MONTE CARLO SIMULATION FOR PHARMACEUTICAL SUPPLY CHAIN DISRUPTION RISK MODELING

1. Project Background

A mid-sized **pharmaceutical manufacturer** was facing recurring stockouts at their regional distribution centers, especially during public health campaigns and seasonal spikes. The operations director reached out to assess **how resilient their current safety stock policies** were in the face of uncertain lead times and fluctuating demand from hospitals.

They wanted a **probabilistic simulation model** to better understand the likelihood of stockouts and to build contingency strategies for key SKUs with long production cycles.

2. Objectives

The main goals of the simulation project were:

- Model **probabilistic demand and lead-time variability** for high-priority pharmaceutical SKUs
- Estimate **stockout probabilities** under current safety stock policies
- Simulate real-world scenarios of **supply chain delays and distribution bottlenecks**
- Recommend **risk-adjusted reorder points** and **buffer inventory** strategies
- Visualize supply chain risks in terms of timelines, inventory depletion curves, and uncertainty zones

3. Tools & Technologies Used

- **Platform:** R
- **Libraries:** truncnorm, data.table, ggplot2, purrr, shiny
- **Simulation Framework:** Monte Carlo (10,000 iterations per SKU per location)
- **Visualization Tools:** ggplot2 (density plots, probability-of-stockout charts), Shiny (optional real-time inputs)
- **Deliverables:** HTML-based simulation report, Excel dashboard with scenario snapshots

4. Input Variables Modeled

Variable	Distribution Used	Notes
Monthly Demand	Normal (μ=1200, σ=250)	Different for each SKU-location combination
Lead Time (days)	Triangular	Min: 12, Most Likely: 18, Max: 30
Shipment Delay %	Uniform	0–20% monthly
Order Frequency	Fixed	Monthly cycles
Safety Stock Level	Client-provided baseline	Evaluated for sufficiency under risk

5. Simulation Workflow

- Created **SKU-level simulations** over a 12-month horizon
- For each month and SKU, generated random demand and lead time
- Modeled **inventory depletion events** and **backorder conditions**
- Simulated **production and delivery delays** due to external factors
- Calculated monthly **probability of stockout** and **days of inventory on hand (DOI)**
- Validated model using **3 years of historical demand and lead time data**

6. Deliverables

Component	Details
R Scripts	Parameterized for monthly updates; documented for internal team use
Visual Summary Report	

- Stockout probability timeline
- Histogram of demand vs. reorder points
- Risk zones plotted with 90% confidence intervals | | Recommendation Memo | SKU-wise analysis of risk-adjusted reorder points and lead time buffers | | Optional R Shiny Tool | Interactive dashboard for “what-if” demand and delay adjustments |

7. Insights Derived

- **18 of 42 SKUs had >20% probability of stockouts** in peak months under current reorder policy
- Increasing lead time from 18 to 25 days **doubled the stockout risk** for 5 critical drugs
- A **12% increase in buffer stock** reduced average monthly risk by **47%**
- Production batching frequency had an outsized impact on low-volume SKUs
- Suggested tiered risk buffer strategy: **High-priority SKUs = 95% service level**, others at 90%

8. Business Impact

- Enabled **data-driven safety stock planning** across 3 distribution centers
- Helped the operations team present **quantified risk scenarios** to senior leadership
- Informed the decision to renegotiate supplier SLAs with **data-backed lead time variability models**
- Reduced emergency backorder costs by **19%** in the next quarter
- Model now used for **quarterly supply chain reviews** and disaster preparedness planning

9. Client Testimonial

“Before this simulation, our stockouts felt random. Now we know exactly when and where risk is creeping in—and how to fix it in advance.”