A Control-Theoretic Framework for Supply Chain Resilience: Applying Disturbance Decoupling to Prevent Cascading Disruptions

Rakesh R Warier, NIT Calicut

rakeshw@nitc.ac.in

Modern supply chains are complex networked systems, comprising interdependent subsystems such as suppliers, manufacturers, and distributors. This structure can be naturally modeled as a multi-agent system. However, their interconnectedness also creates vulnerability; disruptions originating from internal dependencies or external shocks (e.g., geopolitical events or natural disasters) can propagate as cascading failures, severely disrupting vital industries. Therefore, developing methodologies to protect critical segments of the supply chain from these propagating disruptions is a concern for ensuring economic resilience.

This work explores the applicability of the Disturbance Decoupling Problem (DDP), a foundational concept in geometric control theory, to enhance the resilience of supply chain networks. In a multi-agent system framework, DDP provides a formal methodology for designing state or output feedback control laws that protect a specified subset of nodes such as critical manufacturing or distribution hubs from disturbances affecting other parts of the network. By framing the supply chain under this control-theoretic perspective, we investigate the conditions under which such a decoupling is achievable.