Spatiotemporal Risk Drivers of Economic Cascades: Assessing Transportation Hub Vulnerability in Public Health Crises

Topic: Input-Output Modelling: Disaster analyses (1)
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This study addresses a critical gap in economic impact assessment: the lack of node-level analytical frameworks for quantifying cascading risks from transportation hub disruptions during public health emergencies. While existing input-output models effectively capture inter-sectoral dependencies, they treat infrastructure nodes as homogeneous units, overlooking context-specific vulnerability. Furthermore, the spatial and temporal characteristics of emergency responses have not been integrated as stochastic drivers of systemic risk. This study asks: How can we quantify cascading economic risks from transportation hub disruptions, and how do spatial extent and temporal duration jointly determine these risks?

The framework integrates two spatiotemporal risk driversâ€”influenced distance (spatial extent) and control period (temporal duration)â€”into an extended input-output model. It captures economic shocks through four pathways: public health costs, environmental decontamination, business interruption, and supply chain disruption. Building on the Adaptive Regional Input-Output framework, the model incorporates two interacting constraints: labor constraints from illness and quarantine, and transportation capacity constraints from freight disruptions. These constraints interact non-linearly, with the weakest link principle determining maximum production capacity. Bidirectional supply chain disruptions are modeled through forward and backward linkages, captured via a transportation constraint matrix.

The framework is applied to Baiyun Railway Station in Guangzhou, China. Epidemiological parameters are drawn from infectious disease literature. Economic data are obtained from official statistics. The 2017 Chinese Multi-Regional Input-Output table provides inter-regional economic structure. Freight flow data identify 14 railway-transported goods across nine critical sectors. Spatial parameters define contaminated (1.29 kmÂ²) and semi-contaminated (3 km radius) zones. Temporal parameters set baseline control periods of 8 and 4 weeks.

This study makes several novel contributions. First, it introduces a node-level perspective capturing individual facility vulnerability. Second, it explicitly incorporates spatiotemporal parameters as stochastic drivers of systemic risk. Third, it models dual constraints driving cascading failures within an input-output framework. Fourth, it provides bidirectional formulation of supply chain disruptions. Fifth, its scenario-based design enables sensitivity analysis for pre-event risk assessment.

The case study yields three findings. First, significant temporal risk amplification: economic disruptions persisted for 20 weeks, 2.5 times longer than the 8-week control period. Second, spatial risk propagation: while Guangdong Province bears 91% of supply chain losses, shocks propagate to distant regions through trade networks. Third, asymmetric driver sensitivity: total losses are more responsive to control duration than influenced distance, suggesting time-based interventions offer greater risk reduction beyond a certain radius. These findings demonstrate the value of probabilistic risk assessment for identifying vulnerabilities and informing mitigation strategies.