The freeway congestion paradox

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November 13, 2001

Congestion forms once the density of vehicles on a freeway exceeds a critical value, after which vehicle speed and vehicle flow both drop below what they were before the onset of congestion. Proper ramp metering prevents too many vehicles from entering the freeway, avoids congestion and, paradoxically, increases both vehicle speed and flow. This double gain in terms of reduced travel time and increased flow far exceeds any improvements that could be achieved by constructing more freeway lanes.

Figure 1 shows the cause and consequence of congestion. It plots speed and flow on lane 1 (the fast lane) in one section of I10-W in Los Angeles. At 5:00 am, there is no congestion—there is a flow of 2,100 vehicles per hour (vph) moving at 60 mph. More vehicles enter and by 5:30 am, the density (which is proportional to the slope of the line joining the origin to the corresponding data point) has doubled causing congestion, and speed has dropped to 30 mph. By 7:00 am, speed is a stop-and-go 15 mph, and the flow has decreased to 1,300 vph. Only at 11:30 am has demand and the resulting density decreased sufficiently to restore the free flow speed of 60 mph. The efficiency of this section at 7:00 am in the depth of congestion, has dropped from 100% at 5:00 am to

$$\frac{Speed\ at\ congestion \quad Flow}{60mph \quad Max\ flow\ at\ 60mph} \quad \frac{15 \quad 1300}{60 \quad 2100} \quad 15\%$$

Figure 2 gives the macroscopic picture for all of LA. Data from all 3,363 functioning detectors at 1,324 freeway sections in LA are examined for the 12-hour period beginning at midnight on September 1, 2000. For each detector we find the 5-minute interval during which the detector records maximum flow. We then find the average speed at each detector during 25 minutes surrounding this maximum-flow interval. The figure plots the distribution of this "speed at maximum flow" for each lane. The evidence points unmistakably to the conclusion that maximum flow occurs at free flow speeds ranging from 65 mph in lane 1 to 55 mph in lane 4. This means that the most efficient way to operate our freeways is to prevent congestion and to keep traffic moving freely.

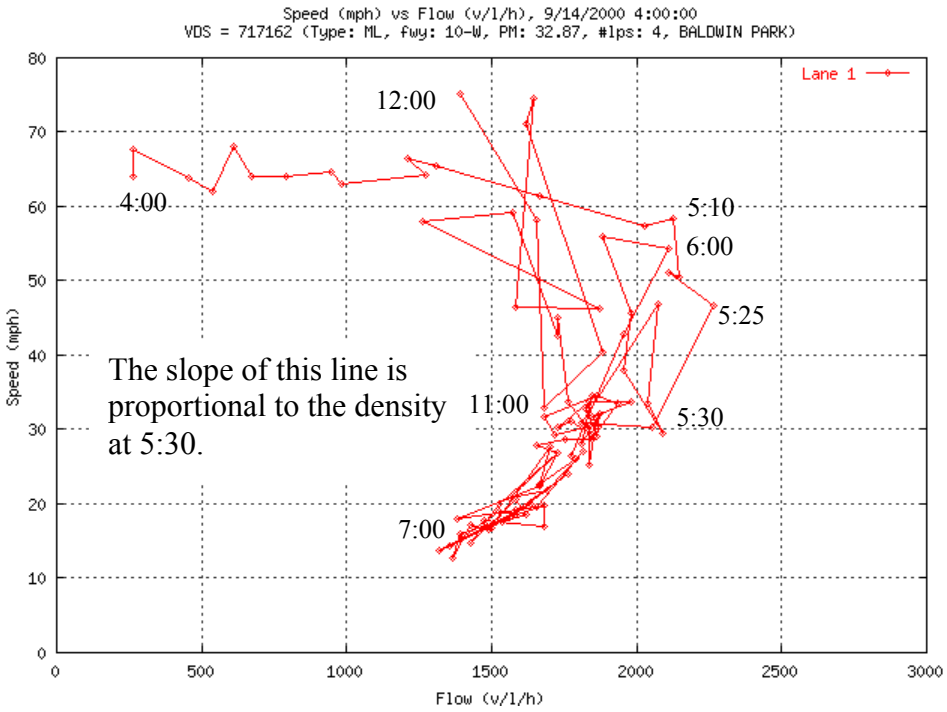

Figure 1 Congestion begins at 5:20 am. By 7:00 am, both speed and flow have dropped dramatically.

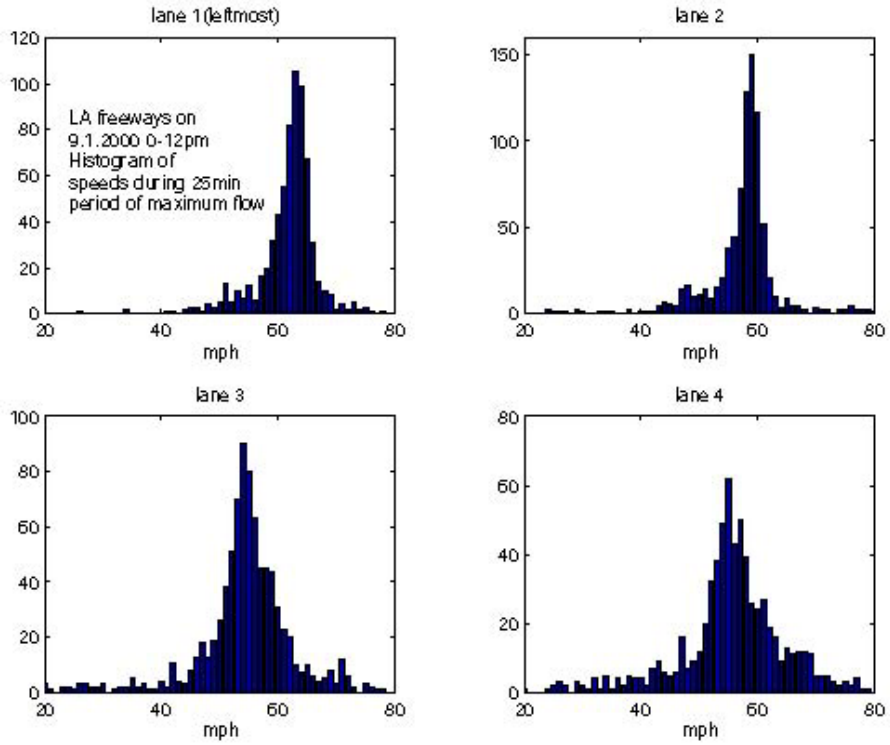

Figure 2 Distribution by lane of average detector speed over a 25-minute interval around the time when the detector records the maximum throughput.