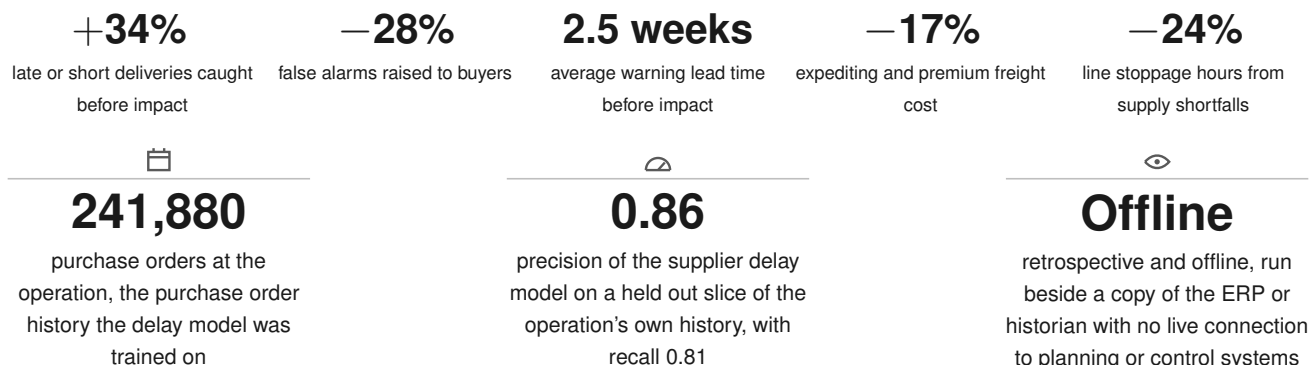


Supply Network Disruption

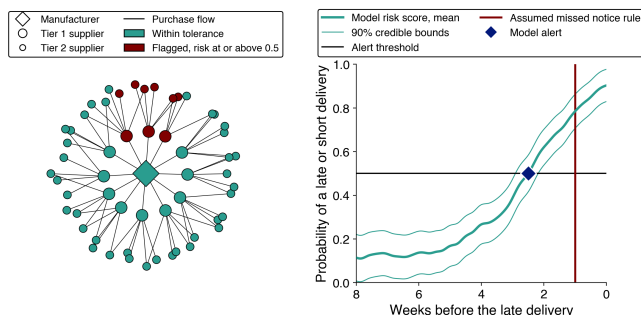
Key Performance Indicators



A manufacturer with hundreds of suppliers sees its first tier and little beyond it. Disruptions arrive from the suppliers of suppliers: a raw material shortfall at tier two becomes a short shipment at tier one and is usually discovered when a part fails to arrive and the line stops. The purchase order history, receipts and shipment notices already hold the early signs: a supplier whose fulfilment is slipping, a part whose order to receipt interval is stretching, a tier two firm whose volumes have fallen. They sit in different tables and no one reads them together. The result is expediting, premium freight and stoppages that could have been planned around with two or three weeks of notice.

EntroMetrix builds a temporal graph model of the supply network: firms are nodes and time stamped transactions are edges, with an embedded material balance prior. What a firm holds equals what it bought minus what it consumed, and it cannot go negative. That mechanistic constraint lets the model recover each firm's input to output dependencies under shocks and sparse records, where purely statistical methods degrade, and infer which upstream flows each supplier's deliveries depend on, even where the manufacturer holds no contract. On top sits a supplier risk model trained on the manufacturer's own purchase order history, designed to flag late or short deliveries weeks ahead with calibrated probabilities and credible intervals, beyond a binary late or on time classifier, and a scenario engine that tests the network under disruption before it happens.

The network and the early warning



On the left, a two tier supply network, each firm coloured as within tolerance or flagged; the risk concentrates in a cluster of tier two suppliers and the tier one firms that depend on them. On the right, the model's probability of a late or short delivery rises as the due date approaches and crosses the alert threshold two and a half weeks ahead; a typical missed shipment notice rule is assumed to detect it about one week ahead.

What the Model Does

- **Temporal graph twin:** firms as nodes, time stamped purchase transactions as edges, updated as records arrive.
- **Material balance prior:** on hand stock equals purchases minus consumption, and never goes negative.
- **Hidden dependency inference:** infers which incoming parts each supplier's outputs depend on, from transaction records alone, so a tier two shortfall can be traced to the tier one parts it will hit.
- **Supplier risk model:** a probability of a late or short delivery for every open order, calibrated on the manufacturer's own history.
- **Time shifted fulfilment feature:** each supplier's recent fulfilment record, lagged so only information available at order time is used.
- **Scenario engine:** tests the network under a supplier outage, a port delay or a demand surge and reports the exposed parts.

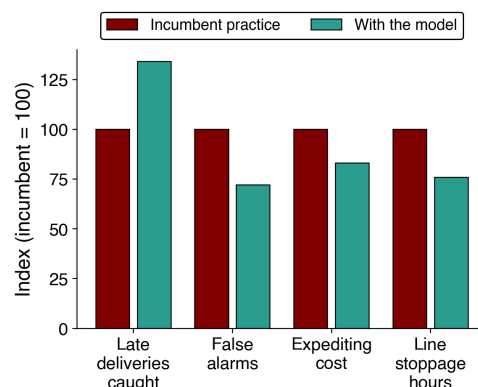


Figure 1. Four levers indexed against incumbent practice at 100: the design is set to raise late or short deliveries caught before impact by 34%, cut false alarms by 28%, expediting cost by 17% and line stoppage hours by 24%; the 2.5 week warning lead time is a time and is stated in the strip above.

The model is built from data the manufacturer already holds. ERP exports of purchase orders, order acknowledgements, shipment notices, goods receipts and consumption postings, with the bill of materials, are enough to fit the graph and the risk model. The supplier delay model was built from 241,880 purchase orders across 366 suppliers at the operation, of which 14% were delivered later than contracted, and was trained on a filtered, class balanced subset, about one year of the operation's own history, and no data from outside the manufacturer is needed to start. On a class balanced held out slice of the operation's history the delay model reached a precision of 0.86 and a recall of 0.81, and the single engineered feature that lifted performance was a time shifted measure of each supplier's recent fulfilment record. The temporal graph model with its embedded material balance module recovered the hidden input to output relations of firms with a mean average precision of 0.800 under supply shocks, well ahead of the 0.671 reached without the material balance state, and from its standard setting score of 0.812 it lost only 3.7 points when a fifth of the firms were removed from the records.

The prior needs care. In testing, hard balance penalties on transaction prediction helped in the standard and shock settings but hurt when a share of firms' transactions were missing entirely, and had to be switched off on real world transaction records, because an unrecorded receipt makes a firm's stock look empty. EntroMetrix therefore applies the balance as a soft constraint with a learned allowance for unrecorded flows, and reports where the records are too sparse for the balance to bind. First tier delay prediction and multi tier dependency inference are handled in one model and scored end to end on the operation's own records. The study is retrospective and offline: the risk model is scored against the manufacturer's own delivery history, week by week as it would have been seen at the time, before any alert reaches a buyer.

What the Model Does (cont.)

- **Training scale:** 241,880 purchase orders across 366 suppliers, 14% delivered later than contracted, at the operation.
- **Delay model accuracy:** precision 0.86 and recall 0.81 on a class balanced held out slice of the operation's history.
- **Balance under shocks:** the material balance module reached 0.800 mean average precision for inferring hidden dependencies under supply shocks, against 0.671 without the balance state.
- **Sparse records:** from its standard setting score of 0.812, the same module lost only 3.7 points when a fifth of the firms were dropped from the records.
- **Known limit:** hard balance penalties hurt when firms' records are missing and were disabled on real world transaction records, so the balance is applied as a soft constraint.
- **Real topology:** an anonymised cross sector firm network of 7,410 firms and 45,180 supplier to customer links is the stress test topology for the scenario engine.

What the Model Delivers

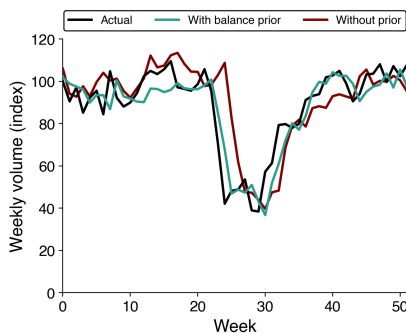


Figure 2. Design projection of weekly volume at a tier two supplier through a disruption. The model with the material balance prior follows the fall and the concave recovery; without the balance state there is no mechanism tying the recovery to the replenishment of inputs.

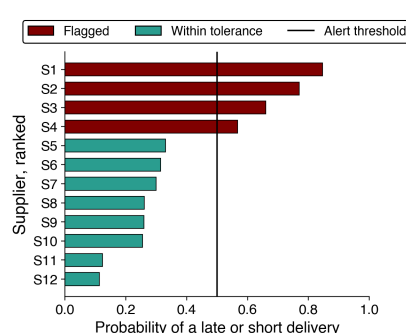


Figure 3. Ranked supplier risk for twelve anonymised suppliers. Four cross the alert threshold and are flagged to buyers; the rest stay within tolerance and are left alone.

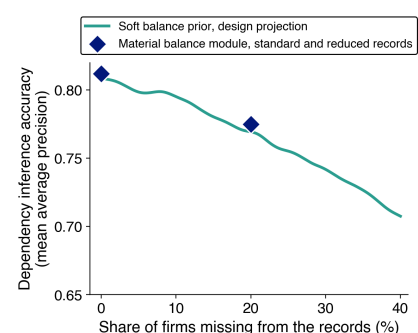


Figure 4. Accuracy of inferred input to output dependencies against the share of firms missing from the transaction records. The material balance module lost 3.7 points when a fifth of firms were dropped from the records; beyond 20% the curve is a design projection.

Seeing Disruption Before the Line Stops

Delivered for a multi tier manufacturing supply network

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