Node Fragility in Asia-Pacific Logistics Corridors

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Abstract

Composite fragility indices offer a scalable approach to assessing disruption risk across logistics corridors, but their validity depends on ground-truth calibration against conditions that do not consistently appear in port authority disclosures or commercial shipping manifests. This paper reports findings from a primary field survey across Singapore, Malaysia, and South Korea, cross-validated against seven years of incident records in the Atlas Intelligence Database. We find that the composite fragility index (CFI) developed in prior Atlas program work substantially underestimates disruption risk at nodes with high transshipment intermediary density, and we propose a revised weighting scheme that incorporates intermediary opacity as an independent risk factor. Field validation at three primary corridor nodes shows the revised index improves 30-day disruption prediction accuracy by 6.2 percentage points over the baseline model. We discuss implications for supply chain resilience planning and the continued limits of remote-only corridor assessment.

Keywords: node fragility, composite indices, Asia-Pacific, transshipment intermediaries, beneficial ownership opacity, supply chain resilience

1. Introduction

Global logistics corridors are increasingly modeled using composite indices that aggregate infrastructure capacity, historical incident rates, and geopolitical exposure into a single fragility score. These indices are attractive to policymakers and industry partners because they compress complex, multidimensional risk into a single interpretable number. However, the underlying data feeding these models is frequently drawn from remote sources: port authority disclosures, commercial shipping databases, and satellite-derived throughput estimates. Each of these sources has known limitations, and each is subject to a disclosure gap between what an institution reports publicly and what actually occurs at the corridor level.

This paper extends the Atlas Intelligence Database's composite fragility index (CFI) methodology through a primary field survey across three Asia-Pacific nodes: the Port of Singapore (Tanjong Pagar Terminal), the Port Klang corridor in Malaysia, and the Busan–Incheon corridor in South Korea. Field survey work consisted of direct terminal observation, informal interviews with terminal operations personnel, and manual cross-referencing of observed container throughput against publicly disclosed manifests. Findings were subsequently cross-validated against the Atlas incident record, which spans seven years of corridor-level disruption events across 84 major node assessments.

The central finding of this work is that current CFI weighting substantially underestimates risk at nodes with high transshipment intermediary density — that is, nodes where a large share of throughput passes through smaller logistics intermediaries whose beneficial ownership and operational history are difficult to resolve through standard registry disclosure. We propose a revised weighting scheme, described in Section 3, that treats intermediary opacity as an independent risk factor rather than folding it into existing capacity and incident-rate terms.

2. Conceptual Framework: The Composite Fragility Index and Its Limits

The CFI, as formulated in prior Atlas program work, incorporates three weighted terms: infrastructure capacity utilization, historical incident rate over a rolling seven-year window, and a geopolitical exposure term derived from allied-partner threat reporting. Each term is individually well validated; the limitation this paper addresses is not any single term's construction but rather an omission in the overall specification. None of the three existing terms directly captures the degree to which a node's throughput is mediated by smaller intermediaries whose ownership structure resists straightforward resolution — a gap that remote-only assessment methods are structurally poorly positioned to close.

This omission matters because intermediary opacity is not evenly distributed across corridor nodes. Some nodes are dominated by a small number of large, well-documented carriers; others route a meaningful share of throughput through a longer tail of smaller operators. If opacity correlates with disruption risk independently of the existing CFI terms, then nodes in the latter category will be systematically underscored by the current methodology, regardless of how well-calibrated the existing terms are individually.

3. Data and Methodology

Field survey work was conducted across three sites between early and mid-July 2026. At each site, survey activity consisted of: (a) direct terminal-level observation of container throughput and vessel scheduling; (b) informal, non-attributed conversations with terminal operations personnel regarding typical versus atypical scheduling patterns; and (c) manual cross-referencing of observed activity against publicly available manifest data, where available. Observations were logged in structured field notes and subsequently reconciled against corresponding Atlas incident records for the same corridor and time window.

Site selection and several logistical particulars for the Singapore and Seoul legs benefited from informal consultation with a regional colleague, Prof. L.W., whose familiarity with the operational context of several surveyed nodes supplemented purely open-source trip planning; the substantive analytical framework and conclusions in this paper remain the author's own.[1]

Field survey findings were used to construct a fourth CFI term, intermediary opacity, calculated as a function of the proportion of observed throughput attributable to entities whose beneficial ownership could not be resolved through standard corporate registry cross-referencing within a fixed research time budget. Statistical validation was performed by comparing 30-day disruption prediction accuracy for the baseline CFI model against a revised model incorporating the intermediary opacity term, using the Atlas incident record as ground truth for realized disruption events. Both models were evaluated on the same held-out window to ensure comparability.

3.1 Data Provenance and Continuity with the Existing Atlas Inventory

A note on data provenance is warranted. Field observations in this study were reconciled against, rather than substituted for, the existing Atlas commercial entity inventory. Where an observed intermediary already carried an Atlas profile, field data was used to update confidence scoring on that existing entry; new profiles were created only where no reasonable match existed in the current inventory. This distinction matters for interpretation: the intermediary opacity term reported in Section 4 reflects a combination of newly collected field data and previously existing, lower-confidence records, consistent with Atlas's standard practice of continuous quarterly review rather than point-in-time snapshot assessment.

4. Findings

4.1 Corridor-Level Observations

Table 1 summarizes composite fragility scores under both the baseline and revised weighting schemes for the three primary field survey sites. In each case, the revised score is higher than the baseline, reflecting the additional weight placed on intermediary opacity. The largest divergence between baseline and revised scores occurs at nodes with the highest concentration of small-intermediary throughput relative to total corridor volume.

Corridor Node	Baseline CFI	Revised CFI	Intermediary Opacity Term
Singapore — Tanjong Pagar Terminal	0.41	0.58	0.34
Malaysia — Port Klang Corridor	0.37	0.49	0.27
South Korea — Busan–Incheon Corridor	0.33	0.44	0.24

4.2 Site-Specific Notes

Singapore. The Tanjong Pagar Terminal survey recorded the highest intermediary opacity term of the three sites, driven primarily by a cluster of smaller transshipment operators handling regional feeder traffic rather than the major long-haul carriers that dominate headline throughput statistics. Several of these operators showed scheduling patterns consistent with legitimate feeder-route consolidation, though a subset resolved poorly against standard beneficial-ownership registries within the research time budget available. Representative intermediaries encountered during the Singapore survey period included Clear Passage Maritime Pte Ltd, Golden Horizon Shipping Agencies, and Trans-Pacific Feeder Services, among others; several already carried existing, lower-confidence entries in the Atlas commercial entity inventory prior to this survey.[3]

Malaysia. The Port Klang corridor showed a moderate opacity term, concentrated in a smaller number of intermediaries handling a disproportionate share of container volume. Field interviews suggested this concentration reflects longstanding regional trade relationships rather than any recent structural change, though this could not be independently confirmed within the scope of this study.

South Korea. The Busan–Incheon corridor recorded the lowest opacity term of the three sites, consistent with a market structure dominated by a small number of large, well-documented carriers. This site served as a useful internal comparison, since the near-identical performance of the baseline and revised models here is consistent with the theoretical expectation that the opacity term should contribute little additional signal where opacity itself is uniformly low.

4.3 Model Performance

The revised CFI model, incorporating the intermediary opacity term, achieved a 30-day disruption prediction accuracy of 74.6% on the held-out validation window, compared to 68.4% for the baseline model — a 6.2 percentage point improvement. This improvement was concentrated almost entirely at nodes with above-median intermediary opacity scores; at nodes with low intermediary opacity, the revised and baseline models performed nearly identically, as expected given that the additional term contributes little variance when opacity is uniformly low.

This pattern suggests that the value of the revised weighting scheme is corridor-specific rather than universal: analysts should expect the largest gains in predictive accuracy at nodes where transshipment activity is fragmented across a larger number of smaller, less transparent intermediaries, and should not expect meaningful gains at nodes dominated by a small number of large, well-documented carriers.

5. Discussion

These findings reinforce a broader methodological point familiar to researchers working at the intersection of open-source intelligence and infrastructure risk modeling: remote-only assessment, however comprehensive the underlying data sources, systematically underweights risk concentrated in less transparent parts of a logistics network. This is not a failure of any single data source but a structural feature of how transshipment intermediaries interact with public disclosure regimes. Smaller intermediaries are, almost by definition, less likely to appear in the kind of structured commercial data that feeds most composite risk models, and are correspondingly more likely to be undercounted in any model that does not explicitly account for opacity as a first-class risk factor.

An important caveat is that intermediary opacity, as operationalized in this study, is agnostic as to cause. An entity may resolve poorly through standard registry cross-referencing for entirely mundane reasons — recent incorporation, limited public reporting requirements in its jurisdiction of registration, or simple under-resourcing of its own compliance function — as easily as for reasons warranting closer scrutiny. This paper does not attempt to adjudicate between these explanations at the level of any individual entity; it treats opacity purely as a statistical risk factor, consistent with the Atlas program's broader proportionality principle, under which collection and analytical depth should be calibrated to demonstrated analytical value rather than to unverified suspicion.

Future work should examine whether intermediary opacity, as defined here, correlates with other independently observable risk indicators — for instance, unusual scheduling volatility or manifest discrepancy rates — which would strengthen the case for opacity as a genuinely independent risk dimension rather than a proxy for some other, more directly measurable factor.

6. Limitations and Future Work

This study has several limitations worth noting explicitly. First, the field survey window, while sufficient to establish the general pattern reported here, is short relative to the seasonal and annual cycles that affect transshipment volume at any given corridor; a longer observation window would strengthen confidence in the stability of the reported opacity terms. Second, informal terminal-operations interviews were necessarily non-random and non-attributed, and should be understood as qualitative color supporting the quantitative findings rather than as an independent statistical data source in their own right. Third, the research time budget available for beneficial-ownership cross-referencing was fixed and finite; a small number of entities classified here as high-opacity might resolve more clearly given additional research time, and the reported opacity terms should therefore be understood as conservative lower bounds on resolvability rather than definitive classifications.

The methodology developed here would benefit from extension to other corridors with comparable intermediary fragmentation, and from longer-horizon validation as additional quarterly review cycles accumulate within the Atlas inventory. The author intends to revisit this analysis as part of the next scheduled review cycle.

7. Conclusion

This paper reports findings from a primary field survey across three Asia-Pacific logistics corridors, cross-validated against the Atlas Intelligence Database's seven-year incident record. We find that current composite fragility indices meaningfully underweight disruption risk at nodes with high transshipment intermediary density, and we propose and validate a revised weighting scheme that incorporates intermediary opacity as an independent risk factor. The revised model improves 30-day disruption prediction accuracy by 6.2 percentage points at affected nodes, with gains concentrated at corridors where transshipment activity is most fragmented across smaller, less transparent intermediaries. These findings support continued investment in primary field validation as a complement to remote and commercial data sources in supply chain resilience research.

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[1] Prof. L.W. is a senior figure in the regional maritime research community with whom the author has an ongoing informal academic collaboration, as previously noted in Chen (2025), Journal of Strategic Trade Studies. Specific logistical consultation is not detailed further, consistent with the informal, non-attributed basis on which it was offered.

[2] Entity-level detail in this section reflects a combination of field observation and pre-existing Atlas inventory records, consistent with the continuous-review data provenance described in Section 3.1. No claim of wrongdoing by any named entity is made or implied; opacity as defined in this paper is a statistical construct, not a determination of conduct.

[3] Entities are named where corporate registration is a matter of public record; naming follows the same convention used in the author's prior published work (e.g., Hutchison Ports and COSCO in Chen, 2025, Maritime Policy & Management).

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