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Research Article

Closed-Loop Integration between Supply Chain Planning and Execution Systems

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ABSTRACT

Closed-loop planning between supply chain demand/supply planning and supply chain execution in Enterprise Resource Planning (ERP) systems is a transformative approach designed to integrate end to end supply chain processes seamlessly. A closed-loop supply chain model bridges the gaps often associated with traditional Material Requirements Planning (MRP) and Capacity Requirements Planning (CRP) thus enabling organizations to overcome inefficiencies in production scheduling, demand fulfillment and inventory management ultimately enhancing responsiveness, flexibility and real-time decision-making. This research article takes a deep dive into the essential components of closed-loop planning, including proposed IT architecture, workflow integration, API connectivity and data management strategies. We explore how the synchronization of demand/supply planning with execution processes results in streamlined production, optimized inventory levels and improved service levels. Additionally, this article will discuss the business benefits, key performance indicators (KPIs) impacted and future opportunities for businesses in the pharmaceutical manufacturing industry.

Keywords: Supply chain planning and execution, closed loop planning.

1. Introduction

The rise of globalization, market complexity, customer expectations and the general pace of business in the pharmaceutical manufacturing domain has increased the demand for a more connected and responsive supply chain. ERP systems and the associated traditional MRP and CRP based solutions have long served as the backbone of supply chain management (SCM) and execution systems. However, these models often operate in silos, causing disconnects between planning and execution activities and thus rendering the supply chain with lack of agility to respond to dynamic market conditions.

Pharmaceutical manufacturing, which operates in a highly regulated environment, faces unique challenges in aligning supply chain planning and execution. Ensuring compliance, maintaining product quality and managing demand fluctuations are critical to achieving business objectives. In such a complex environment, aligning planning processes (demand and supply planning) with execution activities (production planning, inventory management, procurement) is crucial for maintaining operational efficiency. Closed-loop planning offers an integrated approach that links supply chain planning with execution, facilitating a constant feedback mechanism that allows for real-time adjustments based on actual performance. This approach not only enhances visibility but also ensures that decisions made at the planning level are continuously informed by real-time execution data. This research article will examine the closed-loop planning model, the IT architecture that supports it, and its business benefits within the pharmaceutical industry.

2. Conceptual difference between Traditional MRP/CRP Models and Closed-Loop Planning Models

MRP and CRP are established methodologies that have been

foundational in supply chain and manufacturing management for decades. MRP typically focuses on determining material requirements based on demand forecasts, while CRP assesses whether sufficient capacity exists to meet the planned production schedules. MRP is a production planning and inventory control system that converts demand forecasts into requirements for raw materials and components. It ensures that the right materials are available for production at the right time. However, MRP is often 'forward looking' and operates in isolation, with limited feedback from actual production performance. CRP often works in tandem with MRP by checking whether the planned production schedule can be executed with available resources. While CRP provides a capacity check, it typically does not consider real-time feedback from the shop floor, making it difficult to adjust plans dynamically.

In contrast to these traditional models, modern organizations opt for closed-loop planning models that create a continuous feedback mechanism between planning and execution functions. The core advantage of such a mechanism is the integration of real-time data from the execution phase (e.g., production, orders, and inventory) back into the planning phase. For example, if actual production lags the schedule, the system has the capability to adjust procurement and inventory plans to avoid material shortages or excess stock. By incorporating real-time data, closed-loop planning enhances agility, allowing manufacturers to respond faster to market changes, disruptions or demand variability. Closed-loop planning integrates previously siloed functions, ensuring that all business units such as supply/demand planning, procurement, production, sales, etc. operate from a unified dataset and decision-making framework across all material types used in pharmaceutical manufacturing.

3. Elements of IT Architecture

The successful implementation of a closed-loop planning model requires a robust IT architecture that connects planning and execution systems seamlessly. At a high-level, essential to the functioning of a closed-loop planning architecture is a core ERP system that connects various modules related to supply chain execution (production planning, inventory management, procurement) and supply chain planning (demand and supply planning). The ERP serves as the central repository of master data, transactional data and real-time performance metrics. An example of such an ERP system is SAP. The SAP Integrated Business Planning (IBP) module houses tools for demand forecasting, supply planning, and capacity planning. It integrates closely with execution systems to receive real-time updates. Through the execution modules offered by SAP in the SAP Suite for HANA or SAP S/4 HANA, organizations can manage production scheduling, inventory control, procurement and logistics. These modules continuously feed execution/transactional data (production statuses, inventory levels, resource availability) back into the planning layer supported by SAP IBP. An organization may also choose to integrate a non-SAP planning system such as Kinaxis Rapid Response, Oracle Fusion Cloud Supply Chain Planning or O9 Digital Brain Platform.

Another essential component of the IT architecture in this context are middleware systems that provide the necessary connectivity and communication between systems through Application Programming Interfaces (APIs). Custom APIs enable real-time data exchange between planning and execution systems. For example, APIs can integrate third-party demand forecasting tools or manufacturing execution systems (MES) with core ERP systems, allowing for dynamic adjustment of production schedules based on updated forecasts or actual production data. Middleware also facilitates the orchestration of data across systems. It supports data transformation, ensuring that all systems speak the same language, despite differences in data formats or protocols. Some common middleware platforms used for API connectivity and integration in closed-loop planning systems include MuleSoft, Dell Boomi, IBM Integration Bus and the SAP Integration Suite.

Integrating supply chain systems involves the transfer of sensitive and proprietary data. Ensuring data security and compliance with industry standards (such as GDPR, HIPAA in pharmaceuticals) is essential to mitigate risks. Best practices to ensure role-based access management, data encryption, and robust audit trails are key to successful integration. Organizations may also invest in other enriching functions such as continuous performance monitoring and optimization tools, collaboration platforms to communicate with partners, real-time data collection from IoT devices and analytics and business intelligence (BI) capabilities.

4. Data Management and Integration Strategy

Effective data management is the cornerstone of closed-loop planning. The ability to manage, clean and integrate data from various sources determines the accuracy and impact of the planning-execution loop on business processes. Master data objects such as materials, supplier and BOM (Bill of Materials) and production recipes must be aligned between planning and execution modules along with transaction data such as sales orders, purchase orders, production orders etc. In a complex ecosystem with multiple systems, organizations may also choose to implement data lakes that can store large volumes of structured and unstructured data from planning and execution systems. Successively, Advanced analytics tools (including AI and machine learning) can process this data to identify trends, patterns and areas for improvement. Cloud platforms allow for scalable, flexible data storage and processing. Integration between on-premise ERP systems and cloud-based analytics platforms can enhance the performance of closed-loop planning models, especially in handling large volumes of data in real-time.

5. Workflow Integration: Seamless Business Process Flow

The integration between supply chain planning and supply chain execution systems is crucial for creating a seamless business process flow. The workflow typically starts with demand planning activity in the planning system, which is responsible for forecasting customer demand across various markets using historical sales data, market trends and other influencing factors. Demand planners use advanced planning tools to generate a forecast that forms the basis of the overall supply chain plan. These forecasts are shared with supply planners who then use them to develop a comprehensive supply plan, factoring in lead times, production capacities, supplier constraints and inventory policies. Supply planners work closely with the sales and operations planning (S&OP) team to align the demand forecast with the supply capabilities, ensuring that inventory levels are optimized to meet customer demands while minimizing costs. With the help of system automation and effective S&OP

planning, demand and supply integration also involves effective translation of demand pertaining to finished and semi-finished goods into supply planning requirements for their respective components such as raw materials, packaging materials, active pharmaceutical ingredients, excipients and other chemicals.

Once the supply plan is finalized, the data pertaining to planned orders and planned transfers between sites is passed to the supply chain execution systems. For internal manufacturing operations, the data may be passed to manufacturing execution system (MES) where production scheduling and execution take place. The MES receives planned production orders from the supply planning system and translates these into actionable tasks for the shop floor. Here, detailed scheduling is performed to allocate resources, equipment and labor for manufacturing the required products. During production, the MES tracks the progress of each job, providing real-time updates to supply chain planning systems. This data allows for the continuous adjustment of plans if unexpected issues arise, such as equipment breakdowns or quality control problems. The MES also integrates with quality management systems to ensure that products meet the required specifications, capturing quality data that is critical for compliance in regulated industries like pharmaceuticals and medical devices. In other cases, the pharmaceutical manufacturer may rely on contract manufacturing organizations (CMOs) to perform some or all of the manufacturing in the product lifecycle. In such cases, the planned orders/ transfers data from the supply chain planning systems may be processed by the execution system to prepare subcontracting purchase orders for the CMO to execute. There may also be scenarios where only procurement order is required to be executed for raw materials. All orders created in the execution layer will be fed back to the planning layer for the planning system to delete the previously created planned orders. This is to ensure that there is only one single truth reflected in both systems.

Post-manufacturing, the focus shifts to inventory management. Once finished goods are produced, they are transferred to inventory management systems, which are tightly integrated with both supply chain planning and execution systems. Inventory management teams monitor stock levels, coordinate with warehousing operations and update the supply planning system with real-time inventory data. This information is essential for accurate Available-to-Promise (ATP) and Capable-to-Promise (CTP) calculations, which help supply planners respond effectively to customer orders. Inventory data is also crucial for replenishment planning, where supply planners analyze stock levels, lead times and reorder points to generate procurement and production orders that align with future demand forecasts.

Order fulfillment is the next critical step in this workflow. When a customer order is placed, the execution system checks inventory availability against the planned supply. The warehouse management system (WMS), part of the supply chain execution platform, coordinates the picking, packing and shipping of products. Integration with transportation management systems (TMS) facilitates the planning and execution of deliveries, optimizing routes and ensuring that orders are shipped on time. Meanwhile, logistics teams monitor the progress of shipments and provide feedback to the supply chain planning system, allowing it to adjust future plans based on actual delivery performance.

All the transactional data created in the execution system such as sales orders, purchase orders, production orders etc. will be fed back to the planning system at appropriate times to enable transparency and visibility of operations and, ultimately, better planning based on actual business transactions. Throughout this entire process, continuous communication and data exchange between demand planning, supply planning, manufacturing execution, inventory management and logistics teams are crucial. Advanced integration between these systems, achieved through middleware, APIs and ERP systems, ensures that data flows seamlessly across the supply chain.

6. Business Benefits and Impact on Supply Chain KPIs

The closed-loop integration of supply chain planning and execution ERP systems provides pharmaceutical manufacturers with the agility, accuracy and efficiency needed to operate in a complex and dynamic market environment.

1. **Enhanced demand forecast accuracy:** This integration provides real-time data visibility across the supply chain, encompassing sales, inventory and production status. Pharmaceutical companies, which often face volatile demand due to factors like seasonality, regulatory changes, and public health crises, benefit from more precise demand forecasting. With integrated data, planning systems can dynamically adjust forecasts, allowing production schedules and procurement strategies to align closely with market requirements. This leads to a reduction in stockouts and excess inventory, ultimately minimizing costs and improving customer satisfaction.
2. **Optimized Inventory management:** The limited shelf life of pharmaceutical products makes inventory management a complex challenge. Closed-loop integration provides end-to-end visibility of inventory levels, planned production, and distribution networks. This integration allows companies to implement dynamic inventory optimization strategies, adjusting safety stock levels and procurement orders in real-time based on current demand. Improved inventory management reduces excess inventory and the risk of product expiration.
3. **Increased production efficiency:** Closed-loop integration provides visibility into demand fluctuations and supply timelines from the planning systems to production schedules in the execution systems. Thus, pharmaceutical companies can optimize production runs, minimize machine idle times and reduce overproduction, leading to cost savings.
4. **Faster response to market changes:** With this integration in place, pharmaceutical companies can respond swiftly to market changes, such as sudden spikes in demand or regulatory shifts by quickly adjusting production schedules, modify distribution plans or reallocate inventory to meet market needs. This agility is crucial in the pharmaceutical industry, especially during public health emergencies or seasonal demand fluctuations.
5. Improvement in supply chain KPIs such as order-to-delivery lead time, service levels, inventory turnover ratio and order fulfillment rate.

7. Conclusion

Closed-loop planning offers a comprehensive solution for aligning supply chain demand and supply planning with execution

processes. By integrating real-time data from execution systems into planning systems, businesses can enhance responsiveness, reduce operational silos and optimize inventory and production processes. The pharmaceutical industry, in particular, stands to benefit from this model due to its unique challenges in regulatory compliance, product quality, and demand variability. A well-designed IT architecture, seamless API connectivity and robust data management strategy are critical to realizing the full potential of closed-loop planning. As supply chains become increasingly complex, closed-loop planning will be essential for maintaining competitiveness and meeting customer expectations.