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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 (Joins from August)
* **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 |
| --- | --- | --- |
| 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). |
| 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. |
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| **Specific work done this month:**  **Feature Engineering**   * Derived inter-arrival time, disruption severity proxy (Delivery\_Risk x Cost), and lead-time variance, documented in feature\_eng.md.   **Monte Carlo Simulation Development**   * Simulated 10,000 scenarios using preliminary fitted distributions and plotted the distribution of total disruption cost (mc\_simulation\_v1.ipynb). * Created Monte-Carlo simulation version 2, including relevant empirical data and a separate parameters folder.   **Copula Dependency Prototype**   * Developed a prototype for Gaussian copula dependency on severity and inter-arrival times, documented in copula\_dependency\_prototype.ipynb.   **Supply Chain Risk Index (SCRI) Draft**   * Drafted the first possible SCRI and saved it in the repository as scri\_draft.md. * Completed the final SCRI, including an iPython notebook and CSV results.   **Sensitivity and Stress Testing**   * Performed sensitivity and stress testing analyses.   **Distribution Fitting & Goodness-of-Fit (GoF) Matrix**   * For three engineered variables, fit Exponential, Weibull, Lognormal, and Pareto distributions, and provided parameter estimates with KS, AIC/BIC metrics. * Lognormal was found best for severity, and Weibull was best for inter-arrival, while Exponential was rejected.   **Alternative Copula Check**   * Fit Student-t copula and compared tail-dependence versus the Gaussian.   **Risk Dashboard Prototype**   * Began building a minimal Streamlit application for risk simulation and visualization.   **Documentation and Tech Report Draft**   * Drafted a technical report covering data, fitting, copula, SCRI, and key plots. * The monthly report for July was prepared. |
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| **Project Outcome for the month:**  **Feature Engineering**   * Derived inter-arrival time. * Created a disruption severity proxy using Delivery\_Risk x Cost. * Calculated lead-time variance.   **Data Quality Refinement**   * Proposed and documented imputation/deletion rules per variable in  data\_quality\_issues.ipynb. * Updated the README file accordingly.   **Exploratory Statistics Polish**   * Added markdown interpretations for identifying heavy tails and multimodality in  exploratory\_statistics.ipynb. * Pushed histogram and ECDF plots as PNGs to /figures/histogram\_ecdfs.   **Monte Carlo Simulation Development**   * Simulated 10,000 scenarios using preliminary fitted distributions and plotted the distribution of total disruption cost (mc\_simulation\_v1.ipynb). * Created Monte-Carlo simulation version 2, including relevant empirical data and a separate parameters folder. * Confirmed that the parameter-driven Monte Carlo simulation version 2 runs correctly and the overlay plot matches empirical mean/standard deviation within 4%.   **Copula Dependency Prototype**   * Developed a prototype for Gaussian copula dependency on severity and inter-arrival times (copula\_dependency\_prototype.ipynb). * Estimated Gaussian  ρ=0.37 and found Kendall's T\_sim=0.25 against an empirical 0.27, deemed acceptable.   **Supply Chain Risk Index (SCRI) Draft and Finalization**   * Drafted the first possible SCRI and saved it in the repository as scri\_draft.md. * Finalized the SCRI, including an iPython notebook and CSV results.   **Sensitivity and Stress Testing**   * Performed sensitivity and stress testing analyses.   **Distribution Fitting & Goodness-of-Fit (GoF) Matrix**   * For three engineered variables, fitted Exponential, Weibull, Lognormal, and Pareto distributions. * Provided parameter estimates with KS, AIC/BIC metrics. * Lognormal was found to be best for severity, and Weibull was best for inter-arrival, while Exponential was clearly rejected.   **Alternative Copula Check**   * Fitted Student-t copula and compared tail-dependence versus the Gaussian.   **Risk Dashboard Prototype**   * Began building a minimal Streamlit application for risk simulation and visualization.   Demo:    **Documentation and Tech Report Draft**   * Drafted a technical report covering data, fitting, copula, SCRI, and key plots. |
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| **Next Steps (Work Plan for next month):**   * Enhance the Streamlit dashboard (sliders, CSV download, node table) and Dockerize it. * Back-test SCRI on 2019-2021 data slice and generate ROC/PR curves. * Document the SCRI methodology. * Prepare for the August 8th demo run. * Gather EM-DAT/UNCTAD delay data and calibrate severity-cost mapping. * Compare the Gaussian vs. Student-t copula using the full dataset and document the chosen copula. * Reweight SCRI using calibrated parameters and update the SCRI notebook. * Prepare a literature memo on Reinforcement Learning (RL) for supply-chain decisions, defining state-action-reward. * Implement an OpenAI-Gym style environment with a SimPy backend. * Unit test the environment and add a CI workflow. * Implement Q-Learning and heuristic (s, S) agents and train them for 1,000 episodes. * Log KPIs and produce relevant plots. * Analyze results, update the technical report, revise the Gantt chart, and draft the September work plan. * Live dashboard walk-through. |
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**Project Progress:**

**Project Timeline and current work activity:**

| Phase/Work Tasks | Sub-Tasks | June | July | August | Month | 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 | In Progress | Completed |  |  |  |
|  | Exploratory data analysis and distribution fitting | In Progress | Completed |  |  |  |
|  | Monte Carlo simulation prototype | Start | Completed |  |  |  |
|  | Multi-factor risk index design |  | Completed |  |  |  |
|  | Risk index testing and refinement |  | In Progress |  |  |  |
|  | Distribution Fitting & Goodness-of-Fit (GoF) Matrix |  | Completed |  |  |  |
|  | Alternative Copula Check |  | Completed |  |  |  |
|  | Sensitivity and Stress Testing |  | Completed |  |  |  |
|  | Risk Dashboard Prototype |  | In Progress |  |  |  |
|  | Deployment and DevOps |  |  | Start |  |  |
| AI-Based Decision Support System | RL model planning and literature review |  |  | Start |  |  |
|  | Data preparation for RL models |  |  | Start |  |  |
|  | Initial RL model development |  |  | Start |  |  |
|  | Testing and refinement of RL models |  |  | Start |  |  |

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

1. **Puneet**
   * Derived inter-arrival time, disruption severity proxy (Delivery\_Risk x Cost), and lead-time variance, documented.
   * Proposed and documented imputation/deletion rules per variable.
   * Added markdown interpretations for identifying heavy tails and multimodality.
   * Pushed histogram and ECDF plots as PNGs.
   * Simulated 10,000 scenarios using preliminary fitted distributions and plotted the distribution of total disruption cost.
   * Created Monte-Carlo simulation version 2, including relevant empirical data and a separate parameters folder.
   * Confirmed that the parameter-driven Monte Carlo simulation version 2 runs correctly and the overlay plot matches empirical mean/standard deviation within 4%.
   * Developed a prototype for Gaussian copula dependency on severity and inter-arrival times.
   * An estimated Gaussian ρ=0.37 and found Kendall's T\_sim=0.25 against an empirical 0.27, which was deemed acceptable.
   * Drafted the first possible Supply Chain Risk Index (SCRI) and saved it in the repository.
   * Finalized the SCRI, including an iPython notebook and CSV results.
   * Performed sensitivity and stress testing analyses.
   * Prepared the monthly report for July.
2. **Manish**

* Shortlisted datasets for disruption modeling.
* Performed variable mapping and preliminary data assessment.
* Conducted data analysis.
* Performed data cleaning.
* Performed distribution fitting.
* For three engineered variables, fitted Exponential, Weibull, Lognormal, and Pareto distributions, and provided parameter estimates with KS, AIC/BIC metrics. Lognormal was found best for severity, and Weibull was best for inter-arrival, while Exponential was clearly rejected.
* Fitted Student-t copula and compared tail-dependence versus the Gaussian.
* Began building a minimal Streamlit application for risk simulation and visualization (Risk Dashboard Prototype).
* Drafted a technical report covering data, fitting, copula, SCRI, and key plots (Documentation & Tech Report Draft).