International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Application of Large Language Models (LLM's) for Supply Chain Optimization

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Abstract

In today's interconnected and rapidly evolving global marketplace, businesses are constantly seeking innovative strategies to optimise their supply chains and gain a competitive edge. The rise of large language models (LLMs) and generative artificial intelligence (GenAI) presents a paradigm shift in supply chain management, offering powerful tools to identify and address inefficiencies that may otherwise go undetected.

Supply chain operations traditionally involve a variety of complex decision-making problems. Over the past few decades, advances in information technologies have allowed firms working to optimize their supply chains to move from decision-making on the basis of intuition and experience to more automated and data-driven methods, which has increased efficiency and reduced costs. Unfortunately, business planners and executives still need to expend considerable effort to understand the recommendations coming out of their systems, analyze various scenarios, and conduct what-if analyses. They often need to pull in data science teams or technology providers to explain results or make updates to the system. Now, advances in large language models (LLMs), a type of generative AI, are increasingly making it possible to perform those activities without such support. LLM-based technology can automate data discovery, insight generation, and scenario analysis, reducing the time to make decisions from days to minutes and dramatically increasing planners' and executives' productivity and impact.

The insights garnered from this white paper will help both researchers and managers, equipping them to harness the latest advancements in LLM technology and its role within supply chain management.

Problem Statement

Companies face a variety of complex challenges in designing and optimizing their supply chains, since it contains multiple tiers of suppliers, customers and service providers. Increasing their resilience, reducing costs, and improving the quality of their planning are just a few of them. Over the past few decades, advances in information technologies have allowed firms to move from decision-making on the basis of intuition and experience to more automated and data-driven methods. Optimization tools have been widely utilized for decision making in such supply chains. As a result, businesses have seen efficiency gains, substantial cost reductions, and improved customer service.

But, unfortunately business planners and executives still need to spend considerable time and effort to understand the recommendations coming out of these optimization systems, analyse various scenarios, and conduct what-if analyses. In many cases, the operators, planners and executives are not equipped with the necessary background in optimization, resulting in time-consuming back-and-forth interactions with program managers, data scientists and engineers.

In addition to the above, updating the supply-chain-management tools' mathematical models to reflect changes in the business environment is time-consuming as well.

Finally, modern supply chain's must leverage big data analytics, including data science and big data, to enhance the supply chain's processes and performance. However, data quality remains paramount for effective decision-making in supply chain management (SCM), which emphasizes the significance of functional capabilities, information sharing, and data proficiency. The successful management of operations and the supply chain hinges on a data-centric approach, which has evolved from traditional reporting to advanced analytics that encompasses statistical analysis, forecasting, and real-time optimization.

Proposed Solution

Large language models (LLMs), a type of generative AI, is now making it possible for the business planners and executives to perform planning and decision making activities seamlessly in much reduced time, from days and weeks to minutes and hours and dramatically increasing planners' and executives' productivity and impact. LLM's are helping to generate insights from data that will give executives a better understanding of the state of their supply chains, answer what-if questions, and update supply-chain-management tools in order to take into account the current business environment.

An LLM allows planners to ask detailed questions. Here are a few examples: "What would be the additional transportation cost if overall product demand increased by 15%?" "What would be the additional procurement cost if retailer R uses products only from factory F?" "Can we fulfill all demand if we shut down factory F?" "How much would the total cost of producing product P be reduced if the cost of type M raw material were $1 less per unit?" (Refer-Figure-1)

LLM can answer questions accurately and efficiently, by optimizing many tasks which are written in the form of mathematical programs, which takes into account the structure of the supply chain and all the business requirements and generate effective supply chain recommendations. An LLM doesn't replace the mathematical model; rather, it complements it. Specifically, it translates a human query into a mathematical code that is a small change to the original mathematical model used to produce the plan.

For example, mandating that a retailer use products from a particular factory can be done by adding a mathematical requirement, or "constraint," that prohibits other factories from sending products to that retailer. This small change in the mathematical model is then fed to the supply chain tool to produce a modified plan, which is used only for comparison with the existing one. As before, the output of the new mathematical model is then passed through the LLM to produce the answer in human language.

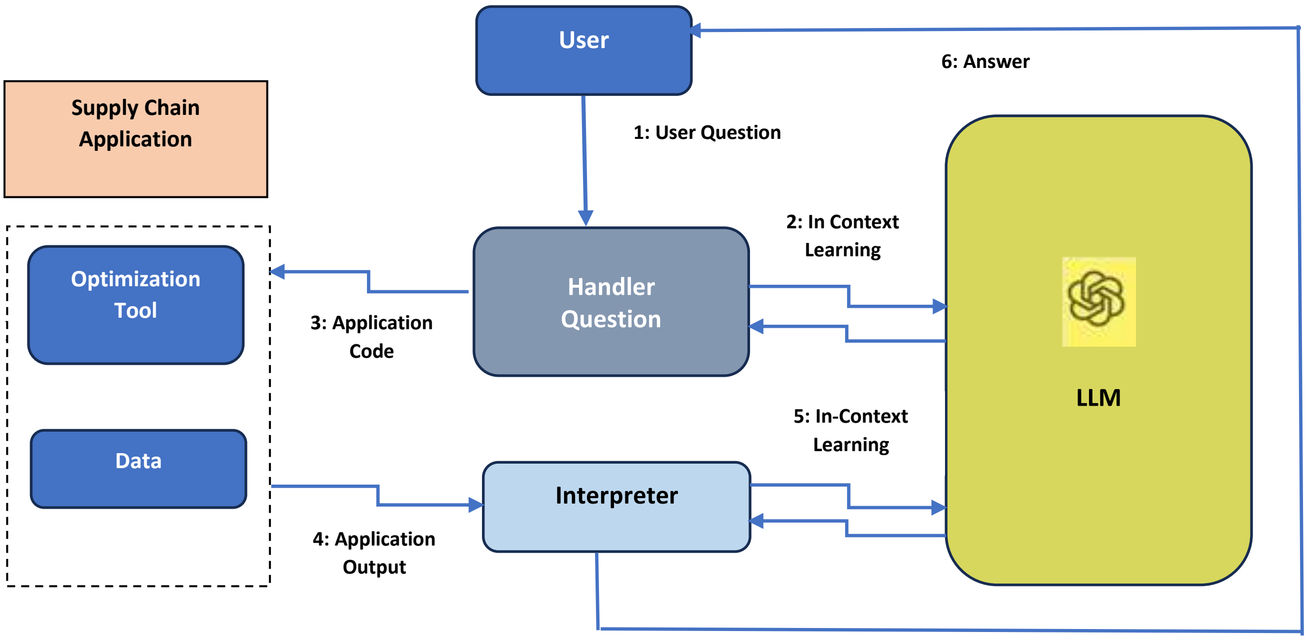

Figure-1

Apart from, providing answers to supply chain strategic and business queries using company's data repositories in SQL databases, LLM's can also retrieve data from unstructured data sources.

Example below highlighting how LLM technology can be used for retrieving trend data from unstructured data sources like social media, industrial reports and forums to generate demand forecasts as part of demand planning exercise, which [illegible]ning optimization tools.

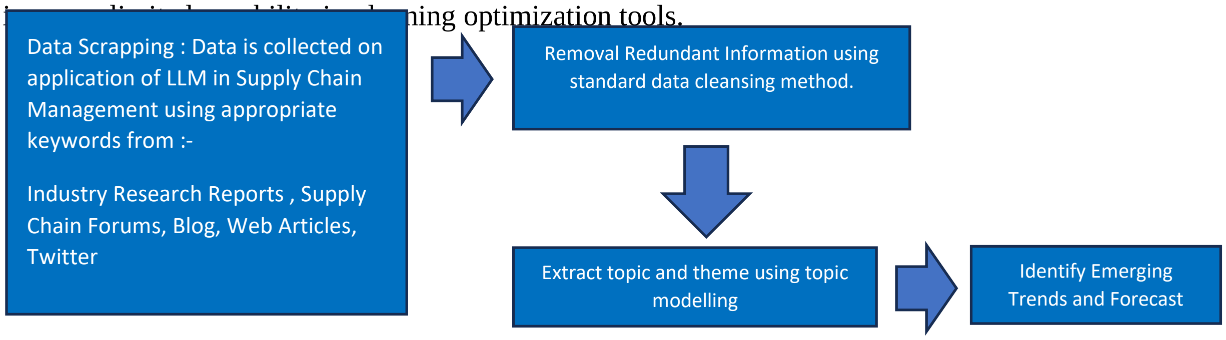

Figure -2

Figure-2

The ADO (Antecedent, Decision, Outcome) paradigm offers a formal framework for LLM-enabled supply chain optimization including antecedents (inputs) like data sources, which include internal repositories that contains inventory data, order records, supplier information and others.

In the decision-making phase of the ADO framework for LLM enabled supply chain optimization, choosing the right LLM, its configuration and implementation plays a crucial role. This leads to efficient analysis of supply chain data pertaining to specific optimization goal. Further selecting the appropriate data sources, frequency of collection and consolidation are included in the decision-making process.

The output phase of the ADO framework assesses the impact of the supply chain optimization system. This phase evaluates the efficiency of the various optimization processes such as the accuracy of the demand forecasting system, optimized transportation and logistics process, and real-time decision support system.

Figure -3

The above outcomes, leads to an effective LLM-enabled supply chain optimization system aligned to organizational goals and objectives.

Business Outcome

- **Improves Forecasting and Demand Planning**: LLMs can analyze historical sales data, weather patterns, and market trends to generate accurate demand forecasts. This enables businesses to optimize inventory levels, reduce stockouts, and minimize costs. It can help greatly in the Sales & Operation Planning (S&OP) process of supply chain management. Research suggests LLM augmented forecasting can lead to a significant improvement of around **24% to 28%** in prediction accuracy compared to traditional methods.
- **Enhanced Inventory Management:** LLMs can identify trends in product movement and predict future demand, allowing businesses to optimize inventory placement, reduce storage costs, and minimize the risk of obsolescence. Studies suggest a significant positive impact, with potential for reducing inventory costs by **10-20%** and improving inventory accuracy by **5-10%.**
- **Streamlined Transportation and Logistics:** LLMs can analyze traffic patterns, weather conditions, and historical shipment data to optimize transportation routes, reduce delivery times, and minimize fuel consumption.
- **Predictive Maintenance and Equipment Optimization:** LLMs can analyze sensor data and equipment performance metrics to identify potential failures and proactively schedule maintenance, preventing downtime and costly disruptions.

Case Study –

Maersk, one of the world's leading shipping companies, is employing LLMs to enhance its supply chain disruption prediction capabilities. The company utilises a LLM named "Maersk Pulse" to analyse a vast array of data sources, including weather patterns, historical shipment data, and real-time traffic conditions, to identify potential disruptions and predict their impact.

Maersk Pulse's ability to process and understand natural language allows it to extract insights from unstructured data sources, such as social media posts, news articles, and industry reports, which traditional disruption prediction tools often overlook. This comprehensive data analysis enables Maersk to anticipate disruptions early on and proactively implement mitigation strategies to minimise their impact. One of the ways Maersk has applied Maersk Pulse's capabilities is in predicting potential port disruptions.

Maersk Pulse analyses historical port congestion data, weather forecasts, and social media sentiment to identify ports at risk of congestion. This information is then used to optimise shipping routes, adjust inventory levels, and communicate with customers to manage expectations.

Conclusion

LLM-based technology will transform supply chain management in the near future—enhancing its efficiency, resiliency, productivity, and accuracy. It will complement today's supply chain technologies, allowing planners to interact directly with their supply chain tools without the need for data scientists or engineers. Firms will be able to automate a significant number of supply chain processes and even create new ones, such as by integrating the trade and forecasting processes. In next few years, LLM-based technology could truly revolutionize the supply chain management in industries like Retail, Logistics and Consumer Goods.

Appendix

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