Sustainable Supplier Risk Monitor: Integrating Cloud Data Pipelines, ESG Metrics, and Agentic AI for Supply Chain Insights

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Abstract - This paper presents the development of a cloud-based supply chain analytics system that integrates operational, environmental, social, and governance metrics to provide a comprehensive view of supplier performance. The project leverages Amazon Web Services for secure and scalable data storage, MySQL for structured data processing, and Google Looker Studio for visualization. An Agentic AI module was implemented to autonomously analyze supplier data and generate targeted recommendations. The dashboard consolidates multiple datasets to track total revenue, average ESG scores, defect rates, inspection outcomes, product type distribution, and supplier-specific recommendations. Through visual filters and geographic mapping, stakeholders can quickly identify high-risk suppliers, monitor performance trends, and prioritize interventions. The integration of ESG metrics into supplier evaluations enables decision-makers to account for both operational reliability and sustainability impact. This system offers a scalable framework for organizations aiming to optimize procurement strategies and align with corporate sustainability goals. The results demonstrate that combining AI-driven insights with transparent, interactive dashboards significantly enhances the ability to detect hidden risks, improve supplier collaboration, and ensure long-term supply chain stability.

Index Terms - Agentic AI, ESG metrics, Google Looker Studio, Supply chain analytics.

INTRODUCTION

In the rapidly evolving landscape of global supply chains, organizations are increasingly challenged by the complexity of managing suppliers across diverse geographies, transportation modes, and compliance frameworks. Disruptions caused by geopolitical instability, environmental risks, and fluctuating market demands have made it imperative for businesses to adopt more intelligent, proactive, and automated decision-making systems. Traditional supply chain analytics often rely on static reporting and manual interpretation of metrics, which can delay response times and reduce operational resilience.

This research presents the design and implementation of an Agentic AI-powered analytics system for supplier performance evaluation and risk mitigation. The system integrates structured datasets covering supplier risk scores, ESG (Environmental, Social, and Governance) performance, shipment costs, inspection outcomes, and AI-generated recommendations into a unified analytical framework. By leveraging an autonomous reasoning pipeline, the AI agent is capable of dynamically analyzing key performance indicators, identifying emerging risks, and recommending actionable mitigation strategies.

The novelty of this work lies in its ability to go beyond traditional descriptive analytics by introducing a decision-support loop that closes the gap between data collection and action planning. Rather than producing passive dashboards, the proposed system synthesizes operational data into targeted recommendations, such as initiating supplier quality audits, diversifying sourcing, or engaging in ESG remediation programs.

The implementation leverages SQL-based data retrieval, a Python-based AI agent, and Google Looker Studio for interactive visualization. This combination ensures accessibility for decision-makers while maintaining scalability for future integration of multi-agent workflows, predictive modeling, and real-time monitoring.

By applying Agentic AI principles to supply chain analytics, this project demonstrates how autonomous systems can significantly enhance operational efficiency, resilience, and sustainability.

LITERATURE REVIEW

Multiple studies (World Economic Forum, 2023; McKinsey & Company, 2024) highlight the growing importance of ESG metrics in procurement strategies. High ESG-scoring suppliers are associated with reduced regulatory risk, better brand alignment, and more resilient operational performance.

However, ESG integration into supply chain risk models remains underutilized due to:

- Fragmented data sources.
- Lack of automation in aggregating and interpreting supplier information.
- Limited adoption of AI for prescriptive recommendations.

Recent research in **Agentic AI** demonstrates its capacity to automate reasoning over structured datasets, continuously refine its outputs based on evolving business logic, and propose context-aware interventions. These capabilities are particularly relevant for sustainable supply chain monitoring, where multiple competing objectives must be balanced.

METHODOLOGY

The methodology for developing the Agentic AI-powered Supply Chain Analytics system consisted of **four primary stages**: data acquisition, data integration, AI-driven recommendation generation, and dashboard visualization. Each stage was designed to ensure seamless interoperability between structured datasets, autonomous reasoning, and stakeholder-friendly visual outputs.

I. Data Acquisition

The primary dataset was sourced from the public repository **"Supply Chain Analysis"** available on Kaggle (Harsh Singh, 2023). This dataset contains detailed supply chain transactional records including product categories, supplier details, freight costs, shipping modes, and delivery times. From this original dataset, key tables were derived and structured into four working datasets:

These datasets were stored as CSV files and served as the basis for all downstream analytics.

- **Supplier Risk Summary**: Containing calculated risk scores, ESG ratings, and defect rates for each supplier.
- **Supplier Summary**: Providing shipment cost data, location details, and product categories.
- **Supply Chain Operations Data**: Covering transactional shipment records, inspection outcomes, and procurement metadata.
- **AI Recommendations Dataset**: Generated by the Agentic AI model based on analysis of the previous datasets, suggesting targeted supplier-specific actions.

II. Data Integration

The Kaggle dataset was first loaded into a MySQL database to allow for structured querying. SQL scripts were used to:

- Calculate aggregate metrics such as average shipment cost, defect rates, and ESG scores.
- Generate supplier-level summaries for performance benchmarking.
- Create custom "views" such as supplier_risk_summary.

After processing in SQL, the derived tables were exported back to CSV format and integrated into a single supplier-centric table. Integration rules included:

- Ensuring one unified supplier column across all datasets to maintain relational consistency.
- Including all relevant metrics from the original and derived tables.
- Removing duplicate fields to avoid redundancy.

This consolidated dataset became the unified data foundation for both AI reasoning and dashboard visualization.

AGENTIC AI RECOMMENDATION SYSTEM

The Agentic AI pipeline was implemented in Python using a free LLM (Large Language Model) deployed locally. The framework operated in three steps:

- **Context Extraction**: SQL queries retrieved aggregated performance metrics per supplier.
- **Autonomous Analysis:** The LLM analyzed supplier performance, compared against predefined thresholds (e.g., high defect rate > 5%, low ESG score < 60), and classified risk severity.
- **Recommendation Generation**: The AI output actionable recommendations, such as:

1. Initiating Corrective and Preventive Actions (CAPA)
2. Dual-sourcing to reduce dependency on high-risk suppliers
3. ESG remediation plans
4. Expedited shipping lanes for critical inventory

This approach transformed the system from static analytics to autonomous decision support, aligning with Agentic AI principles where the AI agent perceives, reasons, and acts without continuous human prompting.

The full SQL scripts, Python code for Agentic AI recommendations, and data preprocessing pipeline are available in the project's GitHub repository: [https://github.com/Juilyyy/Sustainable-Supplier-Risk-Monitor-Agentic-AI-for-Supply-Chain-Insights]

DASHBOARD VISUALIZATION

The final visualization layer of this project was developed using Google Looker Studio, chosen for its ability to integrate multiple datasets, provide dynamic filtering, and produce interactive dashboards suitable for both technical and non-technical stakeholders. The design objective was to create a central analytics hub that delivers actionable insights into supplier performance, supply chain risks, and AI-generated recommendations. Linked here.

The dashboard layout was intentionally structured to balance high-level KPIs with detailed supplier-level metrics. On the left panel, four primary performance indicators are displayed:

- **Total Revenue** – the aggregate revenue generated across all suppliers, allowing quick assessment of the financial scale.
- **Average ESG Score** – an aggregated sustainability performance score, enabling the integration of Environmental, Social, and Governance (ESG) metrics into decision-making.
- **Average Defect Rate** – a quality control metric representing the proportion of defective goods relative to total shipments.
- **Common Risk Trigger** – a qualitative indicator summarizing the most prevalent operational risk, in this case, high defect levels.

The main body of the dashboard contains multiple interlinked visualizations:

- **Average Shipping Cost by Supplier** – a horizontal bar chart enabling quick identification of cost outliers and potential efficiency gaps.
- **Location by Risk Level Map** – a geospatial visualization that categorizes supplier locations into low, medium, and high-risk groups based on aggregated performance and ESG scores.
- **Inspection Results by Supplier** – a segmented horizontal bar chart showing the proportion of pending, failed, and passed inspections for each supplier.
- **Product Types Distribution** – a donut chart representing the share of skincare, haircare, and cosmetics products, providing a breakdown of product portfolio diversification.

A dedicated AI Recommendation Table was integrated at the bottom, displaying supplier-specific recommendations generated by the agentic AI system, accompanied by a confidence score. These recommendations bridge predictive analytics and operational decision-making, allowing stakeholders to quickly identify high-priority interventions such as expedited lanes, CAPA (Corrective and Preventive Actions), or supplier diversification.

Interactivity was built into the dashboard through cross-filtering**.** By blending multiple datasets supplier summaries, risk assessments, AI outputs, and transactional shipment data the dashboard presents a unified view of supply chain health.

This design not only provides a descriptive overview but also serves as a prescriptive decision-support tool, aligning with the project's aim of integrating AI reasoning with human oversight to optimize supply chain operations.

INSIGHTS AND FINDINGS

The completed dashboard provided a comprehensive overview of supply chain performance, integrating financial, operational, and AI-driven insights. By consolidating supplier-level data, inspection results, ESG performance, and product distribution, the tool enabled a multifaceted evaluation of supply chain health.

- **Key Performance Indicators (KPIs)**: The left panel indicators immediately convey the overall scale and risk posture of the supply chain. The Total Revenue of 577.6K underscores the economic magnitude of supplier operations. The Average ESG Score of 66.53 suggests moderate alignment with sustainability goals but highlights room for improvement. The Average Defect Rate of 2.28% indicates a relatively low but non-negligible quality risk. The Common Risk Trigger, identified as high defects, was a recurring issue affecting multiple suppliers.
- **Supplier Cost Analysis**: The Average Shipping Cost by Supplier chart revealed substantial disparities in transportation expenses. Supplier 1 emerged as the highest-cost entity, with costs significantly above average, suggesting potential inefficiencies or geographic disadvantages. Supplier 3 had the lowest costs but also exhibited fewer inspection passes, indicating that lower costs may be linked to quality compromises.
- **Geographic Risk Distribution**: The Location by Risk Level Map illustrated a concentration of medium- and high-risk suppliers in specific regions. This geographic clustering could have implications for geopolitical risk exposure and supply chain resilience, emphasizing the need for diversification or contingency sourcing.
- **Quality Control Performance**: The Inspection Results by Supplier visualization showed that Supplier 4 and Supplier 2 had the highest failure counts, with a notable proportion of pending inspections. Supplier 5 demonstrated a relatively balanced pass rate but still required CAPA measures due to defect patterns. This reinforced the importance of continuous monitoring and rapid corrective action protocols.
- **Product Portfolio Composition**: The Product Types Donut Chart highlighted that skincare products accounted for 40% of the portfolio, followed by haircare at 34% and cosmetics at 26%. This distribution provides insight into revenue dependency and potential exposure to market fluctuations in specific product categories.
- **AI-Generated Recommendations**: The AI Recommendation Table offered targeted, prescriptive actions for each supplier. For example, Supplier 5 was advised to initiate a 30-day CAPA with full incoming inspections for the next two shipments, while Supplier 4's recommendations included expedited lanes and ESG remediation. The confidence scores, ranging from 80 to 90, reflected the AI system's certainty in each prescription. These outputs demonstrated the potential of agentic AI to move beyond descriptive analytics into actionable strategy formation.
- **Strategic Implications**: The integration of AI insights within the dashboard enables supply chain managers to not only observe performance but also take proactive, informed action.

In summary, the dashboard effectively transformed raw supply chain data into an interactive decision-support system. It provided visibility into cost structures, quality issues, risk concentration, and sustainability performance critical elements for modern supply chain optimization.

CONCLUSION

This project demonstrated the design and deployment of an AI-enhanced supply chain analytics dashboard, integrating financial, operational, and quality control metrics into a unified decision-support tool. By leveraging Looker Studio as the visualization platform, the system successfully merged multiple datasets, produced actionable insights, and incorporated AI-generated recommendations for supplier management.

While Tableau was initially explored for the dashboard component, its free version presented limitations particularly in blending multiple datasets, enabling real-time connectivity, and sharing interactive dashboards without licensing constraints. In contrast, Looker Studio offered seamless integration of data sources, greater flexibility for live updates, and unrestricted sharing capabilities, making it the preferred choice for this implementation.

The developed solution transformed static datasets into a dynamic interface capable of highlighting key risks, cost drivers, and supplier performance indicators. Moreover, the embedded AI recommendations bridged the gap between analytics and action, equipping stakeholders with strategies tailored to their operational context.

FUTURE WORK

Future iterations of this project will focus on:

- **Real-Time Data Integration**: Establishing continuous data pipelines from ERP, procurement, and quality management systems into Looker Studio using cloud-based connectors (e.g., Google BigQuery, AWS RDS, or direct API integrations). This will ensure that the dashboard reflects up-to-the-minute supplier performance and market conditions.
- **Expanded AI Capabilities**: Moving from the current rule-based and LLM-powered recommendations toward fully autonomous Agentic AI systems capable of initiating procurement actions, triggering supplier re-evaluations, and adjusting inventory policies without manual intervention.
- **Predictive Analytics**: Incorporating advanced forecasting models to anticipate supplier delays, ESG score fluctuations, and quality control failures based on historical and external data trends.
- **Cross-Platform Compatibility**: Testing integration with other business intelligence tools (e.g., Power BI, Qlik) for stakeholders with different enterprise technology stacks, while maintaining Looker Studio as the primary platform due to its cost efficiency and accessibility.
- **User Interaction Enhancements**: Adding filters, drill-down capabilities, and automated alert systems within the dashboard so users can receive targeted notifications on high-priority risks and anomalies.

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