

## Predictive Analytics in Supply Chain

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### ABSTRACT

Predictive analytics is a sophisticated branch of advanced analytics that leverages historical data, statistical algorithms, and machine learning techniques to forecast future outcomes. It uses historical data and statistical models to forecast what will happen next so that you can act before a problem arrives, not after. It does not predict the future but tries to assess, using probability theories, what is likely to happen based on trends and patterns revealed by studying historical data. Predictive analytics in the supply chain refers to the use of data, statistical algorithms, and machine learning techniques to forecast future events and trends within the supply chain. It uses data to forecast what will happen so you can make smarter decisions about inventory, shipping, and risk. It analyzes historical data and then predicts inventory levels, demand, supplier performance, transportation logistics, and other critical factors. Using predictive analytics in supply chain can indeed increase profits and provide several compelling reasons to do so. This paper aims to explore the role of predictive analytics in supply chain management.

**KEYWORDS:** *data, data analytics, predictive analytics, supply chain, supply chain analytics, supply chain management, supply chain predictive analytics, artificial intelligence.*

### INTRODUCTION

The global supply chain landscape is undergoing a profound transformation, driven by an increasing need for resilience, efficiency, and responsiveness. At the forefront of this evolution is predictive analytics, a powerful capability that leverages data, statistical algorithms, and machine learning techniques to identify the likelihood of future outcomes based on historical data. Predictive analytics, when combined with artificial intelligence (AI), is set to redefine how supply chains operate, shifting them from reactive to proactive and even prescriptive models.

In the modern global economy, the supply chain is no longer a back-office function but a primary driver of competitive advantage and corporate resilience. The transition from reactive to proactive management has been accelerated by the integration of predictive analytics. Predictive analytics has emerged as a key success factor in supply chain management, using historical data and machine-learning to turn uncertainty into actionable insights. This forward-looking capability allows businesses to make

proactive, data-driven decisions rather than reactive ones [1].

Think of predictive analytics as your supply chain's weather forecast. Just as meteorologists use past weather data and current conditions to predict storms, predictive analytics uses your sales, inventory, and supplier data to predict what is coming next. Industries like retail, manufacturing, pharmaceuticals, and consumer packaged goods rely heavily on predictive analytics because their margins depend on getting supply and demand right. Predictive analytics in supply chain works by collecting and analyzing large amounts of historical data from various sources such as sales, inventory levels, weather patterns, and supplier performance. It helps operations leaders forecast demand, spot risks, and optimize inventory by analyzing historical and real time data. It uses past and current data to forecast demand, spot risks, and improve planning [2]. By using predictive analytics in the supply chain, organizations can optimize their supply chain operations, reduce costs, improve

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efficiency, and enhance overall decision-making, ultimately leading to a more agile and responsive supply chain.

### WHAT IS PREDICTIVE ANALYTICS?

As its name implies, predictive analytics is about predicting future trends such as sales demand, exchange rates, and other important metrics. The technique relies on the application of statistical modeling and regression analysis to historical data to determine and understand trends and formulate future trends. Strictly speaking, predictive analytics does not predict the future, but rather use probability theories to determine what is likely to happen based on patterns and trends revealed by analyzing historical data [3]. Predictive analytics accurately anticipates customer demand, preventing overstocking and stockouts while adapting to market changes. Figure 1 illustrates predictive analytics [4], while Figure 2 shows different components of predictive analytics [5].

In general, analytics provides an efficient way to improve planning because it gives you better forecasts. There are different types of data analytics. They are briefly explained as follows [6]:

- *Descriptive Analytics:* Descriptive analytics examines what has happened over the years. They are capable of detecting trends in historical data. Analytics can uncover trends and postulate probable reasons for change by comparing the same data from various periods. It can be seen as the baseline of the industry, which basically assesses past and current data for more meaningful insights and delivers it to the people to use their own intelligence and knowledge to make decisions.
- *Predictive Analytics:* This assists businesses in predicting what might happen and the impact of various situations, such as possible supply chain bottlenecks. Managers can be proactive rather than responsive by pushing them to evaluate these prospective circumstances before they occur. Predictive analytics may be used to identify patterns and trends as well as anticipate breakdowns that may impact suppliers and, consequently, production processes. Predictive analytics for the supply chain leverages data, statistical algorithms, and machine learning techniques to identify the likelihood of future outcomes.
- *Prescriptive Analytics:* Prescriptive analytics builds on predictive analytics and dives deeper into predicting future insights on what next can be done. Prescriptive analytics uses the findings of

descriptive and predictive analytics to recommend what measures a business should take to achieve its objectives. Because prescriptive analytics is increasingly complicated, they need more powerful software capable of rapidly processing and interpreting large amounts of data.

- *Cognitive Analytics:* Cognitive analytics attempts to mimic human thought and behavior, and they can assist companies in answering challenging, complex problems. Cognitive analytics does this by utilizing artificial intelligence (AI), which allows it to be better over time. With the use of AI in the industry, answering complex questions and drawing out contextual conclusions on how humans would have interacted with the situation. It helps with more meaningful data and scale experience and knowledge with better decisions.
- *Diagnostics Analytics:* This gives the ability to identify the root-cause. It is characterized by techniques such as drill-down, data discovery, data mining, and correlations. It involves analyzing overall performance and figuring out why errors, mistakes, and delays occur. It lets the manager know the delays, breakdowns, and disruptions in the demand and supply processes and the reasons behind them.

Figure 3 shows these major types of data analytics [7]. Unlike diagnostic and descriptive analytics, which were designed to analyze situations after they happened, predictive analytics utilizes advanced data analytics techniques to forecast future outcomes. In the supply chain, the time has come to shift from mere descriptive and diagnostic analytics to predictive and prescriptive analytics. Predictive analytics is a branch of data analytics that makes predictions about future outcomes using historical data combined with statistical modeling, data mining techniques, and machine learning. Figure 4 shows predictive analytics process [8].

### PREDICTIVE ANALYTICS IN SUPPLY CHAIN

In today's dynamic business environment, supply chain management (SCM) has become increasingly complex due to globalization, fluctuating consumer demand, and unpredictable market trends. To address these challenges, organizations are turning to predictive analytics powered by artificial intelligence (AI) and machine learning (ML) to enhance demand forecasting. Predictive analytics is a process that connects your existing systems, cleans up your data, and uses statistical models to help you make better decisions. Predictive analytics in supply chain helps you move from reactive to proactive. By leveraging historical data, machine learning (ML), and real-time market signals, organizations aim to anticipate

demand shifts, optimize inventory, and mitigate risks before they manifest. The integration of AI-driven predictive analytics in SCM enables businesses to make data-informed decisions, mitigating risks associated with demand variability [9].

For decades, supply chain planning has been a backward-looking exercise, heavily reliant on spreadsheets and periodic updates. These traditional methods are reactive, often struggling to keep pace with the fast-moving, data-driven supply chains. Globalization, ecommerce, and increased customer expectations have introduced new levels of complexity. The limitations of traditional planning are evident: static forecasts, typically updated monthly or quarterly, simply cannot keep up with the rapid pace of change. Predictive analytics is changing how organizations plan, operate, and compete in real time. It is fundamentally different because it is forward-looking and continuous [10]. AI-driven predictive analytics helps supply chain managers spot early warning signals from global news, weather, trade, and supplier performance, which is not possible with traditional ways of managing supply chains.

Supply chain predictive analytics uses historical data, real-time inputs, and predictive models to help companies plan better and act faster. It allows teams to analyze historical data, track current activity, and respond quickly to changing supply chain challenges. It helps supply chain managers spot problems before they happen and make informed choices backed by data. It also helps companies navigate uncertainty, reduce waste, and make better decisions using real-time data and intelligent forecasting. By applying predictive analytics in supply, teams improve supply chain management, cut delays, and align with future trends [11]. Figure 5 shows some supply chain workers [10], while Figure 6 shows a representation of supply chain [12].

## APPLICATIONS OF PREDICTIVE ANALYTICS IN SUPPLY CHAIN

Predictive analytics enables supply chain professionals to improve several aspects such as logistics, predictive maintenance, demand forecast, pricing strategies, and inventory management. By leveraging predictive analytics, organizations can anticipate disruptions, optimize resources, and enhance their overall supply chain performance. Figure 7 shows some use cases of predictive analytics in supply chains [13]. Common applications include the following [1,13-17]:

➤ *Demand Forecasting:* One of the most impactful applications is in demand forecasting. Accurate demand forecasting is a key component of an efficient supply chain. Traditional forecasting

methods often struggle with the inherent complexities and external variables influencing customer demand. Predictive analytics, however, can integrate a vast array of data points-including historical sales, promotional activities, economic indicators, weather patterns, and even social media sentiment-to generate highly accurate demand predictions. By forecasting demand more accurately, you avoid tying up cash in excess stock. Accurate demand forecasting relies on strong predictive models and clean supply chain data. These tools help companies track customer demand shifts and seasonal cycles. Each company forecast requirements differently, with different time horizons, but the ones that use predictive analytics are one step ahead.

➤ *Inventory Management:* Supply chain managers, by using predictive analytics, can determine the optimal level of inventory to meet the demand at reduced costs for each location. Building on accurate demand forecasts, predictive analytics allows for dynamic inventory management. Instead of static safety stock levels, businesses can use predictive models to determine optimal inventory quantities, anticipate potential obsolescence, and prepare for periods of high demand. This optimization reduces carrying costs, minimizes waste, and ensures product availability when and where it is needed. Figure 8 shows a typical warehouse [17].

➤ *Inventory Optimization:* One of the biggest challenges for businesses is maintaining optimal inventory levels. Predictive analytics algorithms use AI to analyze historical sales, seasonal trends, supplier lead times, and disruption signals, which helps real-time adjustment of reorder points and stock allocations. For example, Walmart uses predictive analytics to optimize store-level inventory, which cuts excess stock and reduces stockouts.

➤ *Price Optimization:* Manufacturers can use advanced analytics in adjusting the pricing as per the market demand. Machine learning algorithms go through a myriad of data points ranging from location to product attributes to make accurate price predictions.

➤ *Risk Management:* The ability to foresee potential disruptions is a game-changer for supply chain resilience. Predictive analytics can help you identify and mitigate supply chain risks, such as disruptions or fluctuations in demand. By minimizing the impact of unexpected events, you can maintain consistent profitability. By analyzing historical data on supplier performance,

transportation routes, geopolitical events, and even natural disaster patterns, predictive analytics can identify high-risk areas and potential points of failure before they materialize. This allows organizations to proactively implement mitigation strategies, such as diversifying their supplier base or rerouting shipments, thereby minimizing the impact of unforeseen events.

- *Predictive Maintenance*: Businesses are using predictive maintenance to improve supply chain efficiency and maximize equipment uptime. Beyond the flow of goods, predictive analytics extends to the maintenance of critical assets. Machine learning and AI-based predictive analytics process IoT sensor readings, usage patterns, and historical maintenance data to forecast equipment wear. By analyzing sensor data from machinery in warehouses, manufacturing plants, or transport fleets, predictive models can forecast equipment failures before they occur. This enables proactive maintenance, reducing costly downtime, extending asset lifespan, and ensuring continuous operational flow. For example, General Motors uses predictive maintenance in its factories by analyzing IoT sensor data, which helps them reduce unplanned downtime by up to 20% while extending the lifespan of assembly-line equipment.
- *Market Volatility*: In an era of increasing volatility, traditional supply chain planning methods are increasingly being outpaced by the complexities and speed of modern predictive logistics. Predictive analytics relies on the assumption that the future will, in some way, resemble the past. However, we live in an era of unprecedented volatility. Geopolitical shifts, climate-related disasters, and global health crises—often termed "Black Swan" events—do not follow historical patterns. Geopolitical events, raw material shortages, climate volatility, and demand swings that used to happen once a decade now happen every year. Predictive supply chain analytics is the only way to manage today's extreme volatility and global risks.
- *Disruption Management*: Predictive analytics in supply chain helps managers by detecting disruptions earlier, tightening forecasts, and making proactive decisions. It enables you to identify and address potential disruptions in your supply chain proactively. This minimizes downtime, delays, and unexpected costs, ensuring smoother operations and ultimately higher profits
- *Last-mile Delivery*: The last-mile delivery option is a key area in supply chain where predictive analytics can have a huge impact. Carbon dioxide emissions from freight transportation account for 30% of carbon emissions from fuel combustion. Using predictive analytics in supply chain areas like route optimization, anticipatory shipping, robotics, and quantifiable improvements can be made in last-mile delivery.
- *Supply Chain Visibility*: Service providers can use predictive analytics in the supply chain process to avoid late shipments by monitoring devices. It will improve the visibility of shipment status and location and eliminates costs related to late or off-schedule shipments. For example, Apple is using forecasting capabilities to establish real-time visibility into demand patterns and anticipate online orders of products iPhone and Apple watches to prevent delayed shipments.
- *Logistics*: Efficient transportation is the cornerstone of any successful supply chain. As transport costs represent a significant portion of the final product price, predictive analytics enable to know the frequency and quantity of transport needed to meet with demand while minimizing costs. Fastest routes according to traffic, distance, weather and delivery point can be known. One of the prominent examples of predictive analytics in supply chains is Walmart, which uses data-driven route planning to cut down on unnecessary mileage and lower its carbon footprint. Figure 9 is a representation of logistics [18].
- *Fraud Detection*: Fraud detection and quality monitoring are critical to maintaining trust and efficiency in the supply chain. Predictive supply chain instruments monitor various data points - from sensor readings on shipments to supplier performance metrics - to identify unusual patterns that may indicate fraud or performance issues. By catching these anomalies early, companies can address potential problems before they escalate into expensive errors.
- *Capacity Planning*: Capacity planning is a critical aspect of supply chain management. It involves determining the optimal level of resources required to meet future demand. With the ability to analyze historical data and identify patterns, predictive analytics can help with accurate demand forecasts, allowing supply chain professionals to make informed decisions about production levels, staffing, and resource allocation.

## BENEFITS

The adoption of predictive analytics in supply chain management translates into several benefits. Supply chain predictive analytics helps companies navigate uncertainty, reduce waste, and make better decisions. By applying predictive analytics in supply chain, teams improve supply chain management, cut delays, and align with future trends. For organizations that bridge the gap between data and decision-making, the benefits are substantial: a more resilient, efficient, and sustainable supply chain capable of thriving in an increasingly unpredictable world. Other benefits of predictive analytics in supply chain include the following [2,16]:

- *Cost Reduction:* Predictive analytics can help optimize inventory levels, reduce transportation costs, and minimize production downtime. You can lower operating expenses and increase overall profitability. Predictive tools eliminate guesswork in day-to-day planning. Fewer delays, faster routing, and better data availability lower transportation costs and streamline workflows. By minimizing costs, companies can reallocate savings toward strategic improvements and meet budget goals more consistently. In procurement, warehousing, and transport, manual reviews often overlook hidden costs like excess safety stock, underutilized fleet capacity, or inefficient supplier contracts, which drain resources over time.
- *Waste Reduction:* Enhanced quality control and production process optimization can reduce waste and product defects. This not only lowers production costs but also enhances your reputation for quality, potentially attracting more customers and increasing profits.
- *Lower Inventory Costs:* Predictive analytics helps you order only what you will actually sell. By predicting what you will actually sell, you avoid tying up cash in excess stock. You need reliable supplier lead times and up to date inventory counts, or you will still end up with too much or too little. By forecasting demand more accurately, you avoid tying up cash in excess stock. This works if your sales and inventory data are updated at least weekly and your team trusts the forecasts enough to act on them.
- *Proactive Decision-making:* Proactive decision-making is essential in today's and tomorrow's fast-paced supply chain planning environment. By identifying potential risks early, organizations can take preventive measures to mitigate their impact. Predictive analytics empowers planners with the tools and insights needed to make smarter decisions, faster. It gives your planners and buyers data driven recommendations. This speeds up planning cycles and reduces second guessing. However, this only works if your team is trained to interpret and trust the model's output.
- *Better Risk Management:* Risk prediction models look for signs of trouble like supplier delays, transport bottlenecks, or quality issues. They use historical incident data, supplier performance, and sometimes external data like weather or geopolitical events. By spotting likely disruptions, like supplier delays or demand spikes, you can act before problems hit. This only works if you have real time or near real time data from your suppliers and logistics partners
- *Improved Customer Service:* Better demand forecasting and inventory management result in improved product availability and on-time deliveries. This enhances customer satisfaction, potentially leading to increased sales, customer loyalty, and positive word-of-mouth, which can boost profits. Stronger predictions lead to faster deliveries, accurate order fulfillment, and fewer delays. With fewer stockouts and better order fill rates, customers get what they want more often. But if your logistics partners cannot deliver reliably, even the best forecast cannot fix service gaps.
- *Enhanced Customer Satisfaction:* Faster, more reliable deliveries make customers happier. Predictive analytics in transportation aims to determine demand spikes, manage delays, and maintain optimal inventory levels. Improved last-mile delivery routes contribute to minimized disruptions, which, in turn, will help you meet tight service-level agreements and provide a seamless customer experience.
- *Efficient Operations:* Predictive analytics can help you schedule labor and shipments more precisely, cutting overtime and rush shipping. This requires close coordination between planning, operations, and logistics teams, which is not always easy.
- *Smooth Supply Chain:* Predictive analytics enables you to identify and address potential disruptions in your supply chain proactively. By doing so, you minimize production downtime, avoid unexpected costs, and ensure a consistent flow of materials for your manufacturing process. This results in smoother operations and higher profitability for your company.
- *Adaptability:* Predictive analytics allows you to adapt quickly to emerging trends and market

shifts. This adaptability can lead to seizing new opportunities and optimizing profitability.

- *Personalization*: Predictive analytics enables continuous analysis of customer data, enabling advanced personalization capabilities. In today's increasingly competitive e-commerce environment, personalization is one of the key differentiators. Consumers are more likely to make a purchase when brands offer a personalized experience.

## CHALLENGES

While the benefits are clear, implementing predictive analytics is not without its challenges, which can limit success without the right strategies in place. In an increasingly complex and volatile global economy, supply chain management faces unprecedented challenges. Challenges such as data quality, model interpretability, and implementation costs remain critical considerations. Other challenges of predictive analytics in supply chain include the following [1,11,18]:

- *Data Quality*: The efficacy of any predictive model is inextricably linked to the quality of the data it consumes. If your data is not accurate, your forecasts will be wrong and so will your decisions. In supply chain management, data is often generated across a disparate ecosystem of systems, warehouse management tools, and external logistics providers. Many organizations struggle with fragmented, incomplete, or inaccurate historical data, which can compromise the reliability of predictive models. The biggest risk is trusting predictions built on bad or incomplete data. Costs rise quickly when your data is messy, you have lots of systems, or you need custom integrations. Clean data and fewer platforms keep costs down.
- *Data Privacy*: Protecting sensitive data and ensuring compliance with data governance policies and regulations can become a significant challenge when implementing predictive analytics in supply chain management. For example, you often need to encrypt data to safeguard it from unauthorized access.
- *Skills Gap*: Implementing predictive analytics requires a unique intersection of skills: deep domain expertise in supply chain operations and advanced proficiency in data science. There is a significant demand for skilled data scientists, machine learning engineers, and domain experts who can develop, deploy, and manage these sophisticated systems. The scarcity of professionals who can "speak both languages"

remains one of the most significant barriers to successful adoption.

- *Integration*: Integrating predictive analytics into any existing supply chain involves several challenges and considerations. Old, legacy systems do not always connect well with modern analytics tools. Many global supply chains are still anchored by legacy systems designed decades ago for record-keeping, not for high-velocity data analytics. These systems often lack the connectivity and processing power required to support real-time predictive engines. Successfully integrating predictive insights into daily operational workflows and ensuring adoption by business teams requires careful planning and change management.
- *Resistance*: Overcoming resistance to change within the organization and gaining buy-in from stakeholders is challenging for any significant system upgrade. And the implementation of predictive analytics is no exception. As a company, you must push for effective communication, training, and education to ensure employees understand the value and use of predictive analytics.
- *Interpretability*: Supply chain managers must understand why a model recommends specific reorder points, shipment schedules, or supplier selections. Modern machine learning models, particularly deep learning architectures, are often criticized for being "black boxes." While they may provide highly accurate predictions, they rarely explain the why behind them. For a supply chain executive responsible for millions of dollars in inventory, following a recommendation without understanding the underlying logic is a high-risk proposition. This lack of interpretability leads to a "trust deficit," where human planners revert to manual overrides or ignore the model's suggestions entirely, rendering the investment in analytics moot. Favor interpretable algorithms and provide contextual insights to support informed decision-making and stakeholder trust.
- *Over-reliance on Technology*: Data can guide decisions, but human oversight remains essential. Teams must use experience, context, and logic to verify results. Blind trust in algorithms without checks can lead to mistakes. Supply chain managers should validate model outputs using real-world experience and operational input.

Figure 10 shows some challenges of predictive analytics in supply chains [13].

## FUTURE OF PREDICTIVE ANALYTICS IN SUPPLY CHAIN

Predictive analytics is improving the efficiency of supply chain processes by collecting and analyzing data for better decision-making. Predictive models are not static. You need to retrain them as business conditions change, or as you get more data. The landscape of predictive analytics continues to shift toward even greater integration and autonomy. AI has become a necessity for predictive analytics in the logistics industry. As organizations increasingly embrace AI-driven solutions, understanding their impact on supply chain performance becomes crucial for sustaining competitive advantage.

The future of predictive analytics in supply chain management is bright, promising a landscape of unprecedented efficiency, resilience, and strategic advantage. By embracing AI-driven forecasting, unified data models, and autonomous decision-making, organizations can move beyond merely reacting to disruptions and instead proactively shape their future. The journey requires a clear vision, robust data strategies, and a commitment to change, but the rewards—in terms of optimized operations, reduced costs, and enhanced customer satisfaction—are substantial [1].

## CONCLUSION

Predictive analytics is no longer a futuristic concept but a present-day imperative for competitive supply chain management. In the contemporary global economy, predictive analytics has transitioned from a competitive advantage to a fundamental necessity for supply chain resilience. Predictive analytics holds the key to a more agile and responsive supply chain, but it is not a “plug-and-play” solution. Predictive analytics is reshaping the landscape of supply chain management. Organizations that continue to rely on traditional, static planning methods will struggle to keep pace with the demands of modern logistics analytics.

There is a strong believe among companies that predictive analytics has the potential to completely transform the supply chain. Its introduction is helping logistics and supply chain companies meet increasing demands. Investing in a predictive analytics solution might no longer be an option; it has become a necessity to maintain competitiveness with other players that have still embraced this solution. More information on the use predictive analytics in supply chain is available from the books in [19-23].

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Figure 1 Predictive analytics [4].



Figure 2 Different components of predictive analytics [5].

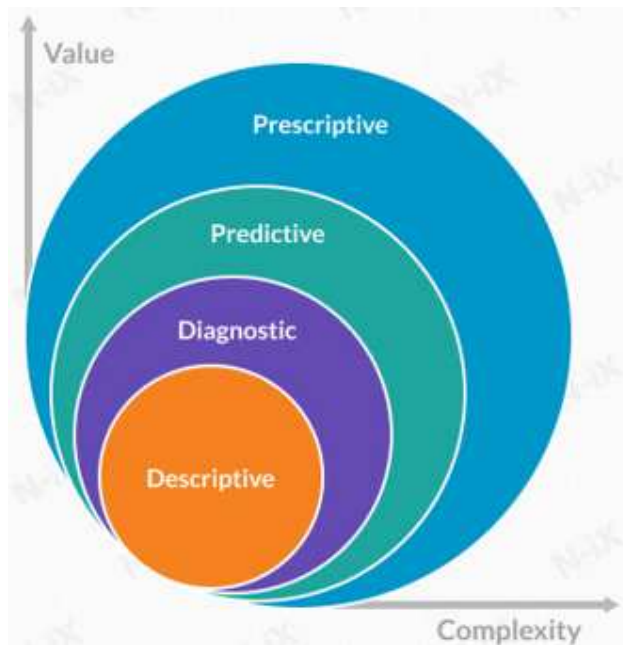


Figure 3 Types of data analytics [7].



Figure 4 Predictive analytics process [8].



Figure 5 Some supply chain workers [10].



Figure 6 A representation of supply chain [12].



Figure 7 Some use cases of predictive analytics in supply chains [13].



Figure 8 A typical warehouse [17].



**Figure 9** A representation of logistics [18].



**Figure 10** Some challenges of predictive analytics in supply chains [13].