What Speeds Up, Must Slow Down – A Call for Realism in Depictions of PRT/ATN Station Lengths

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I sometimes see graphic and video depictions of PRT/ATN in some promotional materials where the length of the guideway for offline stations is far too short to be physically realistic. I think that designers and promoters of PRT/ATN have a moral imperative to illustrate guideway networks ***accurately,*** lest they mislead planners and potential buyers (and themselves!) that vehicles can decelerate (or accelerate) in shorter distances than is possible without restraint (seat belts) or that could result in passenger injury.

Equation 1 below (from Anderson (1978)[1]) shows how to calculate the distance needed for a transit vehicle to stop from a line speed of V_L, considering a maximum deceleration, a_m, and a maximum change of deceleration, J:

$$\text{Stopping distance} = \frac{V_L^2}{2a_m} + \frac{V_L a_m}{2J} \qquad (1)$$

Where:

V_L = line speed

a_m = maximum deceleration during stopping

J = the maximum rate of change of deceleration (called 'Jerk')

Since stations also must have an acceleration region where vehicles can get up to line speed before merging onto the main guideway, the overall station guideway length will likely be at least twice the value calculated by equation 1 (assuming the maximum acceleration is approximately the same as the maximum deceleration).

Figure 1 below shows a graph of stopping distance vs. line speed calculated using equation 1. Two curves are shown, which approximately bound a zone of realistic stopping distances when the safety and comfort of unrestrained passengers are considered. The upper curve is calculated using a maximum deceleration of 1.3 m/s^2 and jerk of 1.3 m/s^3. The deceleration value is in the middle of the suggested range for service braking of railway vehicles according to Powell and Palacín (2015) [2]. The lower dashed curve is calculated using a deceleration value of

[1] Anderson, J. E. (1978). Transit systems theory.

[2] Powell, J. P., & Palacín, R. (2015). Passenger stability within moving railway vehicles: limits on maximum longitudinal acceleration. *Urban Rail Transit*, *1*(2), 95-103.

2.5 m/s^2 (about 0.25g), and a jerk value of 2.5 m/s^3. The deceleration value for this curve is about the maximum seen during emergency braking of rail vehicles (Powell and Palacín, 2015).

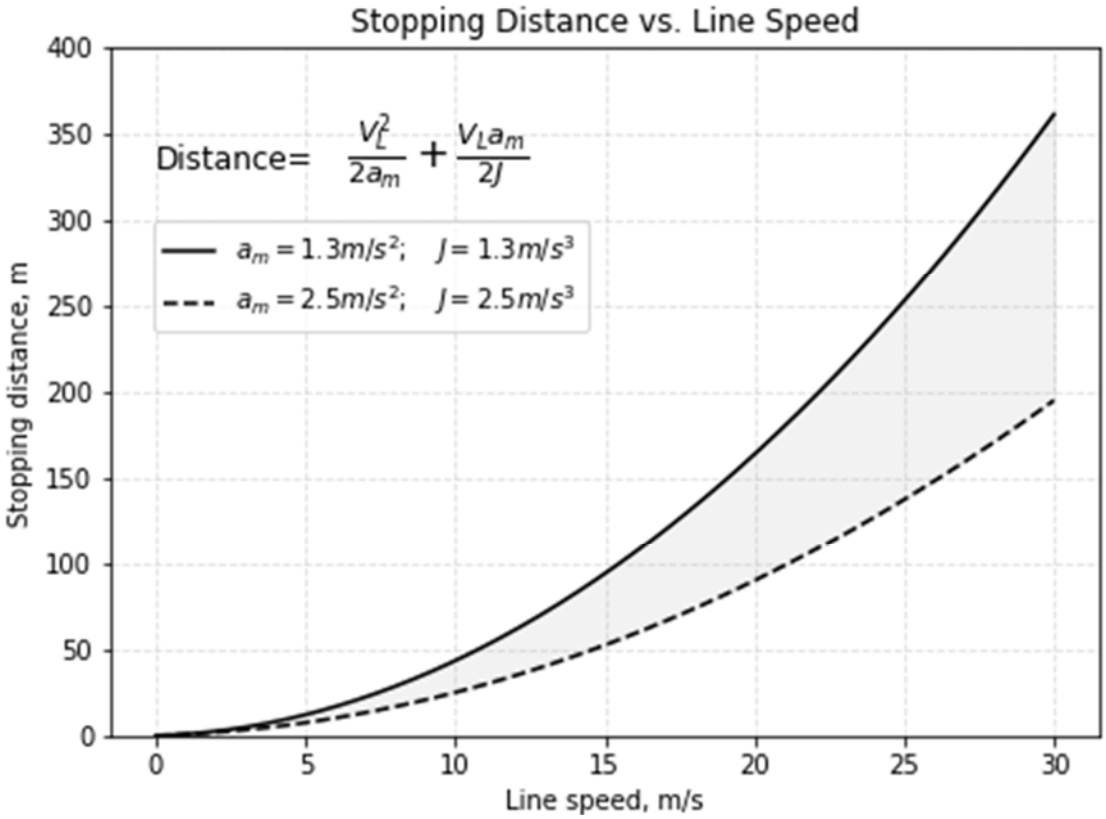

Figure 1. Stopping distance vs. line speed. The shaded region represents reasonable deceleration levels for PRT/ATN vehicles and their corresponding stopping distances for offline stations. The dashed curve represents stopping distances for a deceleration level that is considered to be a maximum for emergency braking conditions for railway vehicles.

Thus, for example, for a line speed of 13 m/s, a station would need to be at least 100 m long to allow for braking and acceleration that is not too uncomfortable for unrestrained passengers.

Care and thought needs to go into choosing maximum deceleration levels for passengers who might be in a wheelchair or who may not have muscle strength to maintain postural stability. Kamper, et. al. (1999)[3] found that the majority of subjects with spinal cord injuries they tested lost posture stability when subjected to deceleration levels below 1.9 m/s^2, which would be about the middle of the range between the curves in Figure 1. It is notable that this level of

[3] Kamper, D., Parnianpour, M., Barin, K., Adams, T., Linden, M., & Hemami, H. (1999). Postural stability of wheelchair users exposed to sustained, external perturbations. *Journal of rehabilitation research and development*, *36*(2), 121-132.

deceleration is insufficient to lock inertial restraint shoulder belts, so even lower deceleration levels may be required to keep PRT/ATN passengers with disabilities safe.

Of course, higher line speeds will require exponentially longer station lengths, because, as indicated by equation 1, scaling of the stopping distance goes as the ***square*** of the line speed.

I urge all in the PRT/ATN community who produce promotional material or visualizations to strive to depict offline station proportions in accordance with physical reality, and accurately show what will be required for safe, comfortable operation.