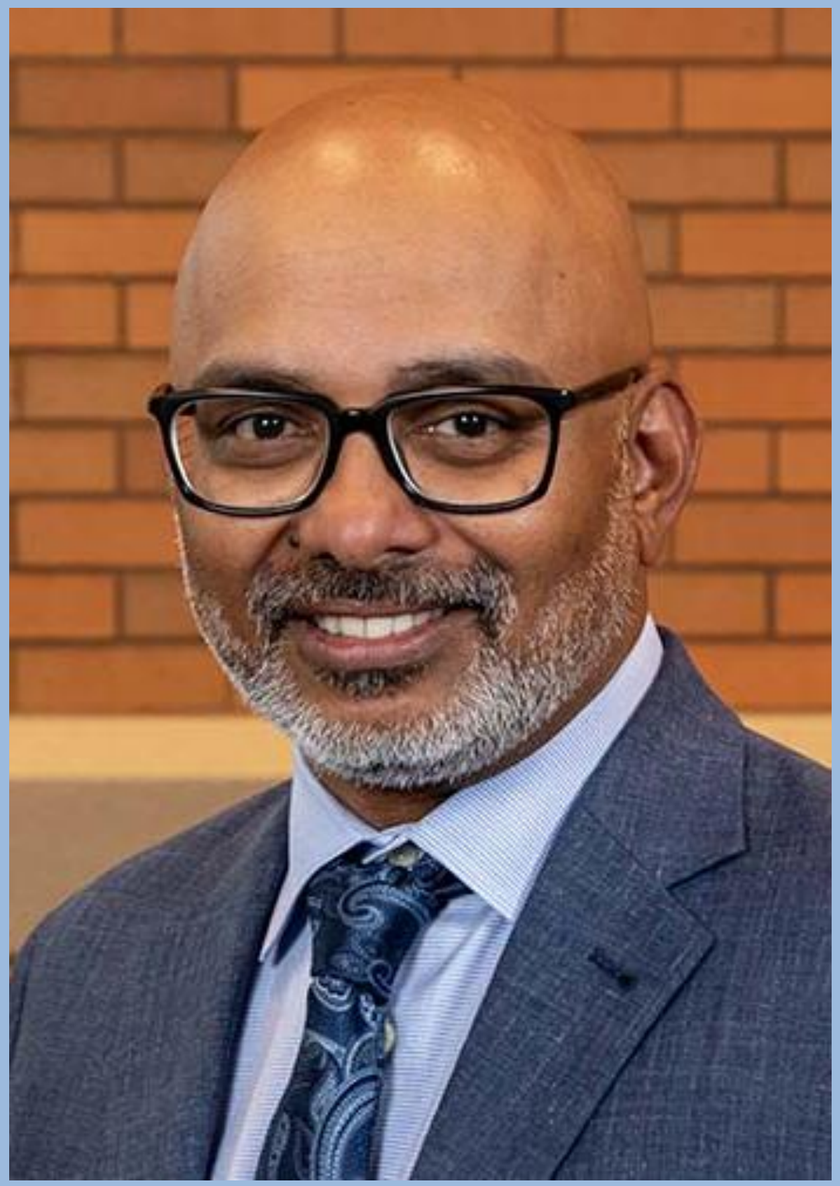
SOUNDTRANSIT

Shankar Rajaram

Executive Director,
Sound Transit



RAIL TRANSIT SEMINAR

August 26-28, 2025

WRI2025RT SEATTLE, WA

WRI 2025 30th ANNIVERSARY

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LRV Procurement: Specifying and Managing Wheel Rail Interaction and Performance Properties

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Overview

- Series 3 LRV draft specification WRIS features
- Wheel rail interface and vehicle dynamics
  - Performance Requirements
  - Contractor Plan
  - Submittal requirements
- Ride quality/comfort
- Vehicle Track Structure Interaction (VTSI)
- Wayside & interior noise
- Groundborne vibration

Typical Vehicle Specifications

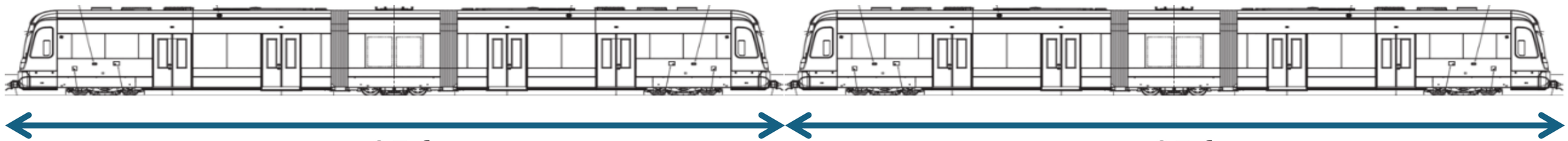
Must Include:

- High speed stability
- Curving and ride performance
- Wayside & interior noise, ride quality, & groundborne vibration
- Need for carbuilder to perform a detailed WRIS study (by making their own reasonable assumptions)

Recommend to Include:

- Dynamics Modeling
- Agency's Track Maintenance limits
- WRI conditions that trigger maintenance interventions (conicity, friction, rail shape)
- WRI wear pattern
- Require OEM Wheel Manangement Recommendations
- Life Cycle Cost (LCC) evaluation

Sound Transit's System Expansion Plans



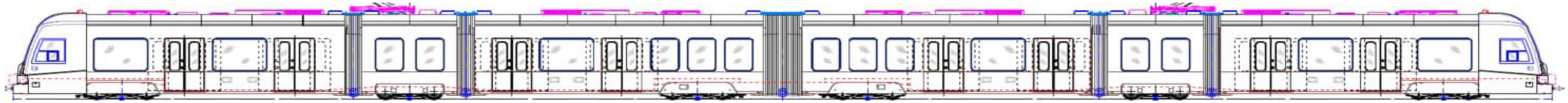
95 ft

95 ft

Power Truck
(A-car)
Solid axle wheels

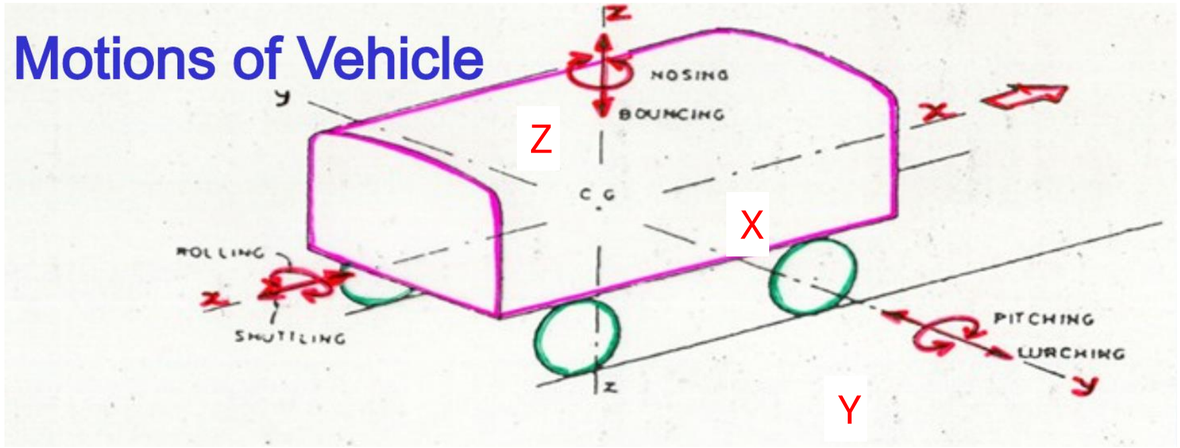
Trailer Truck
(C-car)
Independent rotating wheels

Power Truck
(B-car)
Solid axle wheels



190 ft

6 Modes of Oscillation for LRVs



Axis	Mode of Oscillation	
	Linear	**Rotational**
X	Shuttling	Rolling
Y	Lurching	Pitching
Z	Bouncing	Nosing (Yaw)

Power Truck: Hunting = Rolling + Nosing

IRW Truck: Mostly Lurching + Some Nosing

Reference: Rail Wheel Interaction Presentation by Nilmani, Prof. Track

Vehicle Defects and Oscillation

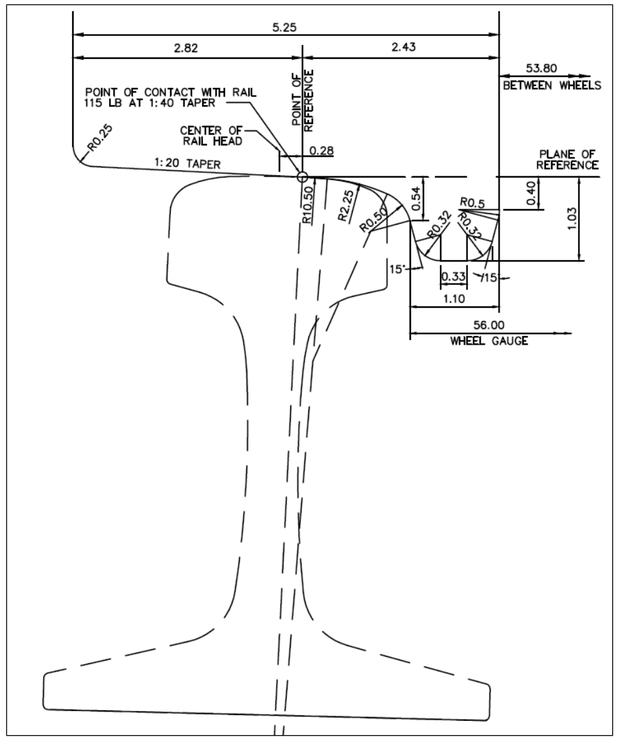
Vehicle Defect	Oscillatory Motion
Worn wheel	**Hunting, Nosing, Lurching**
Ineffective spring	**Bouncing, Pitching, Rolling**
Coupling	Shuttling, Nosing
Side bearer clearance	Rolling, Nosing
Ineffective pivot	Nosing

Reference: Rail Wheel Interaction by Nilmani, Prof. Track

Wheel Rail Interface

- Language updates allowing alternative truck configurations.
- Max wheel diameter 26 in. Existing wheel profiles and back-to-back to be used.
- Min. worn dia. must demonstrate acceptable load transfer for frogs, crossing gaps & rail breaks (3 in)
- Any proposed geometry changes require EN 13232-3 assessment to show geometric compatibility
- **Reports of track design and maintenance limits to be provided by ST.**
- **Contractor to provide wheel maintenance and monitoring guidelines.**

Wheel Dimension



Wheel Gauge = 56”

Conical wheel shape with 1:20 Taper

- All trucks – new wheel diameter **must be** nominally 26” unless approved. [E]

It is intended that we retain consistent diameters with ST2, additionally ST reported the existing wheel truing machine is limited to a max diameter of 26”

- Minimum allowable wheel-diameter wear of 2”
- Must provide wheels with [ST profile] unless otherwise Approved by ST.
- Back-to-back 53.8” +/-0.06 unless otherwise Approved by ST.

Any proposed change to these dimensions must be supported by the Wheel-to-Rail Interface Study (WRIS) and Vehicle Dynamic Analysis. [E]

Truck Dimensions

ST2 Truck Dimensions

TS 2.3.4

- Motor truck wheelbase 71” to 75”
  - Actual MT wheelbase is 74.8”
- Center truck wheelbase 67” to 75”
  - Actual CT wheelbase is 70.8”
- Spacing of motor truck centerline-to-pivot center must be sufficient to comply with **dynamic envelope**

ST3 Truck Dimensions

TS 2.2.4.5

- All trucks – wheelbase must be between **67”** and 75” [E]
- Spacing of trucks must be designed to enable coupled LRVs to:
  - Safely negotiate the entirety of ST track geometry, including OMFs; [E]
  - Comply with the dynamic envelope and maximum curve offset; [E]
  - Comply with the track structure loading requirements; and [E]
  - Comply with the passenger bodyside door position requirements; [E]
  - Comply with the natural frequencies requirements of TS 2.6. [E]

Vehicle Dynamics: Natural Frequencies

- Vehicle body and truck frequencies must be separated from each other by a factor of at least 2, or the modes must be otherwise decoupled from each other. **[E]**
- **Damping rates for LRV and truck modes of vibration must be at least 5% of critical damping for truck modes and 15% of critical damping for vehicle body modes. [E]**
- **Truck spacing must not be an integer multiple of the truck wheelbase. [E]**
- The truck wheelbase must not be an integer multiple of the rail support spacings of 30 in. (762 mm) for direct fixation and 27.5 in. (698.5 m) for ballast and tie track. **[E]**
- The primary suspension resonance frequency must be less than 12 Hz. **[E]**
- The floating slab track at the University of Washington Campus is designed with a natural frequency of 5 Hz, this is a critical area for ground borne vibration compliance. Additionally, lower primary suspension resonance frequency tends to limit ground borne vibration. **[I]**
- **It is preferred that primary suspension resonance frequency is less than 10 Hz. [D]**

Vehicle Dynamics: Safety

- **Resistance to flange climb derailment on twisted track** – Build on APTA standard. Add superelevation with tight curve for worst-case evaluation. Long wavelength evaluation when there are two trucks on the same module.
- **Stability** – Stability up to 65 mph to be demonstrated, **supplier to state assumed maximum conicity**. Additional requirement to **address risk of low speed, low conicity hunting**.
- **Resistance to overturning** – Provide calculations for overturning speeds on various curves to inform risk of overspeed. Any high wind speed restrictions.

Vehicle Dynamics: Track Forces & Overturning

ST3 Vehicle Dynamics

TS 2.6.5 - Track Forces (Not a requirement for Series 2)

- The P2 force for powered axles must not exceed that of the current fleets' powered axles when calculated in accordance with APTA PR-M-RP-009-98. [E]
- The P2 force for un-powered wheels must not exceed that of the current fleets' un-powered wheels when calculated in accordance with APTA PR-M-RP-009-98. [E]
- The P2 force calculations must use the constants defined for PRIIA DMU in Table 2 of APTA PR-M-RP-009-98. [E]

TS 2.6.6 - Resistance to Overturning (Not a requirement for Series 2)

- Considering the network alignment, track and installation and maintenance tolerances, and the line speed profile of the network, the LRV must not overturn on any curves on the Sound Transit network, and must have a minimum of a margin of safety of 100% between the plated line speed of any curve on the Sound Transit network, and the speed at which overturning would occur on that curve. [E]

Vehicle Dynamics: Equalization

ST2 Vehicle Dynamics

TS 11.5.5 Equalization

- Truck equalization shall be such that with the car on level track under an AW0 load, lifting or dropping any wheel of a truck 1.50 in (38 mm) shall not change the load on any wheel of the car more than 60%.
- Raising or lowering any wheel on a truck up to 2 in (50 mm) shall not result in loss of contact between any of the other wheels and the rail.

ST3 Vehicle Dynamics

TS 2.6.2 - Equalization (**part of Resistance to Derailment**)

- Truck static wheel load equalization must be simulated and tested as defined in Section 3 of **APTA PR-M-S-014-06**, with each wheel lifted and lowered. [E]
- Raising or lowering any wheel of a truck 1.50 in (38 mm) must not change the load on any wheel more than 60%. [E]
- Raising or lowering any wheel of a truck up to 2 in (50 mm) shall not result in loss of contact between any of the other wheels and the rail. [E]

Vehicle Dynamics: Curving Performance & Wheel Wear

ST2 Spec: The vertical resonance frequency of the primary suspension system shall not exceed 12 Hz. The longitudinal spring rate shall be selected such that all the requirements of the Specifications are met, but shall permit the axles to align in curves down to a radius of 600 ft (183 m) without flanging. The longitudinal spring rate shall not exceed 90,000 lb/in (15,760 kN/m).

ST3 Vehicle Dynamics

- TS 2.6.8 - Curving Performance
- The LRV **T-gamma values on curves must be the same as or lower than** the values in TS Tables 2-6 and 2-7 without the application of wheel flange lubrication. [E] *(table values from Series 2 baseline)*
- T-Gamma Limit Values – Zero Cant Deficiency & Two-Inch Cant Deficiency

Reasoning

- Series 3 Spec open to alternative vehicle config / truck / suspension designs.
- Why T-gamma?: Contact forces factored more comprehensively, effects of Primary yaw stiffness, and truck rotational stiffness captured.

Ride Quality Vs Ride Comfort

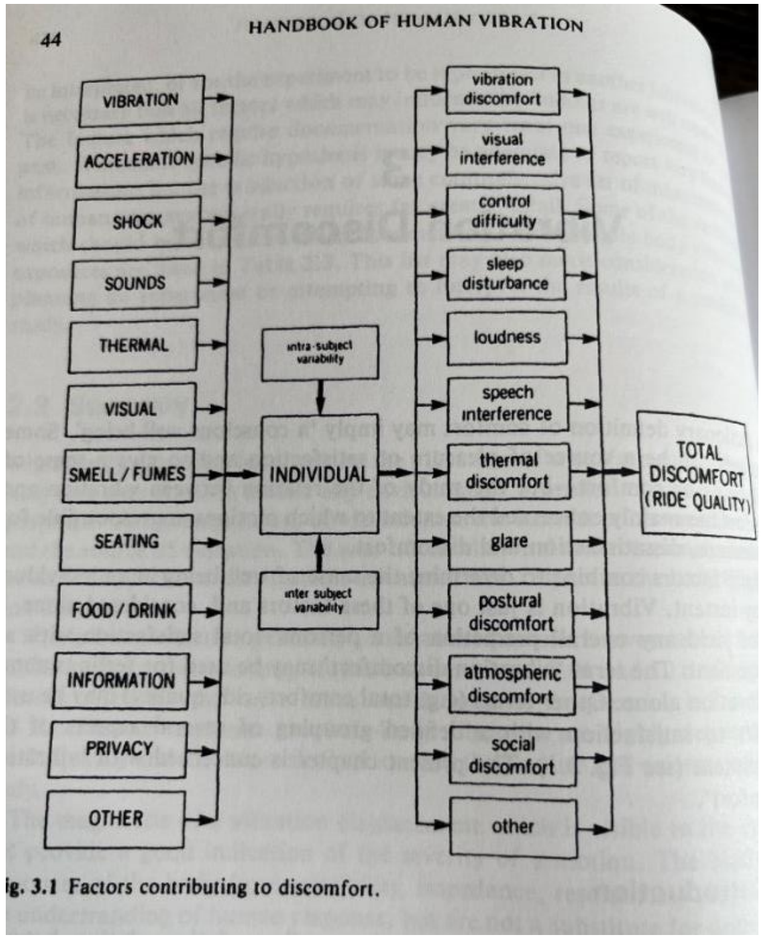


Fig. 3.1 Factors contributing to discomfort.

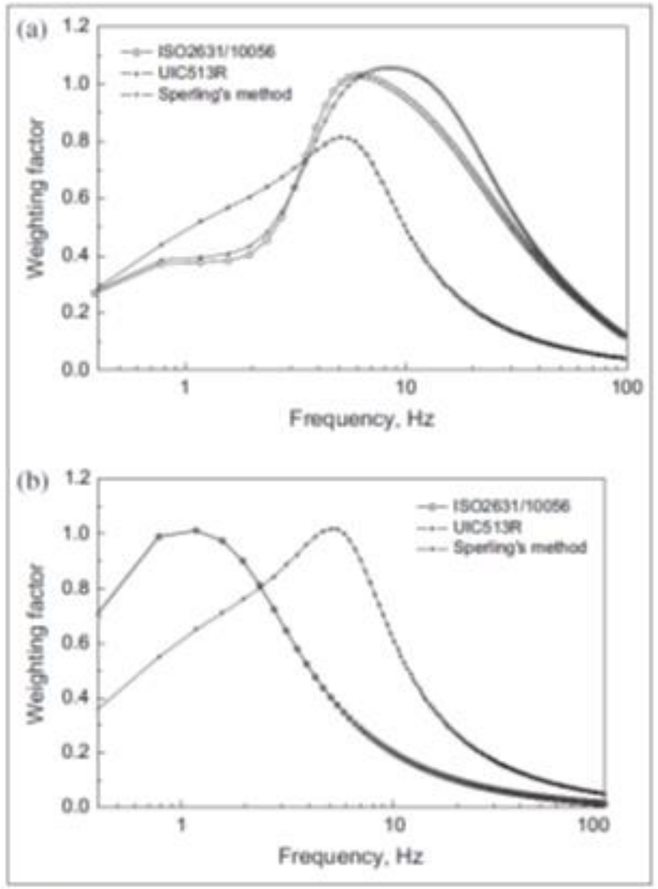
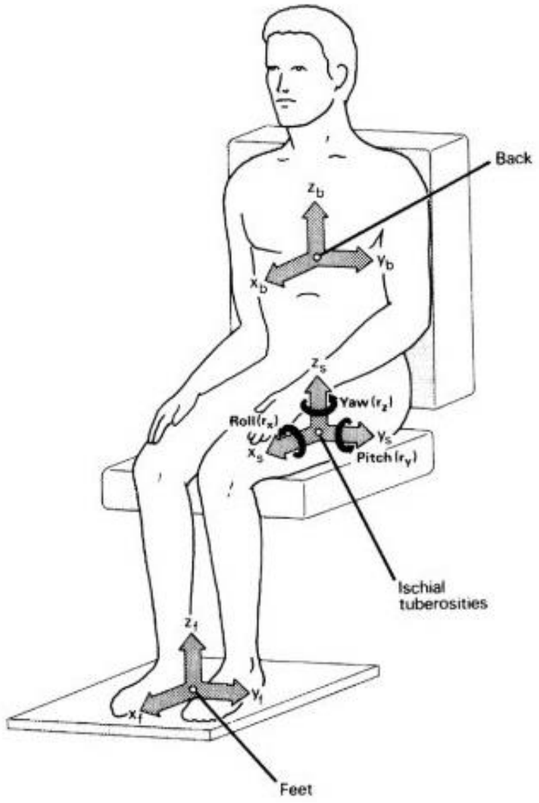


Fig. 2: Frequency weight functions for different standards: (a) vertical direction and (b) lateral and longitudinal directions

1. **ISO 2631 is a ride quality methodology standard. Not a criteria standard.**
2. **Vertical vibration has higher sensitivity between 4 Hz and 12 Hz.**
3. **Lateral vibration has high sensitivity between 0.5 Hz and 2 Hz.**
4. **Sitting vs Standing**
5. **Duration of vibration/shocks – Vibration Dose Value (VDV)**

Ride Quality Vs Ride Comfort



1. ISO 2631 is a ride quality methodology standard. Not a criteria standard.
2. Vertical vibration has higher sensitivity between 4 Hz and 12 Hz.
3. Lateral vibration has high sensitivity between 0.5 Hz and 2 Hz.
4. Sitting vs Standing
5. Duration of vibration/shocks – Vibration Dose Value (VDV)

Vehicle Dynamics – Ride Comfort

ST2 Vehicle Dynamics

TS 2.8.9 – Ride Quality

- The ride quality shall be evaluated according to ISO 2631-4. The basic RMS vertical and lateral acceleration values shall not exceed 1.05 ft/s² (0.32 m/s²) and the vibration total value (root sum of squares summation) for each measurement point shall not exceed 1.64 ft/s² (0.5 m/s²) over the range of 1 Hz to 80 Hz for AW0 and AW3.
- Steady-state ride quality shall be measured with root-mean-square (RMS) responding instrumentation with integrating time or effective averaging time from 1 to 4 s. Averaged vibration level during any 10 s period shall not exceed the defined limitation.

ST3 Vehicle Dynamics

TS 2.6.7 Ride Comfort

- The LRV must achieve a mean **comfort index**, as defined in **EN 12299**, of less than 2.5 (comfortable).
- The **Operator's seat position** must not expose the operator to an equivalent "Fourth Power" Vibration Dose Value (VDV) exceeding the 8-hour lower limit of the "Caution Zone" defined in **ISO 2631-1 1997** Appendix B, Figure B.1, as amended by ISO 2631-1 2010, Amendment 1, when measured in accordance with 6.3.2 and 6.3.3 of ISO 2631-1:1997

Contractor Plan for WRIS, VDAR & VTSI

ST3 Vehicle Dynamics, Wheel / Rail Interface and Track Structures Interaction Plan (5 STEPS)

PR 6.5.10.1

- Contractor must provide a Plan during System Definition Review (SDR) phase that provides:
  - Definition of **all planned desktop assessments** addressing all relevant requirements of TS 2 and TS 11 and pass/fail criteria, including:
    - A Wheel / Rail Interface Study (WRIS),
    - Vehicle Dynamics Analysis Report (VDAR), and
    - Vehicle Track Structure Interaction (VTSI) analysis report
  - **Preliminary geometric and dynamic simulation model parameters and track geometry inputs**;
  - A list of **planned vehicle static and dynamic tests** with preliminary details, e.g. example test procedures from previous projects;
  - Definition of geometric and dynamic **simulation model validation approach**;
  - Plan for Static and Dynamic **Qualification tests**, including those to be performed on the ST network.

Contractor Plan for WRIS

ST3 Wheel Rail Interface Study (WRIS)

PR 6.5.10.2

- WRIS must include assessments in accordance with **EN 13232-3** addressing the geometric wheel to rail interface requirements of TS 2 and TS 11, and compatibility with the Sound Transit track design, including special trackwork.
- Report must confirm critical wheel and truck dimensions, including:
  - Wheel diameters;
  - Wheel back-to-back dimensions;
  - Wheel profiles and widths;
  - Wheel wear and maintenance limits.

Contractor Plan for VDAR

ST3 Vehicle Dynamic Analysis

PR 6.5.10.3

- A **preliminary Vehicle Dynamic Analysis** report must be provided for **PDR and final report for DDR**.
- Must include simulations, addressing the vehicle dynamics requirements of TS 2 and TS 11, with methodologies below
- Simulations must be performed using an industry recognized software package (e.g. NUCARS, VAMPIRE, SIMPACK)
- Contractor must declare all parameters used (including those listed…)
- For each analysis, the **Contractor must state which end of the tolerance band for each relevant parameter is considered to be the worst case and confirm that the simulations have used that tolerance**.
- Must include simulation of failed suspension cases.
- **Multiple simulations may be required where there is no clear-cut worst-case condition**.

Contractor Plan for VDAR

ST3 Vehicle Dynamic Analysis (continued)

PR 6.5.10.3 (continued)

- Contractor must **perform simulations to demonstrate compliance** with the TS 2 requirements below under conditions nominated (speed, track condition, geometry, friction coefficient, etc):
  - Modal analysis.
  - Resistance to low-speed flange climb derailment on twisted track.
  - Wheel load equalization.
  - Running safety over poor track at the track maintenance limits specified. Alternatively measured track data may be supplied by Sound Transit.
  - Stability at up to 110% maximum revenue service speed.
  - P2 Forces
  - Overturning on curves
  - Ride Comfort
  - T-Gamma
- Contractor must submit the native files of the dynamic models.

Performance Requirements for VTSI

ST3 Vehicle Track Structure Interaction (VTSI) (Not required for Series 2 LRVs)

TS 2.6.1.1

- The LRV floor **must not exceed a comfort limit of 0.1g vertical acceleration** when operated in a 380 ft long consist across any bridges and elevated track structures on the Sound Transit Network at any speed up to line speed. [E]
- The vehicle track structure interaction must be verified by a VTSI analysis in accordance with PR 6 and on-track testing. [E]

Contractor Requirements for VTSI

ST3 Vehicle Track Structure Interaction (VTSI) Analysis

PR 6.5.10.4

- Contractor must perform a vehicle track structure interaction analysis to demonstrate compliance with the requirements of TS 2.
- The analysis must contain sufficient degrees of freedom to allow modeling of the bridge or elevated structure, vehicle truck spacing, vehicle primary suspension, vehicle secondary suspension, the car body, and the track imperfections provided by Sound Transit.
- The analysis must make provision for a time history placement of the vehicle along the structure to model the passage of the transit vehicle.
- The analysis must be performed for a 380 ft train operating at AW0 and AW3 load, at speed increments of 5 mph from 5 mph up to line speed.
- **The analysis must be performed for at least three (3) elevated or bridge structures on the Sound Transit network as designated by Sound Transit.**

Vehicle Noise: Requirements Overview

Interior Noise:

Acceptance Criteria: At 55 mph, interior noise shall not exceed 72 dBA on open tracks, 75 dBA on arial tracks and 80 dBA in tunnels

Wayside (Exterior) Noise:

Acceptance Criteria: At 40 mph and 50 ft, exterior noise shall not exceed 78 dBA for a single 190-ft long, empty LRV on ballast and tie tracks.

Incentive-Based Design Target:

- 4 dB reduction for interior noise
- 3 dB reduction for exterior noise.
- Noise Management Plan during Design.

Requirements for Noise

ST2 Noise

TS 2.8.2 Pure Tones

- The maximum allowable noise level shall be reduced by at least 3 dB if significant pure tones in the range from 250 Hz to 4,000 Hz are present in the noise. Pure tone noise shall be considered significant in this context if any one-third octave band sound pressure level is 5 dB, or more, higher than the arithmetic average of the two adjacent bands containing no pure tones.

ST3 Noise

TS 2.5.2 - Pure Tones

- The maximum allowable noise level must be reduced by at least 3 dB if significant pure tones in the range from **125 Hz to 10,000 Hz** are present in the noise. [E]
- Pure tone noise must be considered significant in this context if any one-third octave band sound pressure level is 5 dB or more higher than the arithmetic average of the two adjacent bands containing no pure tones.
- **This applies to whole vehicle noise, as well as individual components and sub-systems** such as traction motors, cooling fans, electrical propulsion systems, etc., prior to and after assembly of the vehicle. [E]

Interior Noise

ST2 Noise

TS 2.8.3 Interior Noise

- Stationary, all auxiliary equipment operating, interior noise level shall not exceed 68 dBA.
- Moving (not in tunnel) up to 55 mph, in any curve down to 82 ft, and under any accel or decel, interior noise shall not exceed 75 dBA.
- Moving in tunnel, up to 55 mph, under any accel or decel, interior noise shall not exceed 80 dBA.
- Noise generated by the Public Address System in a standby condition shall not exceed 40 dBA.
- Noise generated by any side door operation must not exceed the 72 dBA Fast.
- Noise generated by airflow through the return air grill must not exceed 72 dBA when measured 40 in (1000 mm) below the geometric center of each grill.

ST3 Noise

TS 2.5.3 - Interior Noise

- TS 2.5.3.1 - Interior Noise Limits while Stationary
- With all auxiliary equipment operating, interior noise level must not exceed 68 dBA. [E]
- With all auxiliary equipment operating, interior noise level must not exceed 65 dBA. [D]
- Noise generated by any side door operation must not exceed the 72 dBA Fast. [E]
- Noise generated by airflow through the return air grill must not exceed 72 dBA when measured 40 in (1000 mm) below the geometric center of each grill. [E]
- Noise generated by the Public Address System in a standby condition shall not exceed 40 dBA. [E]
- The public address system must automatically adjust its volume per TS 16, but must not exceed a level of 85 dBA at any standing or seated position. [E]
- TS 2.5.3.2 - **Interior Noise Limits while Moving (up to 55 mph and down to 82 ft curve, any accel and decel)**
- Interior noise within tunnel sections on high compliance DF track must not exceed 80 dBA; [E]
- Interior noise within tunnel sections on standard compliance DF track must not exceed 80 dBA; [E]
- Interior noise within aerial structure track sections must not exceed 75 dBA; [E]
- Interior noise within open ballast-and-concrete-tie track sections must not exceed 72 dBA. [E]
- **Interior noise within open ballast-and-concrete-tie track sections must not exceed 68 dBA. [D]**

Wayside Noise

ST2 Noise

TS 2.8.4 Wayside Noise

- Average noise levels emanating from the vehicle shall not exceed the following levels with all auxiliary equipment operating simultaneously:
- Vehicle stationary, empty 68 dBA Slow
- Single vehicle empty, max accel or decel from 40 mph, 75 dBA Fast.
- Two vehicles empty, max accel or decel from 40 mph, 78 dBA Fast.
- The vehicle shall be operated with wheels in new condition.

ST3 Noise

TS 2.5.4 - Wayside Noise

- TS 2.5.4.1 - Wayside Noise Limits while Stationary
- With all auxiliary equipment operating simultaneously under steady state maximum output the wayside noise must not exceed 68 dBA; [E]
- With all auxiliary equipment operating simultaneously under steady state maximum output the wayside noise must not exceed 65 dBA; [D]
- TS 2.5.4.2 - Wayside Noise Limits while Moving (max accel or decel from 40 mph)
- The wayside noise must not exceed 78 dBA Fast; [E]
- **The wayside noise must not exceed 75 dBA Fast; [D]**
- The performance specified above must be met with a vehicle with tires that have run for at least 600 miles (965.6 kilometers). The tire treads must be as free as possible from irregularities such as flats and/or polygonalization.

Equipment Noise

ST3 Noise

TS 2.5.5 - Equipment Noise Generation and Transmission

- Individual pieces of equipment and vehicle construction elements must meet the noise, transmission loss, sound absorption and other performance requirements for each set out in the **Noise Management Plan (NMP)** developed in accordance with PR 6. [E]
- Noise levels produced by the individual operation of any undercar or roof mounted equipment which operates infrequently, and for less than 2 s, such as a circuit breaker or a pneumatic pressure relief device, shall not exceed 100 dBA fast meter response measured from any point 16 ft (4.9 m) from the center of the equipment. [E]

Noise Management Plan

ST3 Noise Management Plan

PR 6.5.11 - Noise Management Plan

- The Contractor must prepare a Noise Management Plan (NMP) [CDRL-PLN-0013] setting out the process for developing the acoustic design of the LRV through to Qualification Testing to validate compliance with the Technical Specification.
- The Noise Management Plan must identify and consider the significant airborne and structure-borne sources, transmission paths and receivers for noise and vibration that are relevant to compliance with the acceptance and target criteria for the LRV internal and external noise limits.
- The Noise Management Plan must include use of prediction methods to optimize acoustic parameters such as the sound reduction properties of LRV panels to achieve low-noise design against constraining factors such as weight, geometry and material options.

Noise Management Plan (Continued)

ST3 Noise Management Plan

PR 6.5.11 - Noise Management Plan

- ……
- The Contractor must develop supplier specifications for source and transmission path components/assemblies that enable the achievement of the acoustic specifications for the LRV.
- Noise specifications for the following items of equipment, as sources of noise within the vehicle, must be developed under the NMP:
  - Traction motors, Propulsion units, Auxiliary power units, Driving gear with gear coupling, Trucks, Gangways, Bodyside doors, HVAC system including air distribution, Compressed air supply (if used), and Brake system.
- Reference parameters for **airborne noise and structure-borne vibration due to wheel/rail interaction that are representative of the Sound Transit system must be applied**.

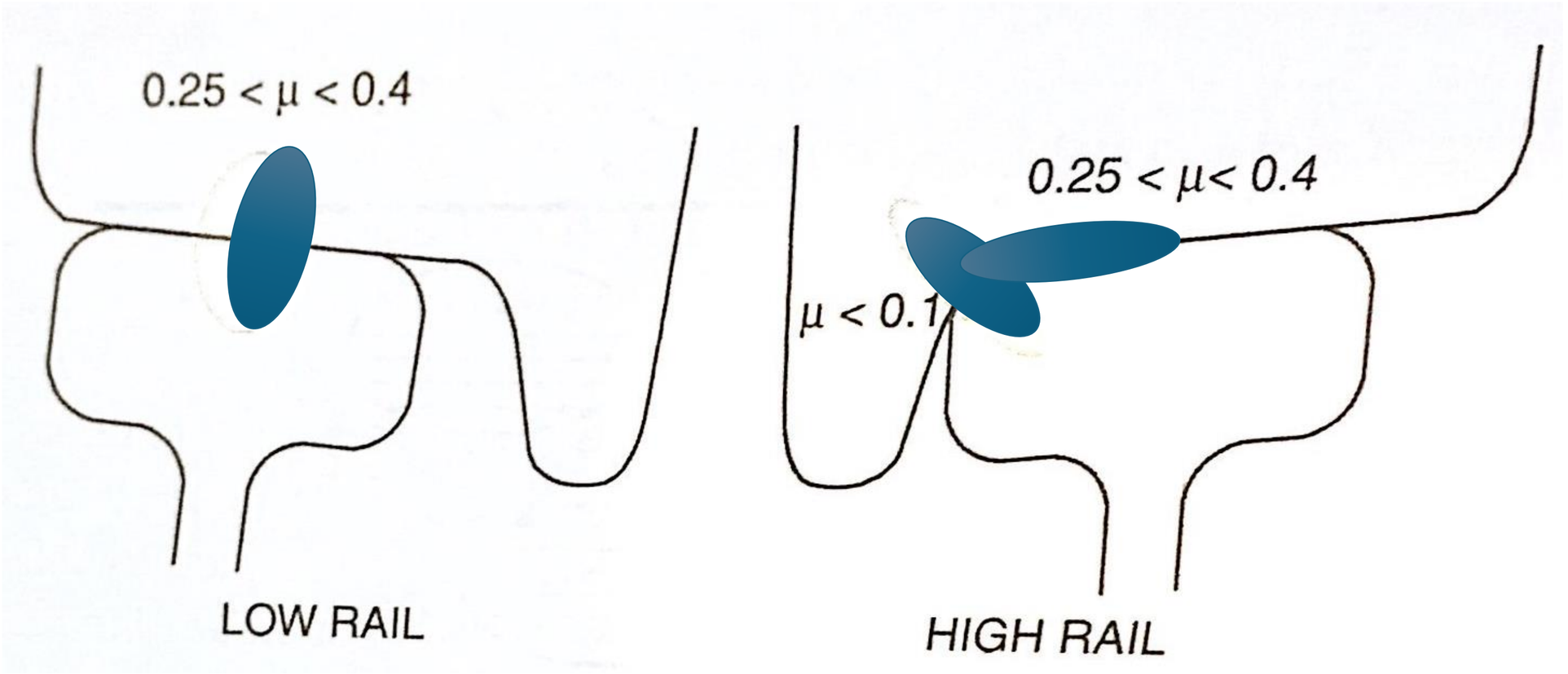
Noise Management Plan

ST3 Noise Management Plan

PR 6.5.11 - Noise Management Plan (continued)

- The source – path – receiver study must apply the understanding of the vehicle construction and materials to develop required sound reduction/insulation and radiation properties of the following structural elements:
  - Floor;
  - Passenger compartment sidewalls (lower panels, between and above windows);
  - Driver's cab sidewalls;
  - Windows;
  - Entrance doors;
  - Bellows; and
  - Roof.
- **The NMP must be submitted for SDR and updated at each Design Stage as necessary.**

Ideal Friction Coefficient in the Wheel-Rail Contact



Source: Iwnicki, S. (Ed.), Handbook of Railway Vehicle Dynamics. 2006

Interior Vibration

ST3 Vibration

TS 2.5.5 - Vehicle Interior Vibration Due to Auxiliary Equipment

- Equipment and auxiliaries mounted anywhere on the vehicle, carbody or trucks must not cause vertical or horizontal vibrations on any surfaces which passengers normally contact such as vehicle floor, walls, ceiling panels, stanchions, and seat frames at any speed from **0 to 55 mph** (88 km/h) and for any acceleration or braking command except maximum braking, in excess of the following: [E]
  - Below 1.4 Hz: Maximum deflection (peak to peak) of 0.10 in. (2.54 mm); [E]
  - 1.4 Hz to 20 Hz: Peak acceleration of 0.01 g (0.10 m/s2); or [E]
  - Above 20 Hz: Peak velocity of 0.03 in/s (0.76 mm/s). [E]
- TS 10.2.9.1.2 - The traction motors must comply with IEC 60349-2. [E] *(the IEC includes vibration limits – same as ST2)*
- TS 10.2.11.1.2 - The traction motor, gear drive and mounting arrangement must be designed to meet the noise, vibration, ride quality, shock loading and maintenance requirements as specified in TS 2. [E]

Wayside Vibration

ST3 Vibration

TS 2.5.7 - Ground Borne Vibration

- Ground borne vibration levels from trains measured on the wayside are a function of the forces generated by the trains at the interface of the wheel and rail, and the efficiency with which energy is transmitted through the ground. The vibration forces generated by trains are largely independent of the ground characteristics and characterized by the 1/3-octave band Force Density Level (FDL). FDL is a function of the vehicle design, train speed, condition of the wheel surface, condition of the rail surface, and track fixation characteristics. [I]
- With the LRV in any loading condition between AW0 and AW3 and moving at 30 mph the 1/3 octave band Force Density Levels (FDL) must not exceed the limits specified in TS Table 2-4 at any of the measurement positions in the Beacon Hill Station Platform at distances of 16.5, 26.5, 36.5, 46.5, 56.5 and 66.5 feet from track centerline. [E]

TS Table 2-4: Maximum Allowed FDL for Direct Fixation Track at 30 mph (48.28 km/h)Train Speed

Frequency	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
FDL dB re 1 lb./ft$^{1/2}$	25	25	29	29	25	25	25	20	20	27	27	27	27	27	27	27

TS Table 2-5: Rail Roughness Levels - dBr Re 1E-6m

Wavelength - mm	2500	2000	1600	1250	1000	800	630	500	400	316	250	200	160	125	100	80	63	50
	50	48	46	44	40	37	34	31	28	25	22	20	18	16	14	12	10	8

Draft Schedule for Series 3 LRVs

- Draft RFP Industry Review#1 – Dec 2024
- Draft RFP Industry Review#2 – Q4 2025
- RFP Publication – Q4 2025 (Goal)
- Car builder Tech Proposal – Q2 2026
- Car builders Detailed Cost Proposal – Q4 2026
- Car builder NTP – Q2 2027
- Prototype car dynamic testing – Q4 2030 – Q3 2031
- Qualification LRV onsite arrival to start commissioning tests – Q1 2032

  (Qualification LRV = 1st LRV for Passenger Service)
- **Initial fleet entering revenue service ~ Q3 2033**

Questions Regarding Series 3 LRV Procurement:
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Conclusion

- Budgeting sufficient time during vehicle design phase is important for optimization of wheel rail interaction.
- Incentive-based design targets in addition to acceptance criteria for performance properties such as noise could motivate car builders to partner with the agency and push the envelope.
- Providing baseline information from existing system will help vehicle designers to improve the quality of their WRIS models.
- Refined Ride Comfort requirement for Passengers and a separate criteria for operators is specified for Series 3 LRVs.
- Series 3 LRV requires a NMP submittal during SDR and updated at each Design Stage as necessary.
- Life Cycle Cost evaluation is a consideration for WRIS.