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Modern Supply Chain: Unleashing the Power of Data and Technology

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Abstract *- The modern supply chain is a dynamic, resilient, and sustainable ecosystem characterized by real-time visibility, data-driven decision-making, increased agility, and a focus on long-term value creation. It is the backbone of global trade, driving economic growth and shaping a more connected and responsible world. The convergence of technology, globalization, and sustainability is transforming supply chains to meet the demands of the modern business environment. Modern enterprise data warehouses, powered by cloud-based platforms, provide a central repository for organized and well-curated data from various sources to power analytics and AI/ML use cases such as real-time inventory visibility, supplier risk modeling, sustainable sourcing, and demand sensing based on marketing and weather data. By leveraging modern technologies and focusing on sustainability, ethical considerations, and global responsibilities, organizations can build resilient and sustainable supply chains that meet the evolving needs of their customers and stakeholders.*

Keywords *- Modern Supply Chain, Machine learning, Supplier risk, Sustainability, Data foundation, Real-time visibility.*

1. Introduction

Throughout history, supply chains have undergone remarkable transformations driven by technological advancements and the evolution of global trade. Initially, organizations focused on optimizing efficiency within their internal operations. Manual processes and limited visibility across the supply chain characterized this phase. Computers subsequently integrated supply chain processes, marking a significant turning point. The introduction of Enterprise Resource Planning (ERP) systems enabled centralized data management, improved inventory control, and enhanced communication among different functional areas.

The advent of the internet era brought about globalization, increased supply chain complexity, and sparked the rise of e-commerce. Globalization introduced the need to manage suppliers and customers across diverse geographies, requiring effective coordination and strategic sourcing. E-commerce introduced new challenges, including rapid order fulfillment, real-time inventory tracking, and seamless customer experience management.

Today, data analytics and Artificial Intelligence (AI) are transforming supply chains in unprecedented ways. Data analytics enables organizations to harness vast amounts of structured and unstructured data to gain insights into supply chain performance, identify inefficiencies, and optimize decision-making. AI technologies, such as machine learning and predictive analytics, further enhance supply chain efficiency by automating tasks, predicting demand, and optimizing inventory levels.

In addition to technological advancements, modern supply chains are increasingly emphasizing sustainability, ethical considerations, and global responsibilities. Organizations are recognizing the importance of minimizing their environmental impact by reducing waste, adopting clean energy and utilizing renewable energy sources. Additionally, they are focusing on ethical sourcing practices, ensuring fair labor standards and promoting social responsibility throughout their supply chains.

The convergence of technology, globalization, and sustainability is transforming supply chains into dynamic, resilient, and sustainable ecosystems. These modern supply chains are characterized by real-time visibility, data-driven decision-making, increased agility, and a focus on long-term value creation. They are the backbone of global trade, driving economic growth and shaping a more connected and responsible world.

This research explores building modern supply chain systems through the integration of data from disparate enterprise systems and external sources, including weather, marketing, Environmental, Social, and Governance (ESG), and real-time logistics data. This data integration aims to

facilitate near real-time decision-making in the supply chain, fostering efficient operations and optimizing logistics processes.

2. Why Every Industry Needs a Modern Supply Chain

In a rapidly changing business environment characterized by evolving customer expectations, globalization, and unforeseen disruptions, industries face the imperative to transform their supply chain operations to maintain competitiveness. Conventional supply chain systems frequently fall short of addressing the demands of the modern business landscape due to their lack of agility, flexibility, and resilience. They continue to rely on outdated batch processing methods, resulting in data that is outdated by the time critical decisions need to be made.

The advent of e-commerce has fundamentally transformed customer purchasing behavior. It offers unparalleled convenience with 24/7 shopping and eliminates geographical limitations, expanding product selection. Customers can easily compare prices and research products, empowering them to make informed decisions. Ultimately, e-commerce has led to heightened customer expectations for fast shipping, easy returns, and tailored experiences across all retail channels.

To remain competitive and satisfy customer demands, various industries, such as manufacturing, healthcare life sciences, retail, and consumer packaging, require updated supply chain systems. These systems must be agile and reactive to real-time market conditions to prevent customer churn.

3. Modern Enterprise Data Warehouse

Businesses often face challenges with data silos, and supply chains are no different. Isolated data pockets within procurement, manufacturing, logistics, and sales hinder visibility. Inconsistent or outdated data across these silos can lead to inefficiencies, stockouts, delays, and ultimately, impact customer satisfaction.

Cloud data warehouses serve as a powerful tool for simplifying and streamlining supply chains. By consolidating supplier data from Supply Chain Management (SCM) systems, Enterprise Resource Planning (ERP) systems and other enterprise sources, cloud data warehouses break down data solos, presenting a unified and comprehensive view.

The scalability of cloud data warehouses is of paramount importance for handling the vast datasets generated by these systems and ensuring secure processing, thereby enabling real-time collaboration across the entire supply chain. Let us take a look at different data sets that power an enterprise data warehouse for modern supply chain analytics.

3.1. ERP Systems

Enterprise Resource Planning (ERP) systems serve as a repository for a wide range of data, including sales orders, product SKUs with inventory levels, supplier details, and purchase orders. This data is critical for understanding product sales patterns and distribution channels and making accurate demand projections.

3.2. Environmental and Social Governance Data

ESG data evaluates a company's sustainability practices and ethics. It plays a crucial role in supply chain management by mitigating risks, attracting investors, enhancing reputation, boosting efficiency, ensuring compliance, and promoting innovation. Dun & Bradstreet, a leading provider of business information, analyze ESG metrics such as environmental impact, labor conditions, and governance. They provide insights into a supplier's financial health, business information, and compliance history. By subscribing to Dun & Bradstreet's data, enterprises can enhance their supply chain decision-making process. This allows companies to make informed choices about their suppliers, ensuring alignment with their ethical sourcing commitments.

3.3. Marketing Data

To bolster product sales, companies launch marketing campaigns across various media channels, with a particular focus on social media platforms like Google Search, YouTube, Facebook, Instagram, TikTok, and many more. Analyzing the data gathered from these campaigns is essential for understanding the dynamic demand for the products. Integrating this data with other datasets in real-time can provide immediate insights into evolving product demand and mitigate risk by streamlining manufacturing and supply chains.

3.4. Weather Data

In supply chain management, accurate demand prediction is crucial, and weather conditions play a vital role. Enterprises can utilize open-source weather data sets, such as the North Oceanic and Atmospheric Administration(NOAA), to enhance their forecasting capabilities. By incorporating weather data into their predictive models, businesses can gain valuable insights and make more informed decisions about product demand.

3.5. Logistics Data

Enterprises adopt different approaches to manage logistics, including operating their own fleet, relying on third-party logistics (3PL) providers, or using a hybrid model combining both. Relevant logistics data is often stored in customers' transport management systems.

Customers can also access third-party data sets like Project44[3]. Through partnerships with fleet owners, these providers offer real-time logistics and emissions information

that can help customers meet their sustainability goals and enhance their supply chain operations.

4. Data Architecture

In today's data-driven world, machine-learning models have become indispensable tools for forecasting and prediction. However, the effectiveness of these models is contingent upon the quality and availability of the data they are trained on. A solid data foundation is crucial in this regard, serving as a central repository for organized and well-curated data collected from diverse sources. This foundation provides a unified view of the data, facilitating seamless access, exploration, and utilization by data scientists and analysts for forecasting purposes. As an example, Google Cloud services are used to build a data architecture, as shown in Figure 1 below. By leveraging these services, organizations can streamline their data management processes to ensure data integrity and consistency

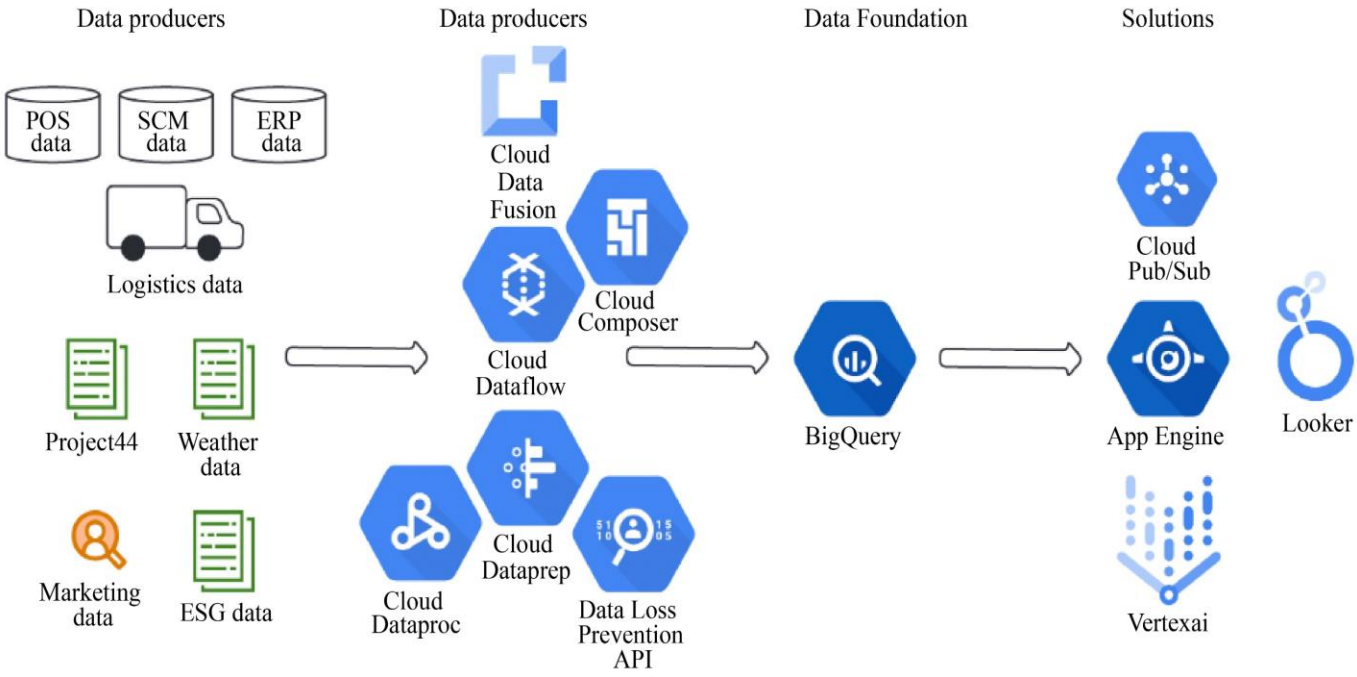

Fig. 1 Data architecture

4.1. Integration Layer

The integration layer, as illustrated in Fig.1, is crucial for data acquisition from diverse data sources. Customers have the flexibility to construct their data pipelines using real-time change data capture facilitated by cloud-native technologies. For customers seeking straightforward solutions, commercial off-the-shelf solutions are available, enabling the efficient extraction and loading of data into a cloud data warehouse.

4.2. Data Foundation Layer

The data foundation layer that sits on top of a cloud data warehouse is a crucial component for enabling effective data modeling. It is composed of carefully curated and structured data from various sources, which facilitates subsequent data modeling or semantic modeling. Semantic models are essentially SQL views that merge data from multiple sources, enriching the contextual information provided. This approach allows for more meaningful analysis and insights to be derived from the data. For example, customers can create an SQL join to map historical sales data from their ERP system with historical weather data. This enables them to identify patterns in the sales of certain SKUs (Stock Keeping Units) that weather conditions may have influenced.

With a well-designed data foundation layer, organizations can easily perform complex data modeling tasks, ensuring that their data is organized in a manner that supports their specific business needs and enables efficient and effective data analysis.

4.3. Solutions Layer

The solution layer in data architecture involves designing and building products for data consumption. This layer focuses on presenting data in a consumable format to end-users through various components such as mobile applications, data visualization tools, AI assistants and reporting tools. These apps enable users to interact with data on their mobile devices and visualize data for better understanding. AI assistants assist users in finding and analyzing data while reporting tools allow the creation of data-based reports.

5. Machine Learning and Analytics with Supply Chain Data

By leveraging a curated data foundation, organizations can create a wide range of analytics use cases that enhance supply chain operations. These use cases significantly boost visibility, enabling real-time, fact-based decision-making, which optimizes supply chain processes.

Moreover, the evolution of cloud platforms has made machine learning capabilities more accessible to businesses. By incorporating data from scalable cloud data warehouse platforms into machine learning models, organizations can substantially augment their forecasting capabilities. Even small improvements in forecast precision can significantly impact revenue by reducing excess inventory, minimizing missed sales opportunities, and enhancing overall supply chain efficiency. It's important to note that the quality of the data directly influences the precision of predictions, customers gain access to real-time data from their ERP with cleaner data yielding more accurate results. Let's take a look at some cross-industry supply chain analytics and machine learning use cases.

5.1. Real-Time Inventory Visibility and Building Obsolescence Engines

By integrating all inventory data into the data foundation, systems enable informed business decisions. Consuming this data into a business intelligence layer allows customers to establish inventory thresholds, ensuring effective monitoring of inventory levels.

With real-time inventory data readily accessible in the data foundation, customers can easily identify aging stock across their various warehouses and formulate data-driven recommendations for price promotions. Leveraging this valuable information, businesses can optimize their inventory management strategies and minimize wastage to enhance sustainability.

5.2. Supplier Risk Modeling

As consumer demand evolves, customers increasingly prioritize working with dependable suppliers. Enterprises can create a supplier risk model that gives their suppliers On-time in-full (OTIF) scores by integrating data from transportation management systems, ERP purchase order data, and third-party logistics providers. This model is based on the suppliers' historical performance in fully fulfilling their orders on time.

When evaluating suppliers, enterprises can look beyond on-time and in-full (OTIF) performance and consider Environmental, Social, and Governance (ESG) factors. Integrating supplier information with ESG data can reveal suppliers who adhere to ethical business practices, minimize environmental impact, and enhance social well-being. This holistic approach enables enterprises to make informed purchasing decisions that align with their values and contribute positively to the community.

By considering both OTIF and ESG factors, enterprises can build a resilient and sustainable supply chain that meets the evolving needs of their customers.

5.3. Sustainable Sourcing

Third-party datasets such as Project44 provide customers with the ability to precisely measure and track the emissions generated by their logistics operations. This granular and accurate data empowers decision-makers to make informed choices that prioritize sustainability. For example, integrating an organization's enterprise data with Project44 data can assist a company's buyer in identifying the most emission-efficient mode of transportation for a particular shipment. This real-time access to information empowers customers to make informed decisions. Customers, for instance, can create a model that provides shipping recommendations grounded in several parameters like optimal transport forms (air, ocean, railway, or road) considering emissions, costs, and urgency, in addition to the most direct route.

With Project44's data, customers gain access to real-time data on emissions associated with their supply chain activities. This transparency allows them to identify areas where they can reduce their environmental impact. Additionally, the data can be used to set meaningful sustainability goals, measure progress, and report on their achievements to stakeholders.

Furthermore, the use of third-party datasets like Project44 enables companies to benchmark their emissions performance against industry standards and peers. This comparative analysis provides valuable insights into areas where improvements can be made. Regular benchmarking also helps companies stay competitive in an increasingly environmentally conscious market.

5.4. Demand Sensing based on Weather Forecasts

By integrating customers' time series sales data from their ERP system and weather data available in the data foundation layer, customers can analyze historical patterns of product demand and make accurate predictions about future demand based on anticipated weather conditions.

As an illustration, a customer in the utility industry who encountered a surge in demand for wooden electric poles during Hurricane Harvey in 2017 could analyze historical data to construct a model for future emergency stock in analogous events. This approach guarantees prompt restoration of services and maintenance of an adequate safety stock inventory.

5.5. Demand Sensing based on Marketing Data

In the competitive realm of retail and consumer packaging goods, businesses commonly launch advertising campaigns to captivate consumers' attention and generate

interest in their products. The primary objective of these campaigns is to attract attention, and their impact is often closely monitored in real-time.

By leveraging historical sales order data in conjunction with real-time marketing data derived from advertising campaigns, companies possess an opportunity to augment their demand-sensing models through the power of machine learning. The insights gleaned from these campaigns hold immense value in comprehending the current inventory landscape, empowering businesses to promptly adapt to potential shifts in demand, thereby optimizing their operations effectively.

5.6. AI Assistants

Generative AI (GenAI) has revolutionized how businesses interact with data, particularly in the retail and supply chain industries. Traditionally, AI has been primarily employed for forecasting and recommendations, but GenAI has introduced new possibilities for data exploration and interaction.

One key application of GenAI is the creation of interactive AI-powered virtual agents, which enable seamless and efficient data interaction. Procurement teams can engage in natural language conversations with these virtual agents for accurate and informative responses that greatly enhance decision-making processes.

The emergence of GenAI has reinforced the importance of a solid data foundation as it uses high-quality and well-structured data to generate meaningful and accurate outputs.

6. Conclusion

In conclusion, the legacy supply chain process lacks the real-time visibility, data-driven decision-making, and long-term value creation focus that characterize modern supply chains. It is characterized by manual processes, paper-based documentation, and limited visibility into the flow of goods and information.

This leads to inefficiencies, higher costs, and a lack of agility in responding to market demands. Modern supply chains, on the other hand, leverage technology to improve visibility, streamline processes, and optimize decision-making. They are characterized by real-time tracking of goods, automated data capture, and advanced analytics, which enable better planning and forecasting. This results in improved customer service, reduced costs, and increased agility in adapting to changing market conditions.

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