

Adding Signal Aspects Cannot Bring Trains Closer Than the Braking Distance Plus the Train Length

— the gain from one more aspect shrinks from **1.286468** to **1.055727** times, and switching from **6** aspects to measuring from the rear raises the trains per hour only **1.200739** times — the separator is whether the line is cut into fixed sections or the gap is measured from the rear of the train ahead — [Paper 893]

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— *From thinking to syncing.* —

Abstract

It is easy to assume that more signal aspects let trains run as close together as one likes. This paper counts, for signals with different numbers of aspects and for measuring from the rear of the train ahead, the spacing that lets a train keep full speed and the trains per hour. No new theorem or law is claimed. First, more aspects shorten the spacing: the head-to-head spacing is **1830.015432** m with 3 aspects, **1422.511574** m with 4, **1286.676955** m with 5 and **1218.759645** m with 6 (Section 2). Second, each added aspect helps less: trains per hour rise **1.286468** times from 3 to 4 aspects, **1.105570** times from 4 to 5, and **1.055727** times from 5 to 6 (Section 2). Third, and this is the core. The spacing cannot fall below the braking distance plus the train length: the rear-measured spacing **1015.007716** m is the braking distance **815.007716** m plus the train length **200** m, and adding aspects only approaches it (Section 3). Fourth, most of that floor is braking distance: switching from 6 aspects to measuring from the rear gives only **1.200739** times the trains, and braking distance takes **0.802957** of that spacing (Section 3). Fifth, searching over positions gives the same spacing: shifting the following train through **4000** positions within a block gave a minimum spacing equal to the formula for all of 3 to 6 aspects (Section 2). Sixth, the separator is whether the line is cut into fixed sections or the gap is measured from the rear of the train ahead: cutting into sections puts extra length into the spacing for each section; measuring from the rear removes that extra, but braking distance remains (Section 4). **Keywords:** fixed block, signal aspects, moving block, braking distance, headway, line capacity.

Scope of this paper (scope note): No new theorem or law is claimed: that a line is divided into blocks with one train per block, that more signal aspects allow shorter blocks, that measuring from the position of the train ahead shortens the spacing, and that braking distance bounds the spacing between trains are all known in railway signalling. No real line is claimed: the speed of 130 km/h, deceleration of 0.8 m/s², train length of 200 m, and the convention of taking the block length as braking distance divided by $n - 2$ are model values matching no line's signalling. No margins are entered: sighting distance, overlap beyond the stopping point, station dwell, and the time to accelerate and brake are not included. Optimal speed is not treated: the speed that maximises trains per hour is not treated. Relation to earlier papers: Paper 394 showed that the same traffic flow is realised in two different states, and measuring the flow does not tell which one you are in. This paper stands beside it. There, on roads, how tightly cars pack set the state. Here, on rails, braking distance sets the floor on spacing, and signal aspects only approach that floor. What is added is laying out spacing and trains per hour for 3 to 6 aspects and for measuring from the rear, measuring that each added aspect helps less, measuring that braking distance takes 0.802957 of even the rear-measured spacing, and placing the separator on fixed sections versus measuring from the rear.

1. Notation and the Question

Setting: a train runs at $v = 130$ km/h (36.111111 m/s) and stops at a deceleration of $b = 0.8$ m/s². Train length is $L = 200$ m. With n -aspect signals, the block length is taken as $D/(n - 2)$, so that a train can stop within $n - 2$ blocks from the signal before the stop signal. For the following train to keep full speed, $n - 1$ blocks, including the one it is entering, must be clear, with the rear of the train ahead beyond them.

$$D = \frac{v^2}{2b}, \quad s_n = (n - 1) \frac{D}{n - 2} + L, \quad s_\infty = D + L$$

s_∞ is the spacing when the gap is measured from the rear of the train ahead. Headway is spacing divided by speed, and trains per hour are 3600 seconds divided by headway. Separately from the formula, the head of the following train was shifted through 4000 positions within a block, and the smallest spacing allowing full speed at every position was searched for.

Question: can more signal aspects close up the spacing between trains without limit?

2. Aspects and Spacing

Computation 2.1: the braking distance is $D = 815.007716$ m. For each number of aspects, spacing, headway and trains per hour were computed.

signals	head-to-head spacing (m)	headway (s)	trains per hour
3 aspects	1830.015432	50.677350	71.037652
4 aspects	1422.511574	39.392628	91.387657
5 aspects	1286.676955	35.631054	101.035462
6 aspects	1218.759645	33.750267	106.665823
from the rear	1015.007716	28.107906	128.077844

Observation 2.2

more aspects shorten the spacing, but each addition helps less. Trains per hour rise 1.286468 times from 3 to 4 aspects, 1.105570 times from 4 to 5, and 1.055727 times from 5 to 6: the minimum spacing found by shifting through 4000 positions within a block equalled the table for all of 3 to 6 aspects. The hardest moment is when the following train enters a block.

3. Measuring from the Rear and Braking Distance

Computation 3.1: the ratio of trains per hour when switching to measuring from the rear was computed from 6 aspects and from 3 aspects. From 6 aspects it is 1.200739 times; from 3 aspects, 1.802957 times.

Observation 3.2

this is the core. The spacing cannot fall below the braking distance plus the train length. As the number of aspects n grows, $(n - 1)/(n - 2)$ approaches 1, and the spacing s_n only approaches $D + L = 1015.007716$ m: measuring from the rear reaches that value, yet braking distance 815.007716 m takes 0.802957 of it. The 1.802957 times from 3 aspects minus 1 equals exactly this share because it is the ratio of the 3-aspect spacing $2D + L$ to $D + L$.

4. The Separator

Observation 4.1

the separator is whether the line is cut into fixed sections or the gap is measured from the rear of the train ahead. With fixed sections, the train ahead blocks a whole section wherever it is within it, so an extra $D/(n - 2)$ enters the spacing: measuring from the rear removes that extra. But braking distance remains in the spacing either way.

Observation 4.2

placed beside Paper 394.394 showed that on roads the same flow is realised in two states, and the flow does not reveal which. Here, on rails, braking distance sets the floor on spacing, and the number of aspects and the way of measuring decide how close one gets to that floor.

Observation 4.3

what is not said. Real lines' signalling or train counts, sighting distance, overlaps, station dwell, and the speed that maximises trains per hour are not treated. What is shown is that, in this model, more aspects cannot make the spacing shorter than braking distance plus train length.

5. Census and Closing

1. spacing $s_n = (n - 1)D/(n - 2) + L$ (Section 1): **n -aspect signals.**
2. braking distance 815.007716 m (Computation 2.1): **130 km/h, 0.8 m/s².**
3. **1830.015432 m with 3 aspects** (Computation 2.1): **71.037652 trains.**
4. **1218.759645 m with 6 aspects** (Computation 2.1): **106.665823 trains.**
5. gain per aspect from 1.286468 to 1.055727 times (Observation 2.2): **shrinking.**
6. same over 4000 positions (Observation 2.2): **entering a block is hardest.**
7. **1015.007716 m from the rear** (Observation 3.2): **the core.**
8. **1.200739 times from 6 aspects** (Computation 3.1): **still a gain.**
9. braking share **0.802957** (Observation 3.2): **most of the floor.**

10. fixed sections, or from the rear (Observation 4.1): the separator; Paper 394.

Closing: Adding signal aspects cannot bring trains closer than the braking distance plus the train length. At 130 km/h and 0.8 m/s^2 , the head-to-head spacing that keeps full speed is 1830.015432 m with 3 aspects and 1218.759645 m with 6, and the gain from one more aspect shrank from 1.286468 to 1.055727 times: adding aspects only approaches the sum 1015.007716 m of braking distance 815.007716 m and train length 200 m. Measuring from the rear of the train ahead reaches that value, and switching from 6 aspects raises trains per hour 1.200739 times, but braking distance takes 0.802957 of that spacing: the extra from fixed sections can be removed by how one measures, but the distance needed to stop cannot. Placed among the earlier papers: beside the roads of Paper 394, where “the same flow is realised in two states”, we placed rails, where braking distance sets the floor on spacing. To be honest: speed, deceleration, train length and the block convention are model values, and sighting distance and overlaps are not included.

References

1. Yamagishi, Y. (2026). *The Same Flow Is Two Different States: Measuring the Flow Does Not Tell You Which One You Are In* [Paper 394]. YOI: <https://www.yamagishiyuuki.com/yoi/394>; DOI: 10.5281/zenodo.22699272

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