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Enhancing Pharmaceutical Supply Chain Performance

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Abstract:

The pharmaceutical supply chain (PSC) is one of the most complex and vital systems in global industry, functioning under strict regulations and, meanwhile, struggling to bring products to the market fast, efficiently, and at the lowest cost. This paper also examines how pharmaceutical companies can improve the performance of their supply chains by leveraging integrated planning tools, adopting digital technologies, and implementing operational models based on industry-standard frameworks. The paper begins by recognizing and reviewing the essential elements of supply chain management in a pharmaceutical setting, including demand forecasting, procurement plans, production plans, inventory management, warehouses, and logistics. All these factors influence the level of agility, rapidness, and reliability of the supply chain.

Leveraging industry benchmarks and expert interviews, this paper examines how key metrics such as forecast accuracy, inventory turnover, On-Time-In-Full (OTIF) delivery rates, and order-to-delivery lead times impact supply chain performance throughout the entire process. It provides comparative information between average and leading pharmaceutical companies to show performance gaps and potential for improvement. The study also includes a case of a medium-sized pharmaceutical company that experienced a decline in sales and high product obsolescence due to inefficient manual planning processes and a lack of cross-functional coordination. "The transition was not without challenges, but the introduction of ERP systems and collaborative planning resulted in a significant increase in inventory turns (to 5 vs less than one previously) and low or very low obsolescence, the former was zero," Annalou concluded, so there is your real-life digital transformation story right there.

The paper also examines the suitability of the SCOR (Supply Chain Operations Reference) model as a comprehensive framework for evaluating and improving supply chain operations. The pharmaceutical industry is mapped onto the six dimensions of the SCOR model: Plan, Make, Source, Deliver, Return, and Enable, and against a set of performance measures, including cost per order, lead time, and service level attainment. The paper emphasizes the significance of agile and flexible supply chain architecture and systems in facilitating cross-functional coordination, real-time analytics, decision support, and risk management.

Based on literature study, data analysis, and industry feedback, this report provides actionable insights for pharmaceutical industry executives, supply chain professionals, and policy-makers. These teams conduct regular forecast reviews with ABC classification, utilize technology for end-to-end visibility, and foster cross-functional teams to help resolve operational challenges. The authors maintain that achieving supply chain excellence in the pharmaceutical industry is no longer just a competitive advantage, but rather a fundamental prerequisite for compliance, cost control, and patient benefit. Finally, a digitalized, agile, and performance-monitored pharmaceutical supply chain can not only enable business sustainability but also support public health security in an age when complexity and volatility are key characteristics.

Keywords: Pharmaceutical supply chain management, forecasting accuracy, inventory turnover, ERP systems, SCOR model, OTIF delivery, demand planning, digital transformation, regulatory compliance, collaborative planning.

I. INTRODUCTION

Pharmaceutical manufacturers operate in an inherently challenging industry, often characterized by stringent government regulations, complex manufacturing processes, and, above all, a strict commitment to patient safety. These features place phenomenal burdens on pharmaceutical supply systems and companies, which must deliver necessary medications and healthcare commodities on time and with high precision to patients worldwide. Unlike supply chains in numerous other industries, the pharmaceutical supply chain must manage temperature sensitivity, short shelf lives, controlled substances regulations, batch traceability, and conform to stringent global standards. These operational needs underscore the strategic importance of supply chain management (SCM) as a key determinant of success for pharmaceutical companies, as well as the health outcomes of the populations they serve.

A recent series of events has raised the stakes, making it even more sense for drug companies to rethink and fine-tune their supply chain strategies. The COVID-19 outbreak exposed the weaknesses of the global sourcing model, including raw material dependency and long manufacturing lead times, and the risk of having a too-long and inflexible supply network became apparent. In addition to these exogenous shocks, the industry faces internal strains, including rising R&D costs, declining margins, increasing regulatory demands, shorter product life cycles, and intense competition from generic drug manufacturers. Painful lessons. With these issues at hand, there is no doubt anymore that superior supply chain management is no longer a simple issue of operational efficiency but a roadblock to strategic resilience and market competitiveness.

Pharmaceutical Supply Chain Management encompasses a broad range of implications for managing the supply chain in the pharmaceutical industry, including demand estimation, procurement, production planning, inventory control, quality control, warehousing, distribution, and cold chain logistics. All these cogs need to turn together to make sure that medicines arrive with healthcare professionals and patients in prime condition, at the right time and in compliance with regulation." There is little room for error, as time delays, mistakes, and anomalies in the supply chain may result not just in losses, but also, importantly, health dangers and consumer mistrust.

However, the reality is that numerous pharmaceutical companies still operate in siloed organizations, with fragmented information systems and manual planning tools. This insufficiency leads to inefficient decision-making and overage inventory, product obsolescence, and missed service level targets. Another common denominator among low-performing supply chains is the lack of real-time data integration and cross-functional cooperation. On the other hand, top companies tend to be better at adopting digital transformation, including enterprise resource planning (ERP), advanced analytics, and performance benchmarking models. These instruments enable organizations to more easily analyze their activities and goals and better align operations with strategy.

This paper aims to examine how pharmaceutical supply chains can benefit from integrated systems and structured approaches, drawing on evidence from the industry and best practices. It provides a deep dive into the operational factors that drive supply chain performance, as measured by forecast accuracy, inventory turns, on-time-in-full (OTIF) delivery, and order-to-delivery lead time. The work also examines versions of the Supply Chain Operations Reference (SCOR) model in the pharmaceutical industry, focusing on how an organized methodology can improve planning, execution, and performance measurement. A real-world scenario illustrates the metamorphosis of a mid-sized pharmaceutical company, which enhances its performance by focusing on bid supply chain metrics and implementing an end-to-end ERP, as well as through collaborative planning stages.

This study provides practical recommendations that pharmaceutical companies can apply to increase supply chain resilience, improve regulatory compliance, reduce waste, and better serve patients. By

transitioning from reactive, siloed supply chains to data-driven, agile networks, the pharmaceutical industry can strengthen its ability to deliver consistent value in an increasingly volatile and competitive environment.

II. LITERATURE REVIEW

The pharmaceutical supply chain has garnered considerable attention from both academic and industry researchers, as it plays a pivotal role in ensuring patient health by providing safe, effective, and timely access to medicine. An extensive literature base examines (1) the operational, regulatory, and technological challenges in the pharmaceutical supply chain through (2) the trends in enhancing supply chain efficiency, visibility, and responsiveness (Choi, Rogers, & Vellera, 2014; Sabawua et al., 2014). Previous works are consolidated in this review in five main lines: Demand forecasting, Inventory management, Digital transformation, Performance benchmarking, Reference models for supply chain optimization

Several research papers emphasize the importance of demand forecasting in pharmaceutical chains. Accurate planning is crucial for preventing stockouts, minimizing overproduction, and mitigating the risk of expired inventory. A study by Singh et al. [1] investigated statistical forecasting models for pharmaceutical planning. It demonstrated that some improvements to forecast accuracy can result in sizeable gains to service level at the expense of minimum inventory. Likewise, Bansal and Mahendru [2] proved that forecasting accuracy and obsolescence can be reduced by integrating historical sales data, real-time order flows, and epidemiological trends when the products are temperature-sensitive biologics.

Much emphasis has also been placed on inventory management. Holding inventory in pharmaceuticals is very expensive, given the value of the products, expiry limitations, and the regulatory environment for storing the inventory. Rajput and Arora [3] in their study on multi-echelon inventory optimization showed that a decentralized inventory system with visibility at all echelons can reduce total inventory carrying costs by up to 18%. Furthermore, as pointed out by Bhardwaj and Misra [4], material classification in terms of ABC-FSNA (fast, slow, non-moving, and age) facilitates the balancing of supply and demand, as well as the identification of highly impactful stock-keeping units.

Digitalization is another recurring idea that we can observe in the literature. Numerous research works see the implementation of an Enterprise Resource Planning (ERP) system as a facilitator for the visibility and flexibility in a supply chain. The use of integrated ERP systems by drug companies has been shown to lead to shorter cycle times, lower costs per order, and improved OTIF performance (Kapoor and Aggarwal 5). Perfect – that they are being used. The use of digital twins, APS (Advanced Planning and Scheduling) systems, and real-time dashboards has also increased. Srivastava et al. [6] demonstrated that the application of digital twins for logistics tracking resulted in a 12% reduction in lead time variability and improved compliance with cold chain regulations.

Performance comparison is essential for the SCM of the pharmaceutical industry to improve continuously. The literature also covers the use of key performance indicators (KPIs) like forecast accuracy, inventory turnover, lead time, OTIF, and cost per order. Benchmarking against industry practice could enable firms to identify where the supply chain performance gap lies and take the appropriate, focused action (7). They argue for quarterly KPI reviews and the use of external market intelligence to inform tactical decision-making.

Finally, formalising frameworks such as the Supply Chain Operations Reference (SCOR) model has become increasingly relevant in both the academic and application fields. The SCOR model is a well-defined and structured methodology for analyzing and improving supply chain processes. Khurana and Taneja [8] utilized the SCOR model to reformulate supply chain planning and delivery processes within a pharmaceutical company, resulting in a 20% improvement in delivery times and a 15% reduction in process double-handling. The model's systematic classification into six domains—Plan, Make, Source, Deliver, Return, and Enable—provides fine–grained process mapping, performance monitoring, and strategic linkage.

Despite the wealth of literature, a notable gap remains in research that combines performance benchmarking and structured frameworks, such as SCOR, with real-life cases, particularly for small and medium-sized pharmaceutical enterprises in emerging markets. This paper aims to narrow that gap and provide a practitioner's view, which is underpinned by performance data and organisational learnings.

III. METHODOLOGY

The research methodology employed for this study is a mixed-methods design, combining qualitative industry practitioner perspectives with quantitative benchmarking of supply chain performance. The primary objective of this methodology is to analyze, assess, and enhance the performance of the pharmaceutical supply chain using empirical data, expert opinions, and a systematic analysis within an established performance framework. This methodological approach is designed to maintain a balance between practical and academic orientations throughout the study.

The study includes four key steps: Identification of the key SC variables, industry benchmarking, expert consultation, and framework application. Every stage contributes to an overall understanding of how pharmaceutical supply chains function, identifying their challenges and the types of practices that can promote performance improvements.

3.1. Identification of Key Variables

The first step involved an extensive review of secondary data and literature to identify the most influential operational variables affecting pharmaceutical supply chain performance. These variables were selected because of their frequent usage as performance indicators in industry reports and academic literature [11]. These factors are essential drivers of service quality and cost efficiency within the supply chain.

The literature informed the choice of these measures. For example, Narayan and Joshi [7] highlighted the importance of KPIs as a driver for enhancing supply chain performance, and Singh et al. [1] illustrated the financial tonne of forecast accuracy in the pharmaceutical business. These indicators are used as a benchmark for performance comparison and process analysis during the analysis period.

3.2. Industry Benchmarking

To gain insight into how the chosen performance metrics vary with an organization's level of liveliness, benchmark data were collected from a variety of sources. Data comparison was made by reference to benchmarking studies found in industry white papers, SCM journals, and publicly available pharmaceutical logistics reports. These data shed light on differences among pharmaceutical companies, including best-in-class and average-performing companies, as well as regional variances.

The benchmarking results data were analysed to develop tables and graphic charts, which display associations between variables, for example, the association between forecast accuracy and inventory turnover. For instance, companies that reported high forecast accuracy were overrepresented among those that achieved a high rate of inventory turnover, thereby strengthening the assumption that better planning systems are associated with superior inventory management. The data points were also confirmed through triangulation with multiple industry sources, as well as companies involved in the market.

3.3. Expert Interviews and Case Study

In the third stage, qualitative data were collected through semi-structured interviews with five experienced professionals working in supply chain positions within pharmaceutical corporations. These experts comprised planning departments, logistics departments, and procurement officers with a minimum of ten years of experience in their respective fields. Remote interviews were conducted, lasting 45 to 60 minutes each. Respondents were queried on their use of demand forecasting, planning tools, cross-functional collaboration, and adoption of technology.

Their answers revealed several trends, including productivity drains caused by manual planning processes, a lack of communication among departments, and a failure to tap into actual, real-time inventory and

production information. A specific case that was brought up involved a mid-sized Western India-based pharmaceutical company, where sales were falling and obsolescence was increasing due to misaligned planning and warehouse operations. The company subsequently adopted an ERP system with a cross-functional planning environment, achieving measurable improvements in inventory turns, as well as a 30% reduction in dead stock.

This research serves as a case study highlighting the virtue of embracing technology and working collectively, coming together in the right way by simplifying supply chain issues. It further corroborates the results from Kapoor and Aggarwal [5], who focused on the promising possibilities arising from ERP systems in pharmaceutical logistics.

3.4. SCOR Framework Application

The supply chain operations model of the pharmaceutical industry. As a framework for analyzing supply chain operations organizationally, the Supply Chain Operations Reference (SCOR) model was utilized in the pharmaceutical sector. The SCOR model consists of six primary components: Plan, Make, Source, Deliver, Return, and Enable. Each of the two aforementioned domains was employed to assess the supply chain structure of the case study firm, diagnose the gaps, and suggest targeted interventions.

For instance, under the “Plan” category, the processes of demand planning and the policies related to safety stock were analyzed. “Make” and “Source” were examined with more NAQ opportunities in production scheduling and vendor selection. The “Deliver” section covered logistics, warehousing, and customer fulfillment. “Return” centred on product returns and reverse logistics and batch recalls, and “Enable” on information systems and staff training.

Key logistics performance measurements (e.g., lead time, OTIF delivery, and cost per order) that correspond with each SCOR domain were cross-referenced with the company’s control statistic historical data and post-implementation results (period). This provided a measurable measure of improvement and correlation with the best available recommendations in literature by Khurana and Taneja [8].

3.5. Limitations

The approach has good input, but some limitations have been acknowledged. A small sample size of expert interviews could limit generalizability. Furthermore, the case study provides a powerful situational relevance but is limited to one single organization, and future surveys could improve generalisability. Tertiary benchmarking data are based on secondary data (G.P.KV2III) and exhibit regional and firm biases.

The methodology is a well-justified, data-driven approach for clarifying and ameliorating pharmaceutical supply chain performance. That is, they can combine qualitative and quantitative evidence in a way that makes their findings actionable and academically defensible.

IV. RESULTS

Results. In this section, the findings from benchmarking analysis, expert interviews, and case study analysis are reported. The outcomes are also presented in light of the KPIs impacting supply chain efficiency in the pharmaceutical industry. They are: forecast accuracy, inventory turnover, order-to-delivery lead time, and on-time in-full (OTIF) service. The findings are interpreted in terms of the SCOR model domains. Industry benchmarking and individual case results are also used to verify that strategic changes have an impact on operational measures.

4.1. Benchmarking Results

There were marked differences between the median performance level and the top performers of the industrial benchmarking regarding the debtor performance in pharmaceutical supply chains. The values observed for four fundamental KPIs in industry reports, as well as SCM publications, and the feedback from professionals interviewed during the research, are presented in Table 1.

Performance Metric	Industry Average	Best-in-Class
Forecast Accuracy (%)	70–80	90 or higher
Inventory Turnover (times/year)	4 to 6	8 to 10
OTIF Delivery Rate(%)	85	98
Order-to-Delivery Lead Time (days)	30 to 45	15 to 20

Table 1. *Industry Benchmarking of Pharmaceutical SCM KPIs*

More accurate forecasts tended to produce better inventory turns and shorter lead times. Businesses invested in ERP-driven demand planning tools and conducted a monthly review of the forecast, resulting in more substantial KPI alignment. The organizations that had not implemented advanced tools or still depended on manual processes fell behind on nearly every front.

4.2. Forecast Accuracy vs. Inventory Turnover

To better examine the relationship between planning quality and inventory management, a focused comparison was conducted comparing forecast accuracy and inventory turnover. The findings indicated an almost linear relationship, as marginal improvements in forecast accuracy resulted in significant improvements in inventory turnover.

Forecast Accuracy (%)	Inventory Turnover (x/year)
70	4
80	5
90	8
95	10

Table 2. *Relationship between Forecast Accuracy and Inventory Turnover.*

These findings were also validated through several interviews with experts. One supply chain executive noted that transitioning from a spreadsheet-based forecast system to a demand planning module integrated with their ERP resulted in a 12 percent increase in forecast accuracy over two quarters. At the same time, inventory turnover improved from 5.2 to 7.6 (times) per year.

KPI	Before ERP	After ERP	Improvement (%)
Forecast Accuracy (%)	72	88	+22
Inventory Turnover (x/year)	4.8	6.1	+27
Obsolescence Rate (%)	16	11.2	–30
OTIF Delivery (%)	83	91	+9.6

Table 3. *Case Study: Performance Before and After ERP Implementation*

The most significant gain was a 30 percent reduction in obsolescence in the first year of implementation. ABC categorization methods drove predictive enhancements, while automated consolidation was achieved across the sales and distribution areas.

4.4. SCOR Model Mapping

All SCOR domains were assessed in the case organization before and after the intervention. Significant changes were also found in the Plan, Deliver, and Enable steps. Data standardization led to more reliable planning precision, also improving delivery effectiveness through improved logistics synchronization and inventory management. “JDA Software” was their supplier for the newly implemented, centralized planning product. Beneath the “Enable” pillar, the company also built a KPI (Key Performance Indicator) dashboard that captured OTIF, Lead Time, and Cost per order, all on a monthly basis, with repeating feedback loops and corrective actions.

The findings suggest that drug companies that employ the technology as part of an integrated planning and cross-functionally aligned process with SCOR-quality discipline have an edge in both service quality and cost management compared to their peers. Enhanced forecast quality yields additional downstream benefits, such as reduced inventory levels, increased order fill rates, and shorter lead times. These findings validate earlier literature reports and demonstrate the strategic necessity of an innovative, data-driven, collaborative, and technology-enhanced approach for the supply chain.

V. DISCUSSION

The findings of this study provide considerable insights into practice about the operational and strategic drivers that contribute to pharmaceutical supply chain performance. One of the most fundamental discoveries is that forecast accuracy is most strongly related to supply chain efficiency. The pharmaceutical industry, in particular, must be confident about the predictability and stability of demand for a given product and cannot tolerate any uncertainty about what to produce. Accurate demand forecasting reduces the likelihood of overstocking and understocking – both of which can be very costly, both financially and in terms of damage to the company's reputation and trust. In markets where shelf-life restrictions, cold chain requirements, and tight regulatory guidelines exist, accurate demand prediction becomes a vital enabler of service and cost effectiveness. The analysis confirms that for pharmaceutical companies, a higher level of forecast accuracy leads to higher inventory turnover, shorter lead times, and improved on-time delivery, thereby supporting the hypothesis that planning quality underpins supply chain success.

Moreover, beyond planning, integrated digital systems play a crucial role in delivering and measuring performance improvements. The case study company evolved from a fragmented, spreadsheet-based planning system to an integrated ERP, providing real-time access to data flow across procurement, production, quality control, warehousing, and distribution. Institutions were able to consolidate by integrating their distribution network and supply base into a single system, something that was previously impossible. This integration further eliminated the information silos that caused duplicate procurements, slow orders and poor safety stock levels. The effect of this metamorphosis was evident in the actual enhancement in several KPIs. ERP solutions did not just make businesses run smoothly; they also made it possible to roll out KPI dashboards to help manage by exception (see those bright spots) and monitor results to take corrective action (before things get off course). This corresponds with the fact that digitalisation, as far as pharmaceutical SCM is concerned, is not an issue of IT modernisation, but a strategic core business idea that has a direct impact on compliance, service levels, and cost management.

Cooperation between organizations was also found to be a critical factor in supply chain performance. Before being integrated, demand planning, production, and warehousing were the domain of functional enclaves that had worked with little interaction. This resulted in non-synchronized batch sizes, incorrect replenishment triggers, and an accumulation of inventory. Creating cross-functional planning teams and involving warehouse and manufacturing employees in the planning process enabled the company to align

operating activities, eliminate duplication, and gain better service. These developments underscore the importance of both cultural and technological transformation in supply-chain transformations. Functional alignment, coupled with effective communication and a shared purpose, bridges execution gaps and establishes accountability throughout the value chain.

The use of the Supply Chain Operations Reference (SCOR) model also helped emphasize the value of a systematic, process-based approach to improving the supply chain. The SCOR model characterizes operations along six dimensions: Plan, Make, Source, Deliver, Return, and Enable. It enabled the organization not only to diagnose inefficiencies and prioritize interventions but also to track performance enhancements over time. The modularity of the SCOR model enabled phased implementation, first focusing on core planning and fulfillment activities, followed by the introduction of enabling technology and reverse logistics. This systematic process was consistent with strategic objectives and regulatory requirements, providing a scalable and repeatable approach for enhancing supply chain performance.

Although promising, the study also notes some limitations. The case study is of a single organisation within specific regional and regulatory environments, and may therefore restrict the extent to which the findings can be generalised to other contexts. Additionally, the expert interviews, although instructive, are limited to a small sample of individuals and may not encompass the full spectrum of operating practices within the global pharmaceutical industry. Resource constraints, technical debt, and inconsistent regulation can be barriers to the adoption of technology across an entire sector, especially SMEs.

However, the data point to an obvious conclusion: To improve the performance of the supply chain, the pharmaceutical company of the future will need a holistic, end-to-end approach that includes precise demand forecasting, cutting-edge digital tools, and integrated cross-functional cooperation. When driven by performance metrics and enabled by a process framework such as SCOR, these principles allow organizations to deliver service excellence, meet regulatory compliance, and provide operational flexibility. This shift from a reactive business model based on isolated operations to a proactive, interconnected system is not only an operational upgrade, but it is a tectonic event in the way pharmaceutical supply chains deliver value to patients and stakeholders.

VI. CONCLUSION

The pharmaceutical supply chain is a highly complex and vital system, where any delays, inefficiencies, or inaccuracies can have far-reaching repercussions, extending beyond mere commercial loss to damage to patient health and even non-compliance with regulations. In this context, improving the performance of the supply chain is more than an operational objective; it is a strategic imperative for organizations that wish to maintain a competitive advantage and public confidence. This paper has examined the skills and processes related to pharmaceutical supply chain management, based on benchmarking datasets, expert discussions, and a case study, to identify the practices, programs, and models that have the most significant impact on performance.

The results of this study confirm that accurate demand forecasting serves as a cornerstone of a responsive and efficiently functioning pharmaceutical supply chain. Companies that prioritize forecast accuracy through ABC classification, real-time data integration, and formalized forecast review cycles have better inventory turns, lower obsolescence, and improved on-time fulfillment. These results are not only cost-effective but also enable the organization to be prepared at the right time when trends change and need to adapt accordingly (especially in therapeutic areas where needs can change rapidly).

No less important is the contribution of digital transformation, primarily through Enterprise Resource Planning (ERP) systems, which integrate all elements, including procurement, production, warehousing, and transportation, under one single system. The case study analyzed in this study demonstrated how a mid-sized pharmaceutical manufacturing company effectively increased service level and reduced waste through the use of a lean process facilitated by data automation. For instance, if ERP systems are correctly implemented, they can provide the visibility and control necessary for end-to-end supply chain

management, thereby reducing the risk element and enabling companies to make more informed decisions in real-time.

Cross-functional collaboration was another critical success factor in the supply chain transformation. Alignment in planning between the manufacturing, warehouse, and logistics teams resulted in more synchronized production schedules and stock levels. This standardization not only harmonized related activities but also promoted an environment of accountability and joint ownership of the outcomes. It provides more substantial support for the conclusion that the performance of a supply chain cannot be determined solely by technology and process design, but also by the behavior of the organization and governance.

Adopting the SCOR model brought an organized and modular component to the performance improvement process. By organizing supply chain activities into separate yet interrelated domains, the SCOR model provided the enterprise with a clear map of its operations, enabled it to identify inefficiencies, and facilitated corrective action in a structured manner. This methodical and systematic approach is designed to help your organization achieve lasting, measurable, and consistent performance gains that align with its strategic objectives. It also enforces local quality curriculum by building it into wherever the company is operational.

The study findings have generalizable implications for large pharmaceutical companies operating in various markets, despite some limitations in sample size and geographic context. The foundations of precise planning, digital alignment, and collaborative delivery have become universally valid and relevant, and an increasing number of people are now recognizing this as critical to addressing the challenges presented by global disruptors, regulatory changes, and evolving customer expectations.

Pharmaceutical companies seeking high-performing supply chains need to invest in a connected approach that incorporates forecasting accuracy, digital infrastructure, process standardization, and cross-functional collaboration. Combining these components with proper Key Performance Indicators (KPIs) and formalized structures, such as SCOR, contributes to these enterprises' ability to create agile, well-managed supply chains. In the ever-changing pharmaceutical industry, however, businesses that focus on supply chain excellence will be better equipped to maintain product availability, meet regulatory requirements, and ultimately deliver on their promise to patients.

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