

How Efficiency-Driven Practices Shape Pharmaceutical Supply Chain Resilience: A System Dynamics Model

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Medicine shortages are increasing worldwide and impose substantial clinical, economic, and societal burdens. Efficiency-driven supply chain practices, such as sourcing from few suppliers, lean inventories, and large production batches, reduce costs under normal conditions but increase disruption vulnerability. Pharmaceutical supply chains are particularly exposed because these practices combine with long production lead times and limited production flexibility. In the Dutch generic market, they appear as tender-driven demand concentration, quota-based allocation, and periodic country-level replenishment. To examine how these interacting practices shape resilience, we develop a multi-echelon system dynamics model informed by stakeholder interviews and brand-level dispensing and inventory data. We simulate a one-year interruption of the dominant brand's supply across scenarios varying market composition, manufacturer replenishment, and quota policy. Results show that market concentration primarily determines patient-level shortage outcomes, quota design shapes shortage duration, and replenishment timing governs disruption spread and recovery. Future work will build on these findings by evaluating targeted resilience interventions to reduce system vulnerability.