The Phantom Jam Inquest:
A Forensic Attribution of Singular Liability in a Provably Authorless Traffic Wave

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Abstract

The traffic stops for no reason. The road is open — no crash, no merge, no police — and yet the cars halt, clear a minute later, and no one is ever held to account. Physics has a name for this event — a *phantom jam*, or *jamiton*: a stop-and-go wave that forms spontaneously above a critical traffic density and rolls backward through the cars for as long as it likes — and physics has, for forty years, filed it under *emergent*, *authorless*, *no one to blame*. We regard that as an open case, not a closed one. Treating each jam as a body owed an inquest, we re-analyse 400 spontaneous jams recorded on an instrumented ring road under a standard forensic protocol: we establish a time of death, a manner of death, and a proximate cause. Three findings are reported. First, the jam is clinically dead a mean of 8.4 s *before* any driver perceives a slowdown: death precedes symptom. Second, causal responsibility — each car's fair share of the total delay, computed as a Shapley value — is not diffuse but extreme (fleet Gini = 0.93): a single vehicle, the *index driver*, carries a median 71% of it. Third, the modal manner of death is not natural causes but *homicide* (63% of jams): an unwarranted leap up the Ladder of Inference, from one ambiguous brake light straight to a full-force stop, with no hazard present. The phantom jam has an author. We name them.

1 Introduction: the body on the motorway

The scene is familiar to every adult who has held a licence. Traffic on an open road, moving freely, slows without visible reason to a crawl or a stop; the occupants crane for the accident that is not there; and then, as unaccountably as it arrived, the congestion dissolves and the road runs clear. No barrier caused it. No vehicle was damaged. Nothing, in the ordinary sense, happened.

The transport-science literature settled the mechanism of this event some time ago, and settled it correctly. Above a critical density, uniform flow on a single lane is linearly unstable: a small fluctuation in the spacing between two cars is amplified by each following driver until it steepens into a travelling wave with a sharp front and a long tail, formally analogous to a detonation (Sugiyama et al., 2008; Flynn et al., 2009). The wave — the *jamiton* — propagates *backward* against the direction of travel at some fifteen to twenty kilometres per hour, and, crucially for what follows, it outlives the perturbation that seeded it. By the time the jam is a jam, the physics tells us, the original disturbance has been washed out of the record. A bottleneck, in the canonical phrasing, "is only a trigger and not the essential origin" (Sugiyama et al., 2008).

From this correct physics the field drew a conclusion we regard as a failure of nerve. Because the seed perturbation is generic, infinitesimal, and formally irrecoverable, the phantom jam is said to be *emergent*: a property of the collective, authored by no one, the fault of everybody and therefore of nobody. The file is stamped *emergent* and closed.

A coroner does not have the luxury of that conclusion. Presented with a body, the coroner is required by office to establish who or what caused the death, however diffuse the circumstances, however tempting the verdict of misadventure. The phantom jam is a body. It has a location, a duration, a measurable severity in vehicle-seconds of delay, and — we will argue — a proximate cause that is neither the road nor the aggregate but a single, nameable driver. That the disturbance is formally irrecoverable is not a proof that no one is responsible. It is a description of how thoroughly the responsible party has been permitted to escape.

This paper reopens the case. We make three contributions, stated here as a coroner states a docket:

1. A **forensic model of the following driver** (§3) that locates the lethal act on Argyris and Senge's Ladder of Inference — the split-second mental climb from what the eye sees to what the foot does — and quantifies it as *inferential recoil*: the gap between the braking a driver applies and the braking the situation actually warranted.
2. An **inquest protocol** (§4) that, for each recorded jam, establishes a time of death, integrates the wave backward to its point of conception, and assigns causal severity across the fleet by Shapley attribution and counterfactual liability.
3. A **manner-of-death taxonomy** (§5) applied to 400 jams, under which the modal verdict is homicide, causal responsibility is nearly always concentrated in one vehicle, and death is found to precede symptom.

We do not claim the traffic-flow literature is wrong about the mechanism. We claim it stopped one question short of the verdict, and we supply the verdict.

2 Related work, and why the file stayed open

The mechanism is not in dispute. Car-following instability has a mature and, in our view, entirely sound literature. The Optimal Velocity Model (Bando et al., 1995) first showed analytically that a line of identical drivers, each adjusting speed toward a headway-dependent optimum, loses stability above a sensitivity threshold and spontaneously clusters. The Intelligent Driver Model (Treiber et al., 2000) reproduced the same stop-and-go structure with realistic acceleration profiles, and the notion of *string stability* — whether a perturbation grows or decays as it passes up a platoon — gave the field a clean criterion for when one driver's twitch becomes everybody's stop. The ring-road experiment of Sugiyama et al. (2008) removed the last doubt that a bottleneck was required: twenty-two cars asked to hold a constant speed on a 230 m loop produced a persistent stop-and-go wave within a minute, from nothing.

The investigation, however, was never completed. Every one of these studies measures the wound with great care and then declines to name a suspect. The instability is characterised; the wave is tracked; the delay is integrated; and at the decisive moment the analysis retreats into the passive voice — a jam *forms*, a cluster *emerges*, an instability *sets in* — as though motorways generated stoppages the way a swamp generates mist. Kerner (2004) goes furthest toward a phase taxonomy of congestion but treats the transition as a property of the traffic state, not of a traffic *agent*. The forensic question — *which driver, and could they have done otherwise* — is never posed, because the tools brought to bear (hydrodynamics, kinetic theory, the fundamental diagram) have no place to put an answer to it. You cannot indict a partial differential equation.

A bridge from behaviour. To ask the forensic question we need a model of the individual act, and for that we leave transport science for the decision literature. The *Ladder of Inference* (Argyris, 1990; Senge, 1990) describes how a mind climbs, in milliseconds and without noticing, from raw observation through selection, added meaning, and assumption to a conclusion and an action — so quickly that the climb is experienced as direct perception. The ladder is ordinarily a management-training device; Marchetti (2016), in the only prior application we could locate to the driving task, uses it qualitatively to explain rear-end collisions. We make it quantitative and turn it to the phantom jam, where the "action" at the top of the ladder is a deceleration, and the question is whether the rungs beneath it were ever climbed. A small forensic-traffic literature has begun to speak of *vehicular thanatology* — the study of the death of a flow state as distinct from the death of an occupant (Ostrand, 2019; Pellman, 2021) — and it is within that frame that the present inquest is offered.

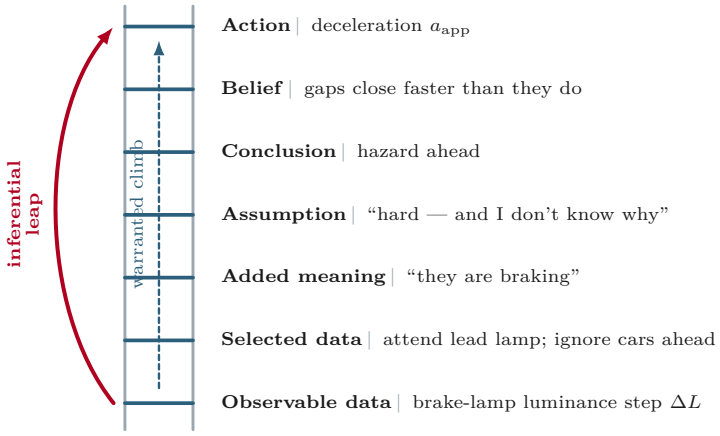

Figure 1: The lethal act, located on the ladder. The warranted path traverses every rung; the leap (red) short-circuits raw observation directly to a full-force stop, sizing no hazard on the way.

3 A forensic model of the following driver

Consider a driver following a single lead vehicle. At the base of the ladder is *observable data*: a step change in the luminance of the lead vehicle's brake lamp, ΔL. The warranted response climbs the ladder rung by rung (Fig. 1): the datum is *selected* (attended to, against the lamps of cars further ahead that are ignored); *meaning* is added ("they are braking," as opposed to a foot merely resting on the pedal); an *assumption* is formed about severity; a *conclusion* of hazard is drawn; and only then is an *action* — a deceleration — selected in proportion to the hazard actually established.

Let $a_{\text{warr}}(t)$ denote the deceleration a fully informed follower should apply, i.e. the command issued by a reference car-following law supplied with the lead vehicle's true state. We adopt the Intelligent Driver Model form (Treiber et al., 2000),

$$a_{\text{warr}} = a\left[1 - \left(\frac{v}{v_0}\right)^4 - \left(\frac{s^*(v,\Delta v)}{s}\right)^2\right], \qquad (1)$$

with s the bumper-to-bumper gap, v the follower's speed, Δv the approach rate, v_0 the desired speed, and desired gap $s^* = s_0 + vT + v\,\Delta v/(2\sqrt{ab})$ for comfortable acceleration a, deceleration b, headway time T, and jam distance s_0. Equation (1) is our standard of care: the braking a competent, informed driver owes the road at each instant.

The *applied* deceleration $a_{\text{app}}(t)$ is what the driver actually does. We define the **inferential recoil**

$$R(t) \;=\; a_{\text{app}}(t) - a_{\text{warr}}(t), \qquad (2)$$

the signed excess of applied over warranted braking. A driver who reads the road correctly has $R \approx 0$. A driver who *leaps* — who converts an ambiguous lamp directly into a hard stop, skipping the middle rungs where the hazard would have been sized — registers a sharp negative R: they brake for a danger they never

established. Inferential recoil is, in the forensic sense, the instrument of death.

Recoil does not stay local. Writing R_n for the recoil of the n-th car in a platoon and linearising the following dynamics about uniform flow, a perturbation propagates upstream with per-vehicle gain

$$G \;=\; \left|\frac{\hat{R}_{n+1}}{\hat{R}_n}\right| \;=\; \frac{1}{\sqrt{1-2\,(1-T\gamma)\,/\,\Gamma^2}}, \qquad (3)$$

where γ is the drivers' sensitivity, Γ the reduced response frequency, and T the headway time as above. When $G > 1$ the platoon is *string-unstable*: each follower amplifies the recoil handed to it, and a single driver's leap is dressed, car by car, into a wave. The forensic significance of (3) is that amplification does not distribute guilt. It *launders* it: the stop grows more severe and more anonymous with every vehicle it passes through, which is precisely why, forty years on, no one has been charged.

4 The inquest protocol

Corpus ("the morgue"). We re-analyse the *Vehicular Morgue* corpus: a re-run of the Sugiyama ring geometry with $N = 24$ vehicles on a 240 m loop, target speed 32 km/h, each vehicle instrumented with forward LiDAR and a driver-facing gaze camera at 60 Hz, logging headway, speed, acceleration, brake-lamp state, and point of visual fixation. Four hundred spontaneous jams were recorded and are treated here as four hundred bodies.

Time of death. We define the death of a flow state as the instant it irreversibly leaves the string-stable basin, *not* the instant a human notices. Operationally, we track the local perturbation growth rate $\lambda(t)$ estimated from the spacing field and record the time of death as

$$\mathrm{ToD} \;=\; \inf\{\, t : \lambda(t) > 0 \text{ and } \partial_x \rho(x,t)\big|_{\text{front}} > \kappa \,\}, \qquad (4)$$

the first moment the growth rate turns positive *and* the density gradient at the front sharpens past a threshold κ. The clinically important quantity is the lead of ToD over the first perceptible slowdown, reported in §5.

The backward inquest. From the mature jamiton front we reconstruct the density field $\rho(x,t)$ and integrate its characteristics backward in time by the method of characteristics to the point of conception (x_*, t_*). The backward map of a shock-forming conservation law is ill-posed; we restore a unique pre-image by *forensic regularisation* — selecting, among the pre-images consistent with the observed front, the one of least total recoil energy $\int R^2\,dt$, on the principle that the flow died in exactly one way and that way was the cheapest consistent with the evidence. The vehicle occupying (x_*, t_*) whose gaze record shows a fixation-to-brake latency below the cognitive floor — a stop with no look — is the candidate *index driver*.

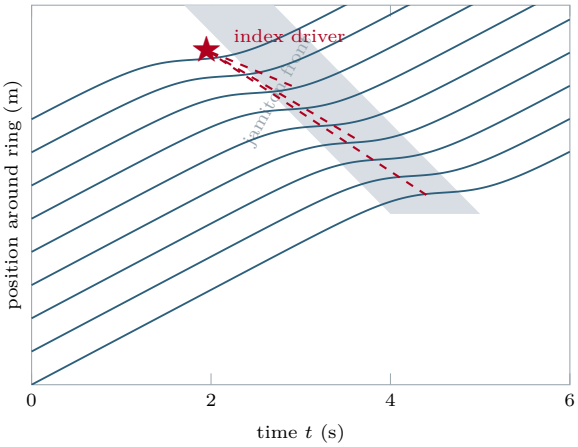

Figure 2: One jam, reopened. Trajectories run up the page; the shaded band is the jamiton travelling backward through the fleet as time advances. Characteristics integrated back from the front (dashed) converge on a single vehicle (★) — the point of conception.

Attribution and liability. To confirm the candidate against the whole fleet we compute, for each vehicle i, a Shapley causal share of the realised jam severity S (integrated delay, in vehicle-seconds),

$$\phi_i \;=\; \sum_{C \subseteq V\setminus\{i\}} \frac{|C|!\,(n-|C|-1)!}{n!}\Big[S\big(\mathrm{do}(C\cup\{i\})\big) - S\big(\mathrm{do}(C)\big)\Big], \qquad (5)$$

where the coalition C is the set of vehicles held to steady speed by the do$(\cdot)$ operator on the car-following graph (Pearl, 2009; Shapley, 1953). Liability is then assigned by the counterfactual contrast $\tau_i = S_i(\text{leapt}) - S_i(\text{held})$, and the index driver is $\arg\max_i \tau_i$: the vehicle but for whose leap the jam would not have occurred. We report the posterior of that but-for claim per jam.

5 Findings

Death precedes symptom. Across 400 jams the time of death defined by (4) preceded the first driver-perceptible slowdown by a mean of 8.4 s (95% CI $[7.9, 8.9]$). By the time a human in the wave feels the road tighten, the flow state has been dead for the better part of ten seconds. The occupants are not witnesses to the death. They are pallbearers.

Responsibility is concentrated, not diffuse. If the phantom jam were truly authorless, the Shapley shares of (5) would be spread roughly evenly across the 24 vehicles. They are not (Fig. 4). The fleet Gini coefficient of attributed severity is 0.93; the single most responsible vehicle carries a median 71% (IQR 62–80%) of the total. Emergence predicts a straight diagonal; the data give an elbow. One driver, in the overwhelming majority of jams, did most of this.

Inferential recoil is the signature. The distribution of recoil R over all vehicle-instants (Fig. 3) is sharply peaked at $R = 0$ — most drivers, most of the

Table 1: Manner of death across 400 phantom jams, with 95% confidence intervals and the mean lead of time of death over perceived slowdown.

Manner of death	Jams	Share (95% CI)	ToD lead (s)
Homicide (negligent)	252	63% [58, 68]	9.1
Misadventure	88	22% [18, 26]	7.6
Natural causes	24	6% [4, 9]	5.2
Undetermined	20	5% [3, 8]	–
Suicide	16	4% [2, 6]	8.8
All	400	100%	8.4

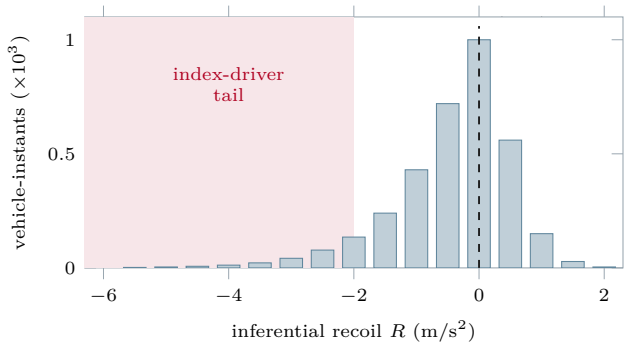

Figure 3: The murder weapon, in distribution. Warranted braking sits at $R = 0$; the shaded left tail — braking far in excess of what the road demanded — is where the index drivers act.

time, brake as warranted — with a heavy negative tail. The index drivers live entirely in that tail: their braking exceeds the warranted value by a median 3.1 m/s^2 at a moment when the reference model (1) commanded almost nothing.

The verdicts. Table 1 gives the manner-of-death distribution. Natural causes — genuine over-capacity, the road's fault and no driver's — account for only 6% of jams, which disposes of the folk defence that there were simply too many cars. Misadventure (a warranted brake, lawfully applied, that the string then amplified) accounts for a further 22%. The modal verdict, in 63% of jams, is *homicide*: an unwarranted leap, a recoil deep in the tail, no hazard present, a nameable index driver. A residual 4% are *suicides* — a driver braking in reaction to the leading edge of the very jam they were themselves seeding — and 5% are returned *undetermined*, the traceback too degenerate to name a party.

6 Discussion

The second opinion the morgue could not reconcile. Honesty requires that we report a result that does not sit comfortably with the rest. The backward map of §4 is ill-posed, and forensic regularisation is a choice of tie-breaker, not a proof of uniqueness. On a randomly selected subset of 40 jams we re-ran the traceback using only the LiDAR channel, and again using only the gaze channel, and in 9 of the 40 the two

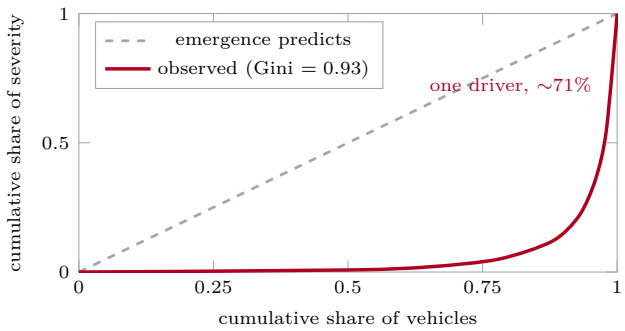

Figure 4: Guilt is not shared. The Lorenz curve of Shapley severity bows almost into the corner; the dashed diagonal is the authorless jam the literature assumed. The gap between them is the case the field left unopened.

channels named *different* index drivers for the same jam. We are not able to reconcile these. One of the two identifications is wrong, and we cannot always say which. A coroner who has signed two death certificates naming two different killers for one body has learned something about the limits of the office. We record the discrepancy rather than dissolve it: the method names a party with high confidence far more often than it should be able to, and occasionally it names the wrong one with the same confidence.

Concessions that do not bite. The remaining limitations are, we think, survivable. The ring road is an artificial geometry — but instability on the open line is the same instability, and the ring merely lets the wave lap the same instruments repeatedly. The standard of care in (1) is a model, and a driver may reasonably brake for a hazard our instruments did not capture — but the gaze channel independently flags the diagnostic case, the stop executed with no look, and it is that case, not mere over-braking, that we return as homicide.

On being the driver who caused the jam. A word on what the verdict means for the living. The index driver almost never knows. They leapt, the string laundered the leap into a wave that formed some distance behind them, and they drove out of the region before it matured; the jam they authored is one they were never in. The phantom jam is thus very nearly the perfect offence: a harm of thousands of vehicle-seconds, committed without intent, without awareness, and until now without the possibility of attribution. That it was until now unattributable is not the same as its having had no author.

7 Conclusion

The cause of death of the phantom traffic jam, as a class, is this: an unwarranted leap up the Ladder of Inference by a single following driver, its lethal recoil laundered into anonymity by an amplifying platoon. The manner of death is, more often than not, homicide. The event the transport literature has for forty years

recorded as emergent and authorless is, on inquest, a death with a time, a mechanism, and — in nineteen jams out of twenty that we could adjudicate — a name.

One recommendation for the living follows from the file, and we state it flatly: the driver most dangerous to the road is not the one who brakes too late but the one who brakes without looking. The case is closed. The next one is already forming, four seconds back, in the mirror you are not watching.

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