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Unified Supply Chain Intelligence Data, AI, Cloud, and Operations Synergy

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ABSTRACT: The financial impact resulting from traditional supply chain issues, estimated annually to be $200-$300 billion, has been compounded by the effects of recent supply chain disruptions such as the Panama Canal droughts and the semiconductor shortage. In this article, we will introduce the concept of Unified Supply Chain Intelligence, which brings together several technologies and processes to allow for self-optimizing supply chains, including: IoT/ERP Integration; AI/ML for predicting ETAs; Cloud Infrastructure; and Autonomous Operations. The article will include real world examples of companies that have gained significant Return-On-Investment from Unified Supply Chain Intelligence, including Siemens who achieved 98% Factory Uptime, and Walmart who reduced Stockout by 45%. Additionally, an Implementation Framework is provided to help organizations navigate through the challenges that arise because of implementing Unified Supply Chain Intelligence, including Privacy and Change Management, and will focus on four areas of focus to implement the technology: Assessment; Data Unification; AI Pilot Programs; and Cloud migration. Finally, the article will suggest that supply chain leaders need to monitor KPIs and investigate high ROI Use Cases to ensure their supply chains remain valuable strategic assets going forward.

I. INTRODUCTION

Global supply chains were severely disrupted this year from several events, which proved how vulnerable these global supply chains are to systemic risks as they face several interconnected shocks. The Panama Canal drought (which has been worsened because of both climate change and El Niño) resulted in major decreases in shipping capacity. Consequently, much of the cargo that would have been shipped via the Panama Canal had to be re-routed through other means of transport, and the time taken to move cargo through the Panamanian port was significantly extended. This has also caused semiconductor supply issues in East Asia, since China's export restrictions were leading to increased production costs and long delays, which were exacerbated by the increasing demand for semiconductor-related products, such as AI solutions and other forms of high-tech consumer electronics. The October strikes at many major European ports were also a major contributor to the disruption of operations resulting from both congestion and delay of shipments [1].

These incidents have demonstrated the inefficiency of traditional supply chains and the significant lack of end-to-end visibility and fragmented data among those systems. As a result, information is frequently stored in silos, and therefore, the resulting information is mainly reactive in nature, rather than proactive in nature. For example, many auto manufacturers overstocked supplies of automobile parts in anticipation of shortages, which resulted in overstocking parts and ending up with excess inventories. By using outdated forecasting techniques and performing manual processes, businesses lost significant amounts of money due to the delays in their goods.

In addition to the events highlighted above, supply chain disruptions have also revealed a large dependency on choke points as well as environmental effects from production such as water shortages in the Panama Canal basin. In addition, there have been labor shortages due to the strikes by workers upset about job losses caused by automation and dispute about wage increases. Such tensions have added complexity to the dynamics of global trade. Geopolitical tensions among countries and the length of production times for semiconductors have compounded the issues faced by supply chains and have shown that if supply chain systems lack integration and resilience, supply chain systems will fail and create additional operating costs for the companies that rely on them [2].

The fragmented data silos throughout the supply chains does not allow for effective decision-making because it creates incompatibility between the multiples of systems utilized in the industry today (ERP, TMS, and procurement platforms), often requiring the manual reconciliation of data, causing significant delays within processes due to unintegrated systems. Furthermore, the lack of a single source of information has resulted in mid-market companies using outdated technologies and systems attempting to integrate them, although the legacy IT systems are widely accepted to be

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inadequate. In addition to these issues, there are many European shippers that will not be able to provide visibility to the entire supply chain due to an inability to manage the volume of data generated from their business, causing on-time delivery rates to decrease significantly and creating a lack of visibility on inventory management, leading to disruptions within the supply chain.

To counteract these disruptions, organizations are depending on costly "crisis management" type actions to manage these issues; this has increased expenses leading to loss of focus on strategic objectives. Additionally, the absence of any predictive tools adds to the overall inefficiencies within the supply chain and disrupts manufacturing processes, creates issues with inventory and creates cash flow problems with organizations. Organizations that employed a reactive management process demonstrated reduced productivity levels, caused degraded supplier relationships and created an increased level of risk due to the inability to recover from shocks quickly. On the other hand, the issue of scalability becomes a challenge as legacy systems cannot integrate new technology, in addition to the large volumes of excessive pooling of data created from trade activities and IoT (Internet of Things). The combination of rising consumer expectations and geopolitical uncertainty has made supply chains more brittle, leading to increased operational cost, security risks, and reduced flexibility; creating a hindrance to competitive advantage in a digitized world.

Proactive supply chain management utilizes techniques such as data analytics, AI forecasting, and risk modeling to anticipate and mitigate any potential disruptions within the supply chain, versus a reactive approach that responds to issues after they occur by manual intervention only. A proactive strategy reduces problems by 50-70% because it allows for earlier insight into potential risks. On the other hand, 80% of the reactive strategies' resources are typically expended on fixing problems after they have already occurred. Therefore, proactive enterprise strategies save costs via long-term contracts and optimize inventory vs. increased costs associated with reactive strategies [3].

During the economic downturn, more proactive companies, such as Procter & Gamble (P&G), weathered the crisis exceptionally well because they had already implemented strategies to reduce their costs and maintain superior operational performance. Conversely, those companies that adopted a reactive approach suffered extensive losses and delays caused by their inability to adapt quickly to changing conditions. Proactive companies are also better suited to managing disruptions. Research indicates that proactive companies manage challenges 30% more effectively than those using a reactive approach. Thus, proactive approaches will enable supply chain efficiency, convert supply chains into assets for strategy, reduce risk, and increase resiliency [3].

In the move from reactive tracking to predictive and real-time intelligence, supply chain participants will receive proactive insights through several advanced technologies. IoT (Internet of Things) Sensors collect real-time data to increase the accuracy of estimated times of arrival (ETAs) and allow for early detection of anomalies. Predictive analytics powered by Artificial Intelligence and Machine Learning allow companies to predict likely demand and disruptions as well as identify bottlenecks and provide automated notification early. In addition, cloud platforms allow companies to manage and communicate all data in a scalable, real-time manner, facilitating the rapid processing of the huge volumes of data generated in a Global Supply Chain.

Utilizing blockchain technology ensures that records cannot be altered to maintain reliability along with compliance across multiple partner networks, and that the use of automation and the application of RFID and GPS technology significantly enhance the ability to track and view inventory levels in real-time which reduces stock errors significantly. Companies such as Shippeo and FourKites leverage both Artificial Intelligence (AI) and machine learning to assist in visibility, thus reducing interruption through advanced planning, as well as GenAI allows for further decision-making capabilities by making use of unstructured data to deliver actionable insights [4].

AI-driven models are highly effective for predicting estimated arrival times (ETA) for shipments in a supply chain as they can make use of various types of data (multi-modal), including GPS, weather, traffic and historical transit times. There are multiple AI models and platforms that provide substantial disadvantages to other models/platforms in this area. Machine learning processes from Shippeo leverage 200 different parameters and provide around 90% accuracy for alerting users to ongoing problems with global modes, filtering GPS 'noise'. ClearMetal and Project44 leverage large datasets to train their machine learning models to improve ETA dispatches and reduce the cost of operations [5].

FourKites uses XGboost and Gradient Boosting, providing risk-scored predictive estimates of arrival times, achieving higher accuracy than traditional methods. Blue Yonder utilizes time-series forecasting using LSTM and Recurrent Neural Networks (RNN). This enables businesses to synchronize demand and supply in real time to enhance

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operational agility in supply chains. Kinaxis' Planning.AI contributes a unique combination of external factors, enabling accurate forecasting and scenario modelling. Collectively, these models excel at utilizing both ensembles and multiple records to achieve accuracy rates between 85% and 95%, allowing users to implement preventive actions like rerouting shipments, which can assist in reducing distribution delays and lowering expenses during disruptions [6].

The creation of 'unified supply chain intelligence' enables data, AI, cloud computing technologies and streamlined operations to enhance logistic planning using an automated predictive ecosystem. The implementation of AI models built using vast IoT and ERP system-generated datasets enables real-time decision-making. A 2025 case study indicated the tremendous benefits to business owners of employing unified supply chain intelligence including an improvement in forecast accuracy (20%-50%), a decrease in inventory expenses (30%) and a quicker recovery from disruptions (40%). It is anticipated that using improved routing and disruption-resilient systems (such as the Panama Canal), all will have an extremely favorable impact on the entire logistics industry. Additionally, this article addresses the key components, synergies, benefits, technologies, implementation methodologies, use case scenarios, and future trends associated with GSCM and unified supply chain intelligence.

II. SYSTEM ARCHITECTURE

Unified supply chain intelligence refers to how these four components work collaboratively as a complete system to create a resilient operational environment that can proactively respond to potential supply chain disruptions.

1. **Data Foundations:** The sources of supply chain data (EDI/XML) are numerous, as demonstrated by EDI/XML feeds, ERP/PLM systems, external news feeds, IoT sensors, etc. As a result, there is a tremendous amount of supply chain data created; however, because the data is trapped in silos and not connected to any type of rigorous standardization, it often has little provenance and lacks the accuracy to make most forecasts. As a result, so many forecasts produced using incorrect data create a significant risk to the supply chain. There are numerous tools (Apache Kafka) that allow real-time ingestion and aggregation of supply chain data into one "single source of truth" with the least amount of delay before data is ingested and reduces inventory discrepancies.
2. **Machine Learning and AI:** Utilizing machine learning and AI to convert raw supply chain data (e.g., raw materials) into meaningful results. Predictive modelling, anomaly detection, and optimization are examples of ML and AI tools that help to identify potential disruptions, recognize anomalies during disruptions, and solve complicated routing dilemmas. Through ML-Ops, there is a continuously improving integration process that unifies models and connects them during their entire lifecycle.
3. **Cloud Infrastructure:** With the flexible scalability of Cloud solutions, Cloud can provide to manage and process a massive amount of supply chain data. By using Data Lakes or Data Storage/Repositories, compliance with ACID is guaranteed. With Serverless Infrastructure, Machine Learning or AI can quickly Scale Up Machine Learning /ML Systems. To support end users, the system will Integrate Edge Computing into the supply chain model to provide low latency data processing to enable remote monitoring of the system.
4. **Layer of Operations:** Approximately 70% of Supply Chain operations are automated, and Workflow can take advantage of Predictive Sequence Operations to help with Continuous Improvement. When human and AI cooperation happens to produce compliance and transparency, the human operator can focus only on the exceptions to the normal processing and will use the model's telemetry from execution to inform the improvement of the order fulfilment metrics as well as purchase history to retrain the model.

The integrated view of Data, AI, and Cloud technologies into single self-regenerating supply chain intelligence will enhance both the resilience and efficiency of the supply chain system. The application of AI for the analysis of massive volumes of supplier, ERP, and IoT data and the ability to derive prediction accuracy levels (85-95%) will help create demand forecasts for the future from the data. The ability of the software programs to simulate different scenario outcomes using XGBoost will improve supply chain workflow processes and will also reduce forecasting errors by over 40%. The supply chain cloud infrastructure will enable performing real-time data processing and connectivity through APIs, which will provide high levels of system reliability through multi-cloud federation architecture and will guarantee system availability through 99.99% availability and fast recovery for outages. The architecture will enable the edge to cloud sync-up using low-latency networks to provide enhanced visibility for international partners.

The operational synergy that results from having the AI-driven automated workflows, which results in a notable increase in operational efficiency for the company, is an example of this type of integration. Automated approval and re-booking actions have reduced the response time associated with the decision-making cycle and provide a means to build continuous feedback loops to continually improve the AI model resulting in a 15% improvement in the overall

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prediction quality and ability to prevent approximately 70% of stocking out events. The transformation of the company's operations from a reactive to a proactive stance will result in a very significant increase in productivity, up to 35%, and will also reduce the amount of time to react to supply chain disruptions by at least 50%. The self-optimizing, layered system architecture provides closed-loop processes to improve the areas of prediction, processing, and action based on a cycle of inputting data to actionable insight back to the system to provide continual improvement feedback.

The data ingestion function at the base layer captures a wide variety of sources of data from edges and cores of the supply chain using Internet of Things (IoT) devices such as AWS IoT Core and/or Azure IoT Hubs and processes over 1 million events per second into Apache Kafka clusters while also managing back-pressure by using Avro/Confluent Schema Registry to provide exactly-once semantically correct events and to provide the capability of passing a petabyte-one-throughput of data through partitioned topics, resulting in normalized event streams to the high many-layered stack above it. The architectural framework for unified supply chain intelligence is designed for maximum scalability, robust performance, and for minimal latency in real-time and is built with microservices and event-driven approaches to enable an uninterrupted flow of data between the various components and through independent optimization for each component. Each layer of this architectural framework provides a specific function; the protocols, tools, interactions, and flow dynamics are designed, analyzed, and defined in their respective layers as illustrated in Figure 1 below.

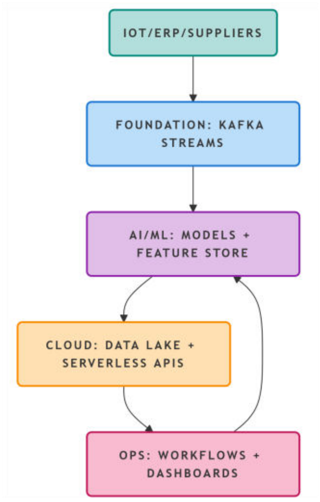

Figure 1: Unified Supply Chain Intelligence Architecture

1. **Foundation Layer – Data Ingestion:**
- The Foundation Layer includes Data Ingestion of raw data streams from both the Edge and Core.
- The Layer leverages IoT Hubs (AWS IoT Core, Azure IoT Hub) using MQTT/AMQP as the primary protocol for capturing over 1 M events/second from various sources into Apache Kafka clusters.
- Schema enforcement and backpressure are accomplished using Avro/Confluent Schema Registry to manage spikes in incoming data.
- Exact-once semantics are utilized to ensure data integrity, with an ability to manage petabyte per second through Partitioned Topics. The normalized event streams produced from this Layer will be ingested by the Layers above this Layer.
2. **Layer of Intelligence – AI/ML Processing of Data:**
- The Layer of Intelligence is primarily focused on transforming Data into Insight via Machine Learning models.
- This transformation is accomplished via Feature Stores (Feast/Tecton) which convert data into vector format to be Telemetry (Prometheus) tracks results and uses API predictions to measure results.
- The Horizontal Pods can be increased to which the MTTR is decreased via 70% through Automation.
3. **Bidirectional & Self-Optimizing Flows:**
- Downward Flow: AI Data is sent from Kafka to Features, optimizing data using AI with the resulting actions executed or alarms triggered by AI.
- Upward Flow: Based on Operational Results (OTIF and Spend) that are fed back into Kafka for continued training of the Models to improve overall Intelligence.

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- Feedback Loops: Weekly A/B Testing for ML-Ops Jobs (Airflow DAGs) and fixing anomalies via Manual Intervention.

Unified Supply Chain Intelligence uses data, AI, Cloud Computing, and Operations to convert the Disruption of 2025 into a Competitive Advantage through quantified improvements in costs, resiliency, and efficiency. By leveraging Unified Streams from IoT and ERP using AI, an estimated 20-50% reduction in forecast errors would lead to an estimated 92% accuracy via Machine Learning compared to the estimated 65% for Traditional Forecasting Model. Using Multi-Echelon Inventory Optimization and Reinforcement Learning, Surplus Inventory is reduced by an estimated 25-40% while maintaining fill rates of 99%. Workflow Automation offers a 30%-45% Increase in Throughput as illustrated by Fulfillment Cycle Time reductions of 50% during Periods of Logistical Difficulty.

Agility and Resiliency will be sustainability practices, especially eco-friendly routing, which may decrease emissions as much as 15-25%. Cloud-based solutions can greatly reduce the energy that companies consume. The return on investment (ROI) can be three to five times greater than capital invested (CAPEX) within a year or a year-and-a-half; similarly, Key Performance Indicators (KPIs) indicate that there will be many operational improvements (OTIF 95-98%, increased inventory turnover).

Unified supply chain intelligence uses many different types of technologies that are designed for scalability, cost-effectiveness and suitability for the ever-evolving supply chain landscape during 2025-2026. Advanced AI and machine learning platforms will enhance the predictive and prescriptive capabilities of companies by using large language models to conduct natural language processing to precisely identify logistics problems. These technologies use methods such as gradient boosting and time-series modelling to enhance routing and forecast demand; they also provide capabilities such as dynamic graphing and reinforcement learning as well as cloud-based platforms that provide flexible infrastructure to meet the specific needs of supply chain professionals that integrate machine learning with IoT and big data lakes [7].
Integrated suites like SAP Datasphere and Oracle Fusion SCM Cloud provide machine learning capabilities for Risk Management and Automating Processes. There are also emerging trends in the use of digital twins for scenario simulation, blockchain for secure transactions, and autonomous technology developments made possible by the implementation of 5G networks. The innovations discussed herein are aimed at improving operational efficiencies and minimizing risks of doing business within Supply Chain Management.

Unified Supply Chain Intelligence is implemented through a methodical and phased approach focused on reducing risk by means of cross-functional collaboration and iterative validation. The implementation uses proven models such as AWS Supply Chain and SAP's Maturity Framework, and the model will adapt to the needs of the enterprise from 6 to18 months. During the initial assessment phase, the focus is on auditing data fragmentation and maturity ratings over the course of a four- to six-week audit, establishing a baseline and developing a roadmap by collecting multiple metrics on the level of data fragmentation and maturity ratings. This phase should give you an idea of any major efficiency improvements and will help you identify any quick win and strategic opportunities.

The integration process is based on agile/sprint methodologies. A common first step in this process would be for all the departments in your organization to create a single repository (a centralized data Lakehouse) that contains all the data from all the departments. This could be done through the creation of a unified data reservoir which allows for real-time synchronization. After that, the organizations pilot AI implementations for their use cases that would provide the most return on investment (ROI). The implementation of cloud migration and operations automation will be subsequent phases of the integration process. The typical challenges and pain points such as data privacy, change management, vendor lock-in, skills integration, and cost overruns will be solved through implementable solutions.

The evaluation of ROI from the phased gates used in the integration process will provide an opportunity to monitor and track the key performance indicators (KPIs) that will provide indications of the return on investment (ROI) during the 18-month time frame. Overall, the integration process is designed to have a dramatic positive impact on both supply chain efficiency and supply chain effectiveness. Integrating data, artificial intelligence (AI), and cloud-based operations will be critical for businesses in the next 12-18 months, particularly with the anticipated disruption impacting industries because of the 2025 pandemic. There are many industries already seeing positive returns on their investments through the unified intelligence that is available through using a single source of data from the supply chain via the internet.

As an example, Walmart has been able to leverage cloud-based AI technologies to improve their localized demand forecasting through their analysis of data from various sources, enabling Walmart to mitigate issues related to shortages

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during port strikes, enabling them to achieve significant cost savings and enhance their delivery performance. Additionally, Siemens has been able to use digital twin technology to optimize their supply chain's production efficiencies and allow them to proactively anticipate and manage supply chain disruptions, which has resulted in increased uptime and reduced carbon emissions.

Finally, in the healthcare and logistics area, the partnership between Maersk-DHL and FourKites has enabled them to improve their visibility within the pharmaceutical logistics supply chain and predict and eliminate potential problems to maximize waste and improve their operational metrics. The use of advanced technology in supply chain management is having a dramatic effect on supply chains in the real world [8].

The evaluation of Unified Supply Chain Intelligence is focused on evaluating the efficiency, resiliency, financial benefits, and AI related to the supply chain; these metrics are tracked on dashboard applications (e.g., Tableau or Power BI) both prior to as well as after implementation. The KPI's for measuring unified supply chain intelligence include forecasting accuracy, on-time complete delivery rate, inventory turnover rate, cost of logistics per order, average amount of time to resolve disruptions, model accuracy and latency, and the perfect order rate. The targets for improvement generally present very high levels of change, including delivery rate (increase to 95%-98%), inventory turnover rate (8-12 per year), logistics cost per order (decrease by 10%-20%), recovery time after disruption (decrease). Best Practices for KPI evaluation include: the establishment of a baseline, quarterly comparison to compare ai with historical methods, utilization of real-time reports with alerts, and the combination of operational and financial perspectives to enhance continuous learning and improvement of machine learning processes [9].

The corporate value created by AI adoption is significantly increased due primarily to the Increased KPI's related to efficiency, financial outcome, resiliency, and model performance. All these KPI's can be tracked via Real-Time Dashboard Applications prior to and after implementing AI. On time complete deliveries are one of the many significant performance improvements made possible by AI. Walmart and Maersk demonstrated this with significantly improved ETA predictions due to improved data processing capabilities using AI.

Substantial improvements can also occur in inventory turnover rate as well as time resolutions for logistics issues. By utilizing AI to detect anomalies, organizations can maximize their perfect order rate and consequently their carrying costs. With the financial impact of AI being the downward pressures on inventory holding costs and improved logistics expenditures, many companies have shown tremendous savings and ROI cycles for implementing these solutions. To quantify the financial impact of applying AI innovations, companies must establish performance baselines prior to implementation, consider latency and accuracy of AI-based models and focus on the combined financial, operational and sustainability aspects of their measurement assessments [10].

When it comes to KPIs that relate to supply chain savings from AI, organizations should examine how their AI interventions (including predictive modelling) are linked to financial outcomes (i.e., logistical and overhead costs). Organizations typically experience supply chain cost savings of 10% to 35% when implementing AI solutions. To quantify total supply chain cost reduction, organizations compare pre- to post-AI implementation costs, with averages ranging from 15% to 30% reduction for these savings is shown below Table 1:

KPI	Pre-AI Baseline	Post-AI (2026)	Savings %
Total Supply Chain Cost	100%	72%	**28%**
Inventory Carrying Cost	25%	16.5%	**34%**
Logistics Cost per Unit	$15.50	$11.80	**24%**
Expedite/Premium Freight	8%	4.2%	**47%**
Average Reduction			**33%**

Table 1: Cost Savings KPIs (Pre vs Post AI)

Many AI applications such as demand forecasting using machine learning reduce stock carrying costs, while using predictive logistics decreases the costs per unit of transportation and the overall transportation expense. Sourcing analytics utilizing AI improves the purchase price variance of suppliers, thereby allowing trading partners to provide better terms. Strategies for avoiding costs related to unexpected disruptions continue to prevent significant increases in spending, and predictive maintenance can reduce costs associated with maintenance by eliminating unplanned downtimes. Companies can accurately attribute savings to their AI interventions by employing measurement tactics such as A/B testing and cohort analysis and expect substantial ROI within a short-term period [11].

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The visualizations produced from this data provide insight into projected growth in the adoption of AI technology and the resulting cost savings realized in supply chain management between 2024 and 2028. The metrics referenced in the dataset include the rate of adoption of AI technologies, the reduction of total supply chain costs using AI technologies, the savings associated with the carrying costs of inventory, and reductions in logistics-related costs, including expedite costs, along with total cumulative cost savings in the billions of dollars. Three charts were generated from the data set. It is a dual-axis line/bar chart displaying the projected growth in AI adoption and the related cost savings for the 2026 projection; it is a stacked area chart plotting cumulative total savings through the use of AI-based solutions that will cumulatively reach $1.2 trillion by 2028; it is a grouped bar chart comparing average pre- and post-implementation costs for different categories of Key Performance Indicators (KPIs). Based on the analysis, AI adoption is projected to reach 78% of the global supply chain by 2028 and the total cumulative savings will be $1.2 trillion. The largest average savings in expedited costs will occur in all KPIs, where the anticipated average savings will be 32% by 2026. The charts generated from this data are provided as images for future references are depicted in Figure 2 below.

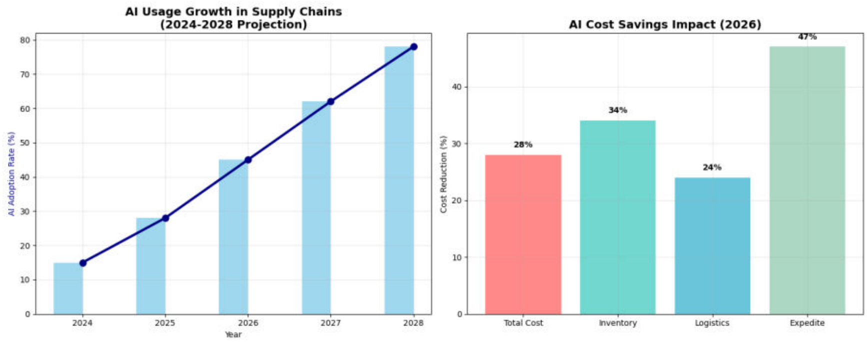

Figure 2: AI Usage Growth & Cost Savings Impact

III. CONCLUSION

Swarms that support the agentic AI will create an infrastructure for fully automated supply chains in Industry 6.0 and will have 99.9 percent autonomy by 2030. Self-coordinating GenAI bot systems will be used to negotiate contracts and find the optimal multimodal routing. The creation of ethical AI frameworks that establish and maintain accountability for critical decisions and detection of bias, and deployment of methods such as SHAP and LIME to provide explanations for AI-generated outcomes will be done in accordance with the European Union's new AI legislation that takes effect in 2026. Sustainability practices will include using carbon-aware routing and digitally tracking recyclables on the blockchain; significant reductions in CO2 emissions will be accomplished by the Agentic AI. To stay competitive, supply chain executives need to act promptly to utilize the following Gartner SCOR models for conducting audits; pilot AI to pilot the highest ROI opportunities; create centers of excellence where talent can collaborate and innovate on solutions; and lastly, eliminate task redundancies by automating operations through multi-cloud Lakehouses. For businesses to build a framework that carries out their operations and utilizes those operations to generate strategic growth potential, it is critical that they measure their results. By using unified supply chain intelligence, organizations can eliminate traditional silos that interfere with the performance of their people and the systems via which they operate. Organizations will benefit from lower costs, higher levels of on-time-in-full performance, and greater levels of resiliency when they utilize AI technology to adapt and sustain supply networks within an increasingly volatile world.

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