JRSSEM 2026, Vol. 5, no. 12, July
E-ISSN: 2807 - 6311
P-ISSN: 2807 - 6494

Lead-Time Variability and Single-Source Dependence as Continuity Risks in an Aerospace Metallic Raw-Material Supply Network

Eko Taufik Sutisna*, Liane Okdinawati
Institut Teknologi Bandung, Indonesia
Email: eko.taufik@gmail.com*

Keywords:
supply chain risk management; lead-time variability; single sourcing; supply-network mapping; continuity risk.

Abstract

Aerospace manufacturers that source flight-critical metallic raw materials over long distances are widely assumed to face continuity risk because of that distance. This paper tests that assumption through an embedded single-case study of a Tier-1 Indonesian manufacturer (pseudonymized as PT VC Aero Bandung) that procures European forged billets and forgings for Airbus A320 flight-control components. The study followed a quantitatively dominant, explanatory-sequential mixed-methods design: it draws on the firm's supplier and origin master data, 692 inbound shipment records (2023–2026), and safety-stock policy data, triangulated with secondary logistics and lead-time benchmarks, and then interprets that evidence through three semi-structured expert interviews. Three procedures are combined to locate where continuity risk resides, supply-network mapping, lead-time and variability analysis by sourcing region, and single-source concentration analysis across the part portfolio. Three findings emerge. First, the binding constraint is not shipping distance but upstream forging and melt capacity: air transit is short and stable across origins (mean 4.4 days), and even by sea the logistics leg is a minority of the 42-week order-to-delivery lead time, so geography enters mainly through the freight-mode decision. Second, the core vulnerability is lead-time variability (±8 weeks), not length: actual safety stock of three to five weeks sits far below the roughly eighteen weeks the variability would require to absorb. Third, all 124 metallic part numbers are single-sourced (close to 100 percent of spend), with one billet supplier (T UK) alone at about 64 percent, and the dependence falls hardest on the NADCAP-qualified flight-control forgings.

INTRODUCTION

For aerospace manufacturers operating to a fixed customer takt, supply continuity is as important as price. A missed delivery of a flight-critical forging cannot be remedied by a cheaper substitute, it stops the line. Manufacturers that source advanced metallic raw materials (titanium, nickel-based superalloys, and aerospace-grade steels) from a small set of distant, highly qualified suppliers therefore face a structural continuity exposure that is easy to attribute to "distance." Whether distance is in fact the operative constraint, or whether the risk lies elsewhere in the network, has direct consequences for how a firm should invest in resilience (Nugraha et al., 2023; Tamir et al., 2017).

This distinction matters because the available levers differ sharply. If distance and shipping are the constraint, the response is faster or more reliable logistics; if the constraint is upstream manufacturing lead time, faster shipping changes little, and the response must address sourcing structure and buffering; and if the dominant risk is dependence on a single supplier, neither logistics nor buffers suffice without supplier diversification (Chod et al., 2019; Polyviou et al., 2023). Supply Chain Risk Management (SCRM) provides the lens for distinguishing among these mechanisms, treating disruption exposure, lead-time variability, and single-source dependence as distinct risks that require distinct mitigations (El Baz & Ruel, 2021; Ivanov, 2020; Ozdemir et al., 2022).

The novelty of this research lies in its systematic, network-level diagnostic approach that empirically separates three commonly conflated mechanisms shipping distance, lead-time variability, and single-source dependence within a single real aerospace supply network. By applying supply-network mapping, lead-time and variability analysis by sourcing region, and single-source concentration analysis across the entire part portfolio, this study provides a granular, evidence-based diagnosis that moves beyond the intuitive but often misleading attribution of continuity risk to distance. The research also contributes a prioritized mitigation agenda directly derived from the diagnostic findings, including a dual-sourcing project with an estimated fourteen-month payback. This approach is consistent with recent research emphasizing that maintaining production continuity in high-stakes aerospace programs demands proactive strategy, eliminating reliance on single-site suppliers and decisively mitigating logistics uncertainty.

Yet the literature that names these risks rarely disentangles them empirically inside a single, real network. Studies of supply chain risk treat distance, lead-time variability, and single-source dependence as parallel concerns, and resilience guidance often defaults to faster logistics without first establishing where the binding constraint sits. This leaves a gap between a rich vocabulary for continuity risk and a concrete, evidence-based diagnosis of which mechanism a given network should invest against (Jie et al., 2024). The issue this paper addresses is therefore diagnostic: in a long-distance, single-sourced aerospace network, is distance actually the operative continuity constraint, or do lead-time variability and single-source dependence dominate? The firm studied is an almost extreme instance of the problem, a Tier-1 Indonesian manufacturer (pseudonymized as PT VC Aero Bandung) that machines Airbus A320 flight-control components under the AS9100 and NADCAP frameworks and sources about 99 percent of its metallic raw materials from Europe, with lead times that have grown both longer and more erratic since 2020. It is exactly the case in which the temptation to blame distance is strongest, and therefore the most revealing place to test that intuition.

Concretely, the analysis pursues three questions in turn: where in the network the delays actually originate, how adequate the firm's inventory buffers are relative to the lead time it faces, and how concentrated its single-source exposure has become. Answering them in sequence builds the diagnosis from the structure of the network outward to the decisions the firm must make.

The contribution is a network-level continuity-risk diagnosis, grounded in the firm's shipment and inventory records, that disentangles three commonly conflated mechanisms (shipping distance, lead-time variability, and single-source dependence), identifies which actually drives the risk, and turns that finding into a prioritized mitigation agenda the firm can act on.

METHOD

The study used an embedded single-case design with a quantitatively dominant, explanatory sequential strategy: the quantitative network analysis is built first and is then interpreted and validated against expert testimony (Creswell & Plano Clark, 2018; Saunders, Lewis, & Thornhill, 2019). The unit of analysis is the inbound supply network itself, the suppliers, origins, consolidating forwarder, and flows that carry forged billets and forgings to the Bandung facility rather than any single shipment or supplier, so that distance, variability, and dependence can be located relative to one another within one structure.

Data Sources

The network and lead-time analysis draws on the firm's direct-material-purchase (DMP) records, which cover all 124 metallic part numbers, their suppliers, and FY2023–FY2025 spend; its inbound OPMC shipment report of 692 shipments covering 2023–2026 (origin and actual transit times); and safety-stock policy records (on-hand and in-transit buffers by material type). On-time delivery, first-pass yield, and supplier-qualification references for regional origins, as well as ocean-transit times, were drawn from clearly labeled secondary benchmarks when internal data were unavailable. One important data caveat: although the procurement dataset includes a lead-time field, its near-constant value of about two weeks reflects an internal goods-receipt or planning parameter rather than the supplier order-to-delivery lead time. Therefore, the procurement lead times used here are taken from the Supply Chain Manager interview (a 26-to-53-week band averaging 42 weeks) and corroborated by benchmarked sector figures. Individual suppliers are reported by role to preserve commercial confidentiality.

The qualitative component comprised three in-depth, semi-structured expert interviews with a Supply Chain Manager, a Supplier Quality Manager, and a Quality Compliance Manager, conducted using the expert-interview approach of Bogner, Littig, and Menz (2009), and recorded, transcribed, and coded deductively against the network and continuity-risk constructs using template analysis (Gale et al., 2013). Following the logic of expert interviewing, the three participants were selected purposively to span the continuity, supplier-qualification, and compliance perspectives rather than as a representative sample, and the small panel reflects the few senior roles with end-to-end visibility of the inbound network; coding stabilized once no new continuity-risk themes emerged across the three accounts. To guard against single-coder bias, the coded findings and the joint display were taken back to the participants for member-checking, and the interview guide that structured the coding is available on request.

Analytical Procedure

The analysis proceeds in three linked steps, and each step pairs a defined method with the specific output it produces. The first step is supply-network mapping. Drawing on the supplier and origin master data and the 692 inbound shipment records, the inbound flow is rendered as a directed network in which every consignment is assigned to a node and an arc, so that the chain resolves into four nodes, the European mills and forges, the single consolidating forwarder, the customs-and-concession checkpoint on arrival, and the Bandung plant, connected by physical-shipment and documentation arcs. Each arc is annotated with its elapsed time and the variability of that time, and the resulting map is read with bottleneck and critical-path logic (Gaudenzi et al., 2021): the bottleneck is the node or arc that contributes the largest and most variable share of total order-to-delivery time, and the critical path is the longest time-consuming sequence from order placement to receipt. The output of this step is a stage-by-stage decomposition of the lead time that separates the manufacturing leg from the logistics leg, rather than treating the whole chain as a single undifferentiated "distance," and that pinpoints the bottleneck nodes the later results quantify.

The second step is lead-time and variability analysis. Using the 692 actual shipment records, it compares order-to-delivery time and its dispersion (the mean and the ± range) by sourcing region, and isolates the logistics leg from the full lead time. Its output is a regional lead-time-and-variability profile and, from the observed variability, the level of safety stock that would be required to absorb it.

The third step is single-source concentration analysis, carried out as a spend-weighted portfolio classification. All 124 metallic part numbers are sorted by the number of qualified sources and by share of spend, in the manner of a Pareto reading of the portfolio. Its output is a count of single-sourced part numbers and the proportion of spend they represent, which makes the most exposed flight-critical items stand out.

The three quantitative threads are triangulated with secondary benchmarks and then integrated with the interview evidence through a joint-display approach (Fetters, Curry, & Creswell, 2013), in which each quantitative result is placed directly alongside the interview testimony that explains it. As a single embedded case, the findings are analytically rather than statistically generalizable: the diagnostic procedure transfers to comparable aerospace networks, while the specific figures belong to this facility.

RESULTS AND DISCUSSION

The supply network and its bottlenecks

Applying the supply-network mapping of Section 3.2 to the master data and the 692 shipment records yields the network in Figure 1 and the study's first result: two bottlenecks dominate the inbound flow, and both lie outside the leg intuitively read as "distance." The mapped network runs from the European mills and forges, through a single consolidating forwarder and a customs-and-concession checkpoint on arrival, to the Bandung plant; on the supply side it terminates in just three sole-source European vendors, T UK supplying 116 billet types, and LISI and Mettis supplying eight near-net flight-control forgings so the origin nodes are few and wholly undiversified. The first bottleneck is the forging lead time at source, the time capacity-constrained mills and forges need to melt, forge, and finish material before it ships; the second is the customs and concession-documentation step on arrival, where clearance and traceability checks add days. Reading the chain as a network, rather than as one undifferentiated link from Europe to Bandung, is what isolates these two constraints from the shipping leg, a separation the lead-time analysis in Section 4.3 then quantifies. Decomposing the 42-week order-to-delivery lead time makes the point in numbers (Figure 1): about 39 weeks, roughly 93 percent of the total and carrying essentially all of the ±8-week variability, accrue in forging and melt at source, whereas outbound transit (about 4.4 days by air), customs clearance (1.5 to 2.1 days), and inbound goods receipt (about two weeks) together account for only some three weeks, about 7 percent, with negligible variability. The mapping is therefore not merely descriptive: it apportions the lead time across stages and locates both its length and its variability in the upstream node.

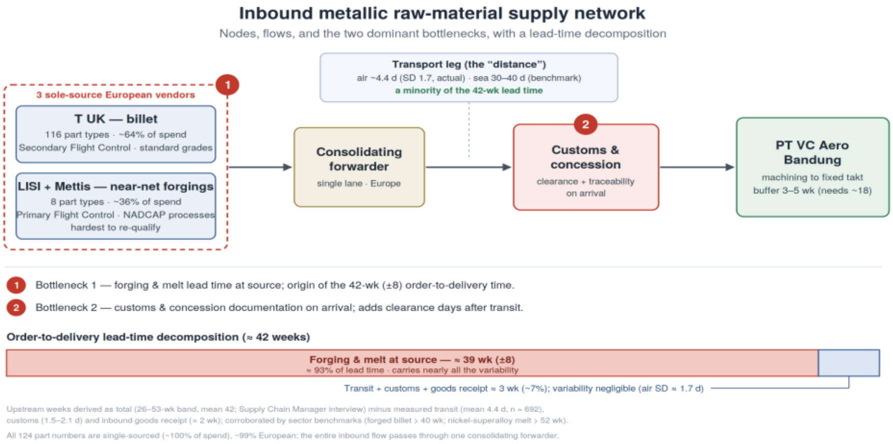

Figure 1. Inbound metallic raw-material supply network

Figure 1. Inbound metallic raw-material supply network: nodes, flows, and the two dominant bottlenecks. The forging and melt lead time at source (1) and the customs-and-concession step on arrival (2) both lie outside the air or sea transport leg; air transit is short and stable (mean 4.4 days, n = 692 shipments), while the 42-week (±8) order-to-delivery time is generated upstream. The decomposition bar apportions the lead time across stages: about 93 percent (≈ 39 weeks), and nearly all the variability, accrue in forging and melt at source, against about 7 percent (≈ 3 weeks) for transit, customs, and goods receipt combined. All 124 part numbers are single-sourced and almost wholly European; suppliers are labelled as in the thesis.

Lead time and its variability by region

For already-qualified billets, European supply has the longest mean order-to-delivery lead time, about 42 weeks, within a wide 26-to-53-week band reported by the Supply Chain Manager, and the widest variability (±8 weeks), compared with 32 weeks (±6) from India and 28 weeks (±5) from ASEAN (Table 1). The European base also leads in delivery reliability and quality (94 percent on-time delivery, 98 percent first-pass yield), reflecting its maturity, while regional origins trail on both because they are not yet fully qualified. The operational significance lies in the variability column: fully absorbing the European ±8-week swing would require roughly eighteen weeks of safety stock, a figure the firm comes nowhere near holding, as Section 4.4 shows.

Table 1. Order-to-delivery and operational metrics by sourcing region (actual for European suppliers; benchmarked for India and ASEAN).

Sourcing region	Lead time (wk)	Variability (±wk)	Safety stock to absorb (wk)	OTD (%)	FPY (%)
Europe (forged billet)	42	8	18	94	98
India	32	6	14	90	95
ASEAN (TH / MY)	28	5	12	88	93

Note. European lead-time, variability, on-time-delivery and first-pass-yield figures are actual, from the firm’s records and the Supply Chain Manager interview; the India and ASEAN figures are indicative secondary benchmarks pending qualification-stage quotations and should be read as scenario estimates rather than measured values. The “safety stock to absorb” column rests on the standard safety-stock principle that the buffer required to protect a target service level rises with both the variability of supply and the service level chosen, SS = z × σLTD (Chopra & Meindl, 2016). That relationship states the governing principle, not the figures themselves: because order-to-delivery variability cannot yet be measured from the firm's records (the procurement lead-time field is a goods-receipt parameter), the column is a planning cover rather than a direct formula output the stock needed to keep the line running when a delivery arrives at the late end of the observed lead-time band across a reorder cycle, on the order of eighteen weeks for European supply at the ±8-week band. These required figures are therefore indicative: they scale with the assumed service level and would be recomputed as a direct safety-stock result once that variability is measured directly (Seyam et al., 2024).

Logistics versus lead time: the upstream constraint

Isolating the logistics leg from the full lead time yields the study's central, somewhat counterintuitive result. The firm's 692 inbound shipments currently move by air, and the door-to-door airfreight transit time is short and stable regardless of origin: a mean of about 4.0 days from European origins (the United Kingdom and France), 4.9 days from India, and 4.3 days from China, with customs clearance adding an additional 1.5 to 2.1 days. Across all 692 shipments, the mean transit time is 4.4 days, with a standard deviation of only about 1.7 days. By air, in other words, geography is almost invisible.

Sea freight, the economical mode for heavy billets and forgings, behaves very differently (Table 2). Secondary benchmarks for the same destination indicate typical port-to-port ocean transit times of roughly 30 to 40 days from European ports, 15 to 31 days from India, and only 7 to 15 days from China. By sea, a regional origin reaches Bandung roughly 15 to 25 days sooner than a European one (about 15–23 days for India and 20–25 for China). Two implications follow. First, even by sea the logistics leg (about five weeks at most) remains a minority of the roughly 42-week order-to-delivery lead time, confirming that the long and variable European lead time originates upstream, in forging and melt manufacturing, rather than in shipping. Published sector data corroborate this, with forged-billet lead times exceeding 40 weeks and nickel-superalloy melt lead times exceeding 52 weeks (Fortune Business Insights, 2026; Future Market Insights, 2026). The routine inbound flows already recorded from India and China also show that the logistics integration for any future regional shift is largely in place. Second, freight mode and sourcing decisions are coupled: air buys a short, stable five-day leg from any origin but at a premium that lifts freight to about a tenth of landed cost, and under air a regional source offers no logistics-leg advantage. Were heavy volume shifted to sea to cut that premium, European sourcing would become some three to five weeks slower than a regional source. Distance, then, enters continuity risk chiefly through the freight-mode decision, not through transit time as such.

Inventory buffers and their adequacy

The firm's actual safety-stock policy is modest (Table 2): forgings and castings are buffered by about 35 days in total (21 on hand plus 14 in transit), and billets by about 21 days (14 plus 7), equivalent to roughly five and three weeks, respectively. These buffers are thin relative to the ±8-week variability of European supply and far below the roughly eighteen weeks required to absorb it fully. This mismatch defines the continuity exposure: when a European delivery slips, the lean buffer is quickly exhausted, and the shortfall must be met by expediting, typically via premium air freight, which raises costs and, when air capacity is unavailable, leaves the line exposed to stoppage. The thin buffer and the long, variable lead time are thus two sides of the same risk.

Table 2. Actual safety-stock policy by material type, against the buffer the European variability would require.

Material type	On-hand (d)	In-transit (d)	Total (≈ wk)	Required (≈ wk)
Forging / casting	21	14	35 (≈ 5)	≈ 18
Billet	14	7	21 (≈ 3)	≈ 18

Single-source dependence and continuity risk

The portfolio analysis turns the abstract idea of dependence into a concrete count. Classifying all 124 metallic part numbers from the firm's direct-material-purchase records by the number of qualified sources and by their share of spend exposes the problem in full: every one of the 124 part numbers is single-sourced, so essentially the entire metallic spend rests on a single vendor per part, and almost all of it originates in Europe. The portfolio resolves into 116 standard-grade billet types drawn from a single UK mill (T UK) and eight near-net flight-control forgings from two specialist suppliers (LISI and Mettis), each vendor being the sole source for what it provides (Appendix A). The concentration is extreme at the top: the single T UK billet account alone is about 64 percent of metallic spend, and the exposure is widening rather than stable, since metallic spend rose from USD 5.21 million in FY2023 to USD 7.86 million in FY2025 (about 51 percent in two years), driven almost entirely by billet, which more than doubled. The dependence is also heaviest where it is least tolerable: the eight forgings feed Primary Flight Control functions and carry NADCAP-controlled special processes, which makes them the hardest parts to re-qualify, whereas the 116 billet types feed Secondary Flight Control functions in standard aerospace grades (2024 and 7075 aluminium; 904, AMS5643 and AMS5659 stainless) that a new mill could be qualified to supply within a twelve-to-eighteen-month horizon. Read as a portfolio, the exposure therefore has a clear Pareto shape, with a small set of high-spend and flight-critical part numbers carrying the bulk of the risk. That shape matters, because it means the problem is targetable: a focused dual-sourcing effort on a handful of items can relieve most of the exposure rather than requiring the whole portfolio to be re-qualified. Layered on top of the long, variable lead time and the funnelling of all inbound flow through a single consolidating forwarder, this concentration creates a tangible line-stoppage risk and recurrent misalignment with takt time: a disruption at any of these nodes has no internal redundancy to absorb it. Sector experience reinforces the case for reducing such concentration, as prime manufacturers have moved to diversify the geographic sources of critical metallic inputs in response to geopolitical exposure (International Policy Digest, 2025).

Qualitative interpretation

The interviews placed the central operational risk firmly in lead-time variability rather than in length. The Supply Chain Manager described how order-to-delivery times for some billets had crept from 16 to 20 weeks up to 28 to 32 weeks, how an individual purchase order could swing anywhere from 20 to 34 weeks, and how that dispersion alone had forced safety stock up by 30 to 40 percent. The problem, in this account, was not that supply had become slow but that it had become unpredictable, and unpredictability is far harder to plan around than a long but steady lead time. This testimony corroborates, almost line for line, the widevariance lead times and the buffer pressure that the shipment and inventory records had already exposed.

"Some billets used to be 16–20 weeks; now they're 28–32. The variability is more damaging than the length." Supply Chain Manager

The other two panel members justified the remaining findings from their own vantage points. The Supplier Quality Manager explained why the single-source exposure is so durable: the eight near-net forgings (from LISI and Mettis) feed Primary Flight Control functions and carry NADCAP-controlled special processes, so qualifying a second forging source is a slow, audit-heavy process under the AS9100 and NADCAP regimes. On this account the fully single-sourced portfolio is not an oversight but the residue of a qualification system that resists quick change, which is precisely why a planned dual-sourcing project, rather than an opportunistic spot purchase, is the only realistic remedy, and why the standard-grade Secondary-Flight-Control billet, easier to re-qualify, is the natural place to begin. The Quality Compliance Manager, for his part, pointed to the customs-and-concession checkpoint as a recurring source of arrival delay, corroborating the second, downstream bottleneck visible on the network map, and observed that routing almost all inbound flow through one consolidating forwarder leaves no fallback when that single lane is disrupted. Read together as a joint display, the three accounts do more than echo the numbers; they supply the operational reasons behind them. Variable lead time, thin buffers, concentrated single sourcing, and forwarder dependence each acquire a cause in the testimony, and it is the convergence of independent quantitative and qualitative evidence, the records and the managers arriving at the same diagnosis by different routes that gives the conclusion its weight (Hong et al., 2017; Ramsay et al., 2022).

Returning to the general problem, the literature describes distance, lead-time variability, and single-source dependence well individually but seldom separates them inside one real network, and resilience advice tends to reach for faster logistics before asking where the constraint lies. This case is informative precisely because it is where that reflex is most tempting: a flight-critical, fully regulated network sourcing almost entirely from Europe, nine thousand kilometres away, where "it's the distance" is the obvious story. The records show that story to be wrong; and because it fails in the hardest case, the finding carries beyond this firm. Any aerospace manufacturer investing in shipping speed to cure a continuity problem may, like PT VC Aero Bandung, be treating the symptom rather than the cause.

Viewed through the SCRM lens, each calculation carries a clear operational meaning, and in each case the interview evidence justifies that reading directly rather than merely echoing it. The logistics calculation returns a mean air-transit time of about 4.4 days (standard deviation roughly 1.7 days) across all 692 shipments, and a sea leg that, even at its longest, is only a minority of the 42-week order-to-delivery time. What this means is that shipping distance is not the binding constraint and that the lead time is generated upstream, in forging and melt capacity. The interviews justify this directly: the Supply Chain Manager located the growth in order-to-delivery time at the mills, with some billets moving from 16–20 to 28–32 weeks, while the only logistics-side delay the panel raised was the customs-and-concession checkpoint flagged by the Quality Compliance Manager, a documentation node, not a function of transit distance.

The variability and buffer calculations return a European swing of ±8 weeks set against actual safety stock of only three to five weeks, far below the roughly eighteen weeks that swing would require. What this means is that the network is structurally under-buffered, and that its exposure is driven by unpredictability rather than by length. The Supply Chain Manager's testimony justifies this directly and in quantitative terms: individual purchase orders swing from 20 to 34 weeks, that dispersion alone had already forced safety stock up by 30 to 40 percent, and, as he put it, the variability is more damaging than the length.

The concentration calculation returns the whole portfolio of 124 part numbers single-sourced, close to 100 percent of spend, with the single T UK billet account alone at about 64 percent routed through a single forwarder. What this means is that the residual risk is concentrated exactly where disruption is least tolerable and least redundant. The Supplier Quality Manager justifies why this figure is durable rather than incidental: qualifying a second forging source is a slow, audit-heavy process under AS9100 and NADCAP, so the concentration is the residue of the qualification regime and can be relieved only by a planned dual-sourcing project, sensibly begun with the easier-to-qualify standard-grade billet. Distinguishing these three mechanisms is the paper's analytical contribution, because each implies a different, non-substitutable remedy.

For practice, the diagnosis yields a prioritized mitigation agenda. Because the constraint is upstream and the dependence is concentrated, the highest-leverage move is a planned dual-sourcing programme sequenced by qualification difficulty: begin with the standard-grade billet, which carries about 64 percent of spend yet can be re-qualified within twelve to eighteen months, and only then extend to the NADCAP-qualified flight-control forgings, which are slower to qualify; the modelled dual-sourcing business case reaches payback in about fourteen months while directly reducing single-source exposure. In parallel, the firm should attack variability rather than length through supplier scheduling agreements, predictive logistics, and buffer optimization targeted at the highest-risk items, since the interviews suggest that even a twenty percent reduction in variability would be transformative for planning. Buffer policy should be re-based on lead-time variability rather than on a flat day-count, and inbound flow should be diversified away from the single forwarder. Faster shipping, by contrast, would address the mechanism that the analysis shows is least binding. Table 4 maps each risk driver to its evidence and its corresponding lever.

Table 3. Continuity-risk drivers and prioritised mitigations.

Risk driver	Evidence	Mitigation / expected impact
Single-source dependence (~100% of spend)	All 124 parts single-sourced (~100% of spend); T UK billet ≈ 64%; flight-critical forgings (LISI, Mettis) hardest to qualify	Dual-sourcing programme, billet first then forgings; ≈ 14-month payback
Lead-time variability (±8 wk)	Upstream forging/melt constraint; melt > 52 wk	Scheduling agreements; predictive logistics; ~20% variability cut is transformative
Under-buffering (3–5 wk vs ≈ 18 wk)	Safety stock far below variability requirement	Variability-based buffer optimisation on highest-risk items
Forwarder concentration	Single consolidating forwarder for inbound flow	Diversify forwarders and lanes

CONCLUSION

The story this paper set out to tell began with an intuition, that a network reaching nine thousand kilometers to Europe must be at the mercy of distance and ended by overturning it. Diagnosing the continuity risk of a Tier-1 aerospace manufacturer's European metallic supply network from its own shipment and inventory records shows the risk to be widely mis-attributed. Distance is not the binding constraint; the actual logistics leg is short and stable, and the long, variable 42-week lead time originates upstream in forging and melt capacity. The core vulnerability is lead-time variability rather than length: the firm holds only three to five weeks of safety stock, whereas roughly eighteen would be required to absorb the swing. The residual risk is concentrated in single-source dependence: the entire 124-part portfolio is single-sourced, close to 100 percent of spend, with T UK alone at about 64 percent and the flight-critical forgings the hardest to re-qualify. Each mechanism calls for a different remedy, led by a dual-sourcing project with an estimated fourteen-month payback and by variability-based buffering, and pointedly not by the faster shipping the distance intuition would have prescribed. Three limitations constrain the precision, though not the direction, of these conclusions. The qualitative interpretation rests on three expert interviews at a single facility; procurement lead times were benchmarked against sector sources rather than measured internally, because the internal lead-time field reflects a goods-receipt parameter; and ocean-transit and regional operating metrics were drawn from secondary data. Future research could measure supplier order-to-delivery lead times directly over time, model the service-level impact of buffer policies built on variability rather than on a flat day-count, and test whether the same distance-versus-variability-versus-dependence pattern recurs in other long-distance, single-sourced aerospace networks.

REFERENCES

Chod, J., Trichakis, N., & Tsoukalas, G. (2019). Supplier diversification under buyer risk. *Management Science, 65*(7), 3150–3173.

Chopra, S., & Meindl, P. (2016). *Supply chain management: Strategy, planning, and operation* (6th ed.). Pearson.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

El Baz, J., & Ruel, S. (2021). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International Journal of Production Economics, 233*, Article 107972. https://doi.org/10.1016/j.ijpe.2020.107972

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs: Principles and practices. *Health Services Research, 48*(6 Pt. 2), 2134–2156. https://doi.org/10.1111/1475-6773.12117

Fortune Business Insights. (2026). *Aerospace cold forgings market size, share & industry analysis and regional forecast, 2026–2034*. Fortune Business Insights.

Future Market Insights. (2026). *Nickel-based superalloys market: Size, share, and forecast, 2026–2036*. Future Market Insights.

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology, 13*, Article 117. https://doi.org/10.1186/1471-2288-13-117

Gaudenzi, B., Siciliano, G., & Confente, I. (2021). Supply chain risk management: A network and bottleneck analysis approach. *Journal of Purchasing and Supply Management, 27*(3), Article 100689.

Hong, Q. N., Pluye, P., Bujold, M., & Wassef, M. (2017). Convergent and sequential synthesis designs: Implications for conducting and reporting systematic reviews of qualitative and quantitative evidence. *Systematic Reviews*, *6*(1), Article 61.

International Policy Digest. (2025). *The geopolitics of titanium: Why the West still depends on Russia*. International Policy Digest.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review, 136*, Article 101922. https://doi.org/10.1016/j.tre.2020.101922

Jie, T. W., Xin, P. N. H., & Rahmat, M. F. (2024). Explainable analytics of blockchain-driven green innovation: A multi-factor framework for supply chain systems. *Journal of AI Analytics and Applications*, *2*(2), 1–22.

Nugraha, R. N., Putra, G. M., & Nofitri, R. (2023). Analysis of drug stock inventory at the pharmacy of HAMS Kisaran Hospital using the SCM method. *Journal of Computer Science and Technology (JOCSTEC), 1*(1), 28–34. https://doi.org/10.59435/jocstec.v1i1.11

Ozdemir, D., Sharma, M., & Govindan, K. (2022). Supply chain resilience: A systematic literature review and bibliometric analysis. *Annals of Operations Research*.

Polyviou, M., Wiedmer, R., Chae, S., Rogers, Z. S., & Mena, C. (2023). To concentrate or to diversify the supply base? Implications from the U.S. apparel supply chain during the COVID-19 pandemic. *Journal of Business Logistics, 44*(3), 502–527.

Ramsay, J. A., Mascaro, S., Campbell, A. J., Foley, D. A., Mace, A. O., Ingram, P., Borland, M. L., Blyth, C. C., Larkins, N. G., & Robertson, T. (2022). Urinary tract infections in children: Building a causal model-based decision support tool for diagnosis with domain knowledge and prospective data. *BMC Medical Research Methodology, 22*(1), Article 218.

Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson.

Seyam, A., El Barachi, M., Zhang, C., Du, B., Shen, J., & Mathew, S. S. (2024). Enhancing resilience and reducing waste in food supply chains: A systematic review and future directions leveraging emerging technologies. *International Journal of Logistics Research and Applications*, 1–35.

Tamir, M., Ouzayd, F., & Chiheb, R. (2017). Literature review and classification of performance analysis methods: Hospital supply chain.

Wong, C. W. Y., Lirn, T.-C., & Yang, C.-C. (2024). Single versus multiple sourcing: A systematic review and future research agenda for supply chain resilience. *International Journal of Production Economics, 266*, 109–123.