Comparison of Results from the STEAM Rail Noise Model to Potential Alternatives

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1 Introduction

This paper provides a high-level comparison of the STEAM ("Sound from Trains Environmental Analysis Method", FTA (Federal Transit Administration), and FRA (Federal Railway Administration) models with a specific focus on the emission levels/methods.

2 Background

2.1 "STEAM"

Prepared by the Ontario Ministry of the Environment (1990) [1], the STEAM model has been used for decades in Ontario and across Canada for prediction of rail activity sound levels.

2.2 Federal Transit Administration (FTA)

Originally released in 1995, the FTA "Transit Noise and Vibration Impact Assessment Manual" [2] provides an alternative model for predicting sound levels resulting from commuter/intercity rail activity (last updated 2018).

2.3 Federal Railway Administration (FRA)

The FRA released a similar manual in 1998 titled "High-Speed Ground Transportation Noise and Vibration Impact Assessment" ([3], last updated 2012) which includes Appendix E for the assessment of freight rail activities.

2.4 Comparison of Model Variables

Rather than presenting the specific sound level relationships, Table 1 presents a comparison of the variables that impact the sound level predictions for each of the models.

Table 1: Comparison of Variables in the Three Models.

	STEAM	FRA	FTA
Loco- motive	Speed Locos/period "Loading"	Speed Locos/period Type of Loco	Speed Locos/period Type of Loco Throttle
Wheel- Rail	Speed Veh/period	Speed Veh/period Type of Car	Speed Veh/period Type of Car

In the FTA and FRA models, the type of locomotive/car determines the SEL_{ref} and as such applies a speed independent adjustment to the emission level.

The STEAM model includes a term for "loading" (the number of cars per locomotive) that is unique to that model. As loading increases, locomotive sound level also increases.

3 Modelling Inputs and Scenarios

This study focusses on the relationship of speed and type of locomotive/car to the predicted sound level. Results are presented as the L_{eq} for a single train in a 24-hour period ($L_{eq,24hr}$). To eliminate any propagation characteristics, the reference distance of 50 ft (or 15 m) was used in this study.

The models assume a single rail segment, infinitely long in both directions with no variation in operation (speed, etc.)

3.1 Freight Rail Scenario

For freight rail, the STEAM model is compared against the FRA model using the "freight" parameters in Appendix E.

Both models have been analyzed using a total consist of 4 locomotives and 180 freight rail cars. Locomotives and cars are assumed to have a length of 90 and 68 feet, respectively.

3.2 Commuter Rail Scenario

For commuter rail, the comparison is based on a typical intercity train comprised of 1 locomotive and 12 coaches.

4 Model Results

4.1 Freight Rail Scenario

Figure 1 shows the locomotive and wheel-rail sound levels as a function of speed for the STEAM and FRA models.

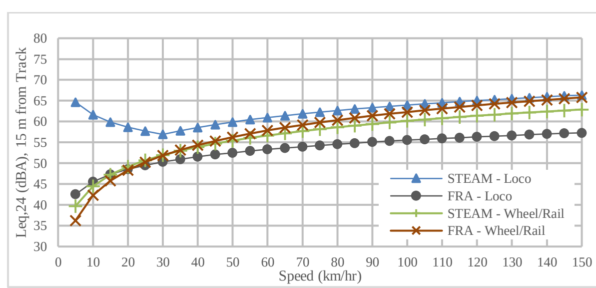

Figure 1: Freight Locomotive and Wheel/Rail Noise as a function of Speed

Above 30 km/hr, the shape of the locomotive sound level relationship is largely the same (emission level from the FRA model is approximately 7-9 dB lower than that for STEAM). Below 30 km/hr, the locomotive models exhibit opposite behaviour with regard to the speed relationship.

As shown in Figure 1, the wheel-rail trend is similar for both models (FRA model exceeding the STEAM model by

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as much as 3 dB at 150 km/hr). Note that the STEAM model uses a 15.7log(S) relationship for the wheel-rail noise where the FRA model uses a 20log(S) term.

Figure 2 shows the total source sound levels (loco plus wheel-rail) in the freight scenario as a function of speed.

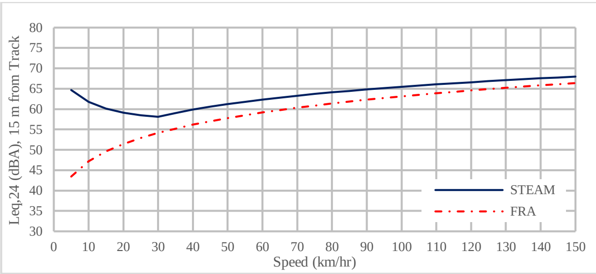

Figure 2: Total $L_{eq,24hr}$ as a Function of Speed, STEAM vs. FRA

The models agree reasonably well above 30 km/hr with STEAM exceeding FRA by up to 3.5 dB. As above, below 30 km/hr the models diverge rapidly.

4.2 Commuter Rail Scenario

Figure 3 shows the locomotive and wheel-rail sound levels as a function of speed for the STEAM and FTA models.

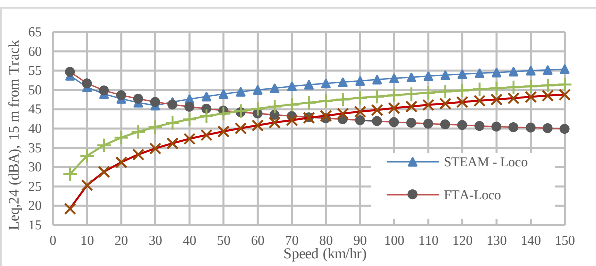

Figure 3: Commuter Locomotive and Wheel/Rail Noise as a function of Speed

In absolute terms, the locomotive sound models show excellent agreement below 30 km/hr where the STEAM model increases in sound level with decreasing speed (the comparison here assumes a throttle setting of 1). However, above 30 km/hr (where the STEAM relationship inverts), the two models diverge in their predicted sound levels.

The wheel-rail sound level trend is similar for both models in the commuter scenario. However, the absolute sound level is greater for the STEAM model by as much as 9 dB at very low speeds (with the difference decreasing with increasing speed).

Figure 4 shows the combined source sound levels in the commuter scenario as a function of speed.

Note that throttle position 1 (no correction) and throttle position 8 are both shown. Without the throttle correction (i.e. throttle 5 or lower), the models agree well below 30 km/hr.

Above 30 km/hr, the models show a significant divergence.

With the throttle correction (throttle 8) included, the predicted sound levels from FTA are up to 7 dB higher than from STEAM for speeds below 55 km/hr. Above 55 km/hr, the STEAM predictions are higher than the FTA predictions

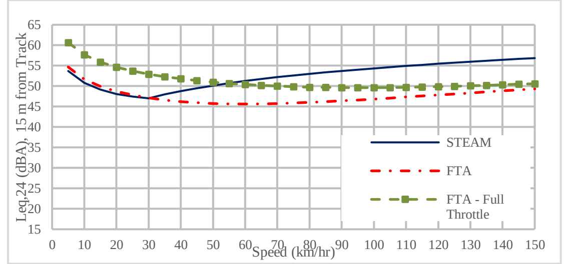

Figure 4: Total $L_{eq,24hr}$ as a function of Speed, STEAM vs. FTA

5 Discussion

The duration of a pass-by of a moving point source emitting a constant sound level will decrease as the speed increases, resulting in a lower time-averaged sound pressure level at a receptor (in simple terms, a faster train spends less time in the vicinity of the receptor than a slower train). This is reflected in the FTA reference emission levels for passenger locomotives and the STEAM model (below 30 km/hr), both of which have a 10log(1/S) relationship. However, the reference emission levels for locomotives in the FRA model and STEAM model (above 30 km/hr) increase with increasing speed. This implies that the sound energy emitted by the locomotive increases with increasing speed signify-cantly enough to compensate for the shorter pass-by duration.

This creates a significant divergence in the modelling between the STEAM model above 30 km/hr and the FTA model (although, it should be noted that below 30 km/hr, the models agree very well). In general, the models are thought not to agree well as most sound level predictions (for the purpose of assessing noise exposure) are done at speeds in excess of 30 km/hr.

Conversely, the FRA and STEAM models diverge below 30 km/hr but agree well in both shape and overall predicted sound level above 30 km/hr. As above, the models are generally in agreement in the important speed range.

6 Conclusion

With regard to the speed versus sound level relationship, the FRA model shows better agreement with the STEAM method above 30 km/hr (at least in terms of the shape of the relationship).

Conversely, the FTA model shows significant divergence from the STEAM model (above 30 km/hr).

Further study is recommended, with a focus on commuter operation, including a comparison of both model results with recent sound measurement data, in order to better understand which model provides superior agreement with real-world conditions.

References

[1] V. Schroter, Sound from Trains Environmental Analysis Method, July 1990.

[2] A. Quagliata et al., Transit Noise and Vibration Impact Assessment Manual, FTA Report No. 0123, September 2018.

[3] C. Hanson, J. Ross, and D. Towers, High-Speed Ground Transportation Noise and Vibration Impact Assessment, September 2012.