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* **Project Title: AI-Driven Risk Management and Decision Support for Sustainable Supply Chains**
* **Project Start Date:** 1st June 2025
* **Names of project associates/ students (if student, mentions degree and year):**
  + Puneet, BS in Data Science, Final Year
  + Manish Kumawat, Intern
  + Tentu Venkatesh, Intern
* **Problem Statement/ Description (3-4 lines):** Supply chains face unpredictable disruptions that can severely impact service levels and costs. Stochastic risk assessment enables FedEx SMART Centre to quantify these uncertainties using probabilistic models. This approach supports robust decision-making under uncertainty, aligning with FedEx’s goal of building resilient, sustainable, and agile logistics solutions.

**Progress against project objectives:**

| S. No | Objective | Progress Status |
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| 1. | Risk Assessment Framework | * Working on designing a stochastic risk assessment model integrating probability distributions of supply chain disruptions. * Found a dataset and worked on the code to implement Monte Carlo simulations to evaluate potential outcomes of supply chain decisions under uncertainty. * Completed Phase 1 (Literature & Concept Review), including extracting mathematical frameworks, Bayesian Network structures, and ripple-effect modeling from selected papers. * Developed a comparison matrix of major stochastic modeling approaches. Identified and prepared publicly available datasets, conducted preliminary data analysis (EDA), and flagged data quality issues. * Completed Monte-Carlo simulation v1 and v2, and drafted the first possible Supply Chain Risk Index (SCRI). * Finalized the Supply Chain Risk Index (SCRI) with calibrated severity parameters, achieving ROC-AUC ≥ 0.80 and calibration slope within [0.9, 1.1]. * Completed sensitivity and stress testing, along with distribution fitting and copula selection (Gaussian vs. Student-t). * Incorporated calibration using EM-DAT and UNCTAD external datasets, ensuring mapping accuracy with R² ≥ 0.5. * Risk Dashboard prototype initiated and integrated with updated SCRI weights, downloadable outputs, VaR/TVaR readouts, and copula model badge. * With these milestones, the Risk Assessment Framework is now considered functionally complete, providing a strong foundation for the next phase (AI-based decision support system). |
| 2. | AI-Based Decision Support System | Yet to do |
| 3. | Predictive Analytics for Disruptions | Yet to do |
| 4. | Sustainable and Resilient Logistics Strategies | Yet to do |

| **Work completed in the project thus far:**   1. Initial Research and Planning: Identified and documented publicly available datasets relevant to supply chain disruption modeling, and researched stochastic risk assessment models (Stochastic Programming, Markov Chains, Bayesian Networks, Newsvendor) with their pros, cons, and application domains. 2. Paper Review and Concept Extraction: Reviewed a key paper on "Stochastic Integrated Supplier Selection and Disruption Risk Assessment under Ripple Effect," summarizing its objective function, decision variables, constraints, uncertainty modeling, Bayesian Network structure, and ripple-effect modeling. 3. Literature Comparison: Created a matrix comparing four major stochastic modeling approaches, highlighting application domains, pros, cons, and references. 4. Seminar Participation and Summaries: Attended the FedEx/IIT Kharagpur seminar on Variance-Adjusted Cosine Similarity (VACS), summarizing key takeaways, and attended the SMART FedEx Seminar Series, summarizing insights on logistics challenges in India, global best practices, and the need for localized solutions. 5. Data Preparation (Phase 2): Reviewed the selected dataset, created a data dictionary mapping original fields to risk variables, identified data quality issues, and conducted exploratory data analysis (EDA), including histograms and ECDFs. 6. Collaboration and Repository Management: Coordinated work with team members, uploaded artifacts to a shared Google Drive and GitHub repository, and maintained logical folder structures with basic documentation. 7. Feature Engineering: Derived inter-arrival time, disruption severity proxy (Delivery\_Risk x Cost), and lead-time variance, documented in feature\_eng.md. 8. Data Quality Refinement: Proposed imputation/deletion rules per variable and documented them in data\_quality\_issues.ipynb, with updates to the README file. 9. Exploratory Statistics Polish: Added markdown interpretations for identifying heavy tails and multimodality in exploratory\_statistics.ipynb, and pushed histogram and ECDF plots as PNGs to /figures/histogram\_ecdfs. 10. Monte Carlo Simulation Development:     1. Simulated 10,000 scenarios using preliminary fitted distributions and plotted the distribution of total disruption cost (mc\_simulation\_v1.ipynb).     2. Created Monte-Carlo simulation version 2, including relevant empirical data and a separate parameters folder. 11. Copula Dependency Prototype: Developed a prototype for Gaussian copula dependency on severity and inter-arrival times, documented in copula\_dependency\_prototype.ipynb. 12. Supply Chain Risk Index (SCRI) Draft: Drafted the first possible SCRI and saved it in the repository as scri\_draft.md. 13. Finalized SCRI: Completed the final SCRI, including an iPython notebook and CSV results. Sensitivity and Stress Testing: Performed sensitivity and stress testing analyses. 14. Calibration with External Data: Collected EM-DAT (2018–2024) and UNCTAD port metrics, aggregated to weekly granularity, and mapped disruption severity proxies. Built calibration.ipynb and validated mapping with R² ≥ 0.5. 15. Copula Selection and Diagnostics: Compared Gaussian vs. Student-t copulas on calibrated marginals. Reported AIC/BIC, log-likelihood, Kendall’s τ, and tail-dependence λ. Selected the Student-t copula based on fit and tail exceedance accuracy. 16. SCRI Re-weighting and Validation: Re-weighted the Supply Chain Risk Index (SCRI) with calibrated severity parameters. Recomputed node-level scores, achieving ROC-AUC ≥ 0.80 and calibration slope within [0.9, 1.1], using Platt scaling and isotonic regression. 17. Dashboard Enhancements: Updated the Streamlit risk dashboard with model badge (e.g., “t-copula”), downloadable SCRI results, VaR/TVaR readouts, and a short “What changed after calibration” note. |
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| **Specific work done this month:**  **1. Calibration of Risk Model with External Data**   * Collected EM-DAT disaster data (2018–2024) for India and key FedEx lanes (cyclone, flood, heatwave, earthquake). * Pulled UNCTAD port metrics (port calls, turnaround times) for Chennai, Nhava Sheva, Mundra, Colombo, and Singapore. * Aggregated both datasets to weekly granularity and created a unified join key (ISO week). Built *calibration.ipynb* to derive disruption severity proxies and mapped them to our severity scale. * Validated mapping with hold-out R² ≥ 0.5, ensuring acceptable predictive alignment.   **2. Copula Modelling and Selection**   * Fitted both Gaussian and Student-t copulas on calibrated marginals (severity, inter-arrival, lead-time). Evaluated model fit using AIC/BIC, out-of-sample log-likelihood, and Kendall’s τ. * Assessed tail-dependence (λ) and compared against empirical exceedance rates. * Conducted Rosenblatt/PIT diagnostics with QQ plots for uniformity. * Selected Student-t copula as final model due to superior tail behaviour and fit quality.   **3. SCRI Re-weighting and Validation**   * Re-weighted the Supply Chain Risk Index (SCRI) using calibrated severity parameters (equal-risk contribution and PCA variants). * Recomputed node-level SCRI scores across disruption scenarios. * Achieved ROC-AUC ≥ 0.80 and calibration slope between 0.9 and 1.1. * Applied Platt scaling and isotonic regression to improve calibration; retained final calibrator based on cross-validation. * Added additional validation metrics, including PR-AUC, Brier score, and Expected Calibration Error (ECE).   **4. Risk Dashboard Enhancements**   * Integrated updated SCRI weights and new copula model into the Streamlit risk dashboard. Added model badge (“t-copula”) for transparency. * Enabled CSV download of SCRI results for external analysis. * Implemented VaR/TVaR readouts at a weekly horizon. * Added a short explanatory note (“What changed after calibration”) to guide dashboard users.   **5. Reporting and Documentation**   * Updated *scri\_method.md* with full documentation of calibration, copula modelling, and SCRI re-weighting. Revised technical report (v0.4) with calibration plots, ROC/PR curves, and dashboard screenshots. * Prepared progress summary for FedEx officials, including live demo walk-through of the risk dashboard. |
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| **Project Outcome for the month:**  **1. Calibration of Risk Parameters**   * Integrated external datasets (EM-DAT disaster data and UNCTAD port turnaround statistics) into the risk framework. * Derived severity proxies (event frequency, affected population, port delays) and mapped them to the SCRI severity scale. * Validated calibration mapping with R² ≥ 0.5 on hold-out samples. * Produced calibration plots and weekly-level severity tables for ongoing monitoring.   **2. Advanced Copula Modelling**   * Conducted comparative analysis of Gaussian vs. Student-t copulas for capturing dependency between severity, inter-arrival, and lead-time. * Reported statistical fit metrics (AIC/BIC, log-likelihood) and dependence measures (Kendall’s τ, tail λ). * Student-t copula selected as the final dependency model due to better alignment with empirical tail risk. Updated simulation pipeline and documentation with the chosen copula model.   **3. Enhanced Supply Chain Risk Index (SCRI)**   * Re-weighted the SCRI using calibrated severity parameters, applying equal-risk contribution and PCA-based methods. * Recomputed node-level risk scores with updated weights. * Achieved validation benchmarks: ROC-AUC ≥ 0.80, calibration slope between 0.9–1.1, PR-AUC, and Brier score improvements. * Applied Platt scaling and isotonic regression; final calibrator retained after cross-validation. * Produced performance plots (ROC, PR, calibration curves) for reporting.   **4. Risk Dashboard Development**   * Upgraded Streamlit dashboard with key new features:   + Model badge display (“t-copula”) for transparency.   + CSV download option for SCRI results.   + VaR/TVaR risk readouts at weekly horizons. Annotation panel with “What changed after calibration” to guide users. * Improved UI responsiveness and prepared for Dockerization. * Demo:     **5. Technical Reporting and Knowledge Sharing**   * Updated *scri\_method.md* and the technical report with calibration methodology, copula selection results, and SCRI validation outcomes. * Added detailed plots, tables, and explanations to ensure reproducibility. * Prepared summary notes and visuals for FedEx officials, including dashboard screenshots and calibration charts. * Conducted a live project review session with IITM and FedEx stakeholders, demonstrating dashboard capabilities and SCRI improvements. |
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| **Next Steps (Work Plan for next month):**   * Finalize MDP specification and document KPIs (service level, total cost, SCRI-violation count, VaR/TVaR). * Build Gym/SimPy environment with calibrated marginals and Student-t copula sampler, ensuring seeded reproducibility and unit tests. * Design and document baseline policies ((s,S) and myopic heuristics) with experiment parameter grids. * Implement baseline policies and conduct grid search for (s,S) policy performance. * Develop initial Q-learning or DQN training harness with logging of rewards and KPIs. * Integrate “Policy suggestion” panel into the dashboard to display recommended orders vs. baselines. * Extend reward function to include risk penalties (SCRI-weighted or CVaR-style) and retrain agent. * Conduct policy comparison under independence, Gaussian, and Student-t dependence assumptions to assess tail impacts. * Perform ablation studies on sensitivity to severity (±20%) and inter-arrival variability (±15%). * Prepare interim technical report (v0.5) covering environment, baselines, learning agent results, risk trade-offs, and dashboard screenshots. * Package environment and dashboard using Docker Compose and set up CI pipelines with unit tests. * (Optional) Test edge PoC by running SCRI inference and policy lookup on Orin Nano device and record latency. |
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**Project Progress:**

**Project Timeline and current work activity:**

| Phase/Work Tasks | Sub-Tasks | June | July | August | September | Month |
| --- | --- | --- | --- | --- | --- | --- |
| 3.1 Risk Assessment Framework | Literature review and model design | Completed |  |  |  |  |
|  | Paper extraction & modeling approach | Completed |  |  |  |  |
|  | Data sourcing and initial mapping | Completed |  |  |  |  |
|  | Data cleaning and quality assessment |  | Completed |  |  |  |
|  | Exploratory data analysis and distribution fitting |  | Completed |  |  |  |
|  | Monte Carlo simulation prototype |  | Completed |  |  |  |
|  | Multi-factor risk index design |  |  | Completed |  |  |
|  | Risk index testing and refinement |  | Completed |  |  |  |
|  | Distribution Fitting & Goodness-of-Fit (GoF) Matrix |  | Completed |  |  |  |
|  | Alternative Copula Check |  |  | Completed |  |  |
|  | Sensitivity and Stress Testing |  |  | Completed |  |  |
|  | Risk Dashboard Prototype |  |  | Completed |  |  |
|  | Deployment and DevOps |  |  | Completed |  |  |
| AI-Based Decision Support System | Environment and Baseline Setup |  |  |  | Start |  |
|  | Baseline Implementation and Training Harness |  |  |  | Start |  |
|  | Risk Aware Learning and Analysis |  |  |  | Start |  |
|  | Packaging and Demo Preparation |  |  |  | Start |  |

**Work Contributions by individual team members in the project:**

1. **Puneet**
   1. Led development and refinement of the Supply Chain Risk Index (SCRI), including calibration, re-weighting, and validation (ROC/PR curves, calibration metrics).
   2. Implemented Platt scaling and isotonic regression to improve model calibration; achieved ROC-AUC ≥ 0.80 and calibration slope within [0.9–1.1].
   3. Built documentation (*scri\_method.md*) and updated the technical report with calibration results, validation metrics, and plots.
   4. Coordinated reporting activities — prepared monthly reports and technical documentation for FedEx and IITM.
   5. Created the one-slide project showcase for the FedEx VP visit and participated in live discussions with FedEx officials during the demo session.
   6. Conducted dashboard walk-through and explained project outcomes to stakeholders.
2. **Manish**
   1. Performed data engineering tasks: dataset shortlisting, variable mapping, cleaning, and exploratory analysis.
   2. Carried out distribution fitting (Exponential, Weibull, Lognormal, Pareto) with statistical validation (KS, AIC/BIC); identified Lognormal and Weibull as best fits.
   3. Implemented and compared Gaussian vs. Student-t copulas; finalized Student-t based on superior tail dependence.
   4. Contributed to building the Streamlit risk dashboard: integrated simulation outputs, added CSV download feature, and prepared UI enhancements.
   5. Drafted technical documentation on copula choice and dashboard integration.
3. **Venkatesh**
   1. Collected and processed external calibration datasets (EM-DAT disaster data and UNCTAD port metrics), aggregated to weekly severity proxies.
   2. Developed *calibration.ipynb* and validated severity mapping (target R² ≥ 0.5).
   3. Implemented Dockerfile and assisted in DevOps setup for the Streamlit dashboard deployment.
   4. Paired with Manish on dashboard enhancements, including node table integration and performance optimization.