

Strategic VMI Adoption in LSP Operations: Minimizing Truck TAT in JIT Supply Chains

Adithya Narayanan Rajesh

Department of Production Engineering, National Institute of Technology Tiruchirappalli

Tamil Nadu, India

adithya.mechie@gmail.com

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Abstract— This study explores the evolution of Vendor Managed Inventory (VMI) within the supply chain of a large-scale motorcycle manufacturer, tracking its progression from a traditional non-VMI model to a centralized VMI system, and eventually to a decentralized, logistics service provider (LSP)-integrated framework. It examines the challenges associated with each VMI model, key structural changes, and the innovative solutions that enabled the company to overcome operational challenges. The shift to a centralized VMI model led to increased transportation costs and supplier resistance, limiting its overall effectiveness and prompting the company to adopt an LSP-integrated VMI framework. This decentralized approach balances cost efficiency with improved supplier collaboration, making it well-suited for manufacturers with geographically dispersed supplier networks. The study also analyzes issues related to last-mile delivery—particularly high truck turnaround time (TAT) in a Just-In-Time (JIT) environment—and how the implementation of a Logistics Control Tower (LCT), along with other strategic initiatives, helped reduce TAT from eight hours to four. The findings offer actionable insights for manufacturers aiming to enhance inbound logistics through effective VMI models, while addressing common implementation challenges with practical, real-world solutions. The study also contributes to the existing body of knowledge on VMI by introducing a decentralized framework integrated within LSP operations.

Keywords— *Vendor Managed Inventory, Just-In-Time, Supply Chain, Logistics, 3PL, Turnaround Time*

1. Introduction

VMI has emerged as a transformative strategy in modern supply chain management, enabling suppliers to take responsibility for inventory replenishment based on shared data. This

approach reduces overall inventory costs, optimizes production and logistics planning, and offers several other benefits [1]. Initially pioneered in the retail sector by companies such as Walmart and Procter & Gamble, VMI has since been widely adopted across various industries, including automotive manufacturing [2], [3].

The origins of VMI can be traced back to the introduction of Quick Response (QR) strategies in the 1980s, designed to minimize lead times in the textile industry by synchronizing supplier production with real-time point-of-sale data [4]. During the 1990s, this concept evolved into the Continuous Replenishment Program (CRP), marking a transition from traditional push-based models to dynamic pull-based systems driven by actual consumer demand [4]. Over time, VMI expanded the supplier's role, granting them greater control over inventory replenishment while ensuring alignment with production schedules and market requirements.

The implementation of VMI varies significantly across industries, influenced by various factors. The success of a VMI strategy depends on several critical decisions—including inventory placement, ownership models, control limits, replenishment frequency, and the degree of demand visibility shared between partners. These elements must be carefully configured to align with a company's operational objectives and technological capabilities [5].

This study examines the strategic implementation of VMI in a network of LSP warehouses located near the original equipment manufacturer (OEM) within the inbound supply

chain of a leading automotive company. It traces the evolution from a conventional non-VMI model to a centralized VMI system, and ultimately to a decentralized, LSP-integrated framework. In addition to the middle mile, the study investigates last-mile delivery—from the LSP warehouse to the OEM plant—executed under JIT principles, analyzing challenges like high truck TAT and plant congestion, and assessing the impact of VMI at the LSP warehouse on last-mile performance.

2. Literature Review

VMI was first popularized in the late 1980s by Walmart and Procter & Gamble in the retail industry. Since then, companies such as Whitbread Beer Company, Barilla, Johnson & Johnson, Kodak Canada Inc., and Campbell Soup have successfully implemented it [6]. Over time, VMI adoption has expanded beyond retail into sectors like automotive, machinery services, chemicals, packaging, and furniture [7]. A wide range of industries handling diverse products, accessories, and raw materials have also embraced VMI [8].

In a VMI system, customers authorize suppliers to manage inventory replenishment based on shared data such as demand forecasts, point-of-sale (POS) information, and production schedules [9]. Effective collaboration and information sharing between suppliers and customers enable suppliers to make more accurate replenishment decisions while enhancing responsiveness to the customer's inventory needs by ensuring timely replenishment [10]–[12].

As emphasized in the existing literature, VMI implementation offers key benefits, including reduced inventory levels, fewer stockouts, improved production planning flexibility, and enhanced customer service [6]. In a VMI program, customers and suppliers have distinct yet complementary goals: customers aim to achieve higher service levels while minimizing inventory costs, whereas suppliers focus on reducing inventory and transportation costs [4]. VMI also fosters shared objectives that enhance collaboration—such as streamlining material and information flows, mitigating the bullwhip effect, and improving responsiveness [13].

3. Vendor Managed Inventory

3.2 VMI Components

3.2.1 Inventory Location

Inventory location refers to where stock is physically stored and managed by the vendor, and this choice directly impacts supply chain responsiveness [14], [15]. Inventory can be positioned in a distributed manner at the customer's premises—such as on a manufacturer's production line or a retailer's shop floor—enabling direct replenishment at the point of consumption, albeit with increased administrative burden for the supplier. Alternatively, inventory may be delivered to a centralized warehouse at the customer's site, consolidating goods from multiple vendors to reduce safety stock levels and transportation costs [6]. A third option is the use of a third-party warehouse, which enhances flexibility, particularly when the supplier lacks nearby facilities but needs to maintain proximity to the customer [6]. While centralized inventory management improves delivery efficiency and reduces overhead, placing inventory closer to consumption points improves responsiveness. Thus, an optimal balance between cost efficiency and service level requirements must be maintained.

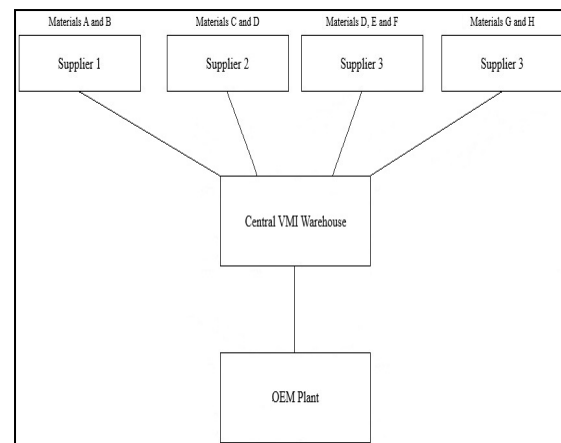


Figure 1. Centralized VMI

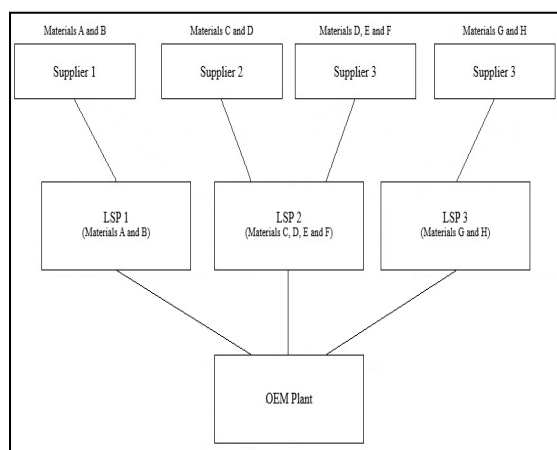


Figure 2. LSP-Integrated VMI

3.2.2 Inventory Ownership

Inventory ownership determines who holds financial responsibility for the stock and when the invoice is issued to the customer [16]. In a VMI arrangement, the supplier may retain ownership of the inventory at the customer's location, invoicing the customer only when the stock is withdrawn from storage—this model is known as Consignment VMI [17]. Alternatively, ownership may transfer to the customer upon receipt of the inventory, with invoicing occurring at that point; however, payment may still be deferred until the inventory is consumed, following a pre-agreed payment schedule [6]. In a more traditional setup, ownership transfers to the customer upon delivery, and the invoice is issued once the shipment is made [18]. In this case, the customer assumes full responsibility for the inventory investment and holding costs but may benefit from protection against potential future price increases.

3.2.3 Level of Demand Visibility

Effective demand information sharing enables suppliers to optimize inventory management. Various types of data can be shared, including sales figures, stock withdrawals, production schedules, inventory levels, goods in transit, backorders, incoming orders, and returns [6]. Greater visibility into this information allows suppliers to plan replenishments more accurately. In retail, sales data, and in manufacturing, stock withdrawals and inventory levels are valuable for stabilizing supplier's production. By analyzing shared data, suppliers can anticipate seasonal fluctuations and identify critical demand periods [19]. Demand forecasts are typically updated weekly. Electronic Data Interchange (EDI) is commonly used to

transmit this information [20]. For effective decision-making, data must be accurate and updated promptly. The more comprehensive and reliable the shared data, the greater the benefits for both parties [21].

3.2.4 Inventory Control Limits

Inventory control limits define how the supplier manages stock levels to ensure consistent availability [14]. In a VMI arrangement, the supplier is responsible for maintaining inventory within predefined thresholds, which are determined based on expected demand and replenishment lead times [6]. These limits help prevent inventory imbalances—such as excess stock or stockouts [22], [23]. Reducing the maximum inventory level can lower average stock levels and, consequently, reduce carrying costs, while setting minimum limits ensures product availability. Many VMI implementations incorporate penalty clauses for suppliers who fail to maintain inventory within the agreed-upon limits [7]. However, in a true VMI model, rigid minimum and maximum inventory constraints are often absent, granting the supplier greater flexibility in production planning and replenishment scheduling, provided the agreed service levels are consistently met [24].

3.2.5 Replenishment Decisions

In a VMI program, replenishment decisions are made by the supplier, providing them with autonomy and flexibility to manage inventory on the customer's behalf [25]. This control enables suppliers to optimize manufacturing and distribution processes while reducing the risk of stockouts [26]. In contrast, when customers manage replenishment, suppliers may struggle to maximize distribution efficiency due to unsynchronized delivery schedules and suboptimal transportation planning [6]. Misalignment between delivery frequency and production cycles can further contribute to inefficiencies [24]. Therefore, granting suppliers control over the replenishment process yields greater benefits than a customer-managed approach, especially when suppliers have access to real-time demand data and can determine the optimal timing and quantity for inventory replenishment [6].

3.3 Advantages of VMI

VMI offers several advantages for both customers and suppliers. A key benefit is the reduction in inventory carrying costs. By transferring inventory responsibility to the supplier, VMI helps optimize stock levels, reducing the need for excess safety stock. It also minimizes the bullwhip effect—a common supply chain challenge where demand fluctuations become amplified upstream, leading to inefficiencies such as excessive inventory, stockouts, and increased costs. Enhanced demand visibility allows suppliers to smooth order variability and reduce the bullwhip effect by up to 50% [4], [26]. With access to data on customer demand, production schedules, and inventory levels, suppliers can optimize production and logistics planning [25]. Coordinated replenishment enables streamlined manufacturing and distribution, lowering production, transportation, and logistics costs [10]. Additionally, VMI improves replenishment efficiency by enabling more frequent but smaller deliveries, which ensures timely restocking and reduces storage and handling expenses [11], [27].

4. Company Overview

The company under discussion is one of the leading motorcycle manufacturers in the world. Headquartered in Chennai, India, the company operates four manufacturing plants, all strategically located within the city. Of these facilities, two are

dedicated to the assembly of complete motorcycles and engines, leveraging advanced vehicle and engine assembly lines to ensure efficient and high-quality production. The other two plants specialize in the production of in-house components. The company manufactures approximately 3,500 motorcycles daily, catering to a diverse customer base across various markets. Its product portfolio includes 13 distinct bike models, each designed to address the needs and preferences of different rider segments.

5. LSP-Integrated VMI Framework

Material movement from the supplier's warehouse to the OEM plant involves two key stages: the middle mile and the last mile. The middle mile refers to the long-haul transportation of materials from the supplier's warehouse to the LSP warehouse located near the OEM plant. This stage is typically managed by the supplier, who determines the mix of materials, shipment quantities, and dispatch schedules. The OEM buyer monitors inventory levels at the LSP and tracks in-transit shipments. The last mile involves short-distance delivery from the LSP to the plant, following JIT principles [28]. This movement is managed by the OEM buyers through SA call-offs or coordinated via the LCT, using shift-wise indents. We can view this network from two perspectives:

Perspective 1: LSP Warehouse as the OEM's Inventory Storage

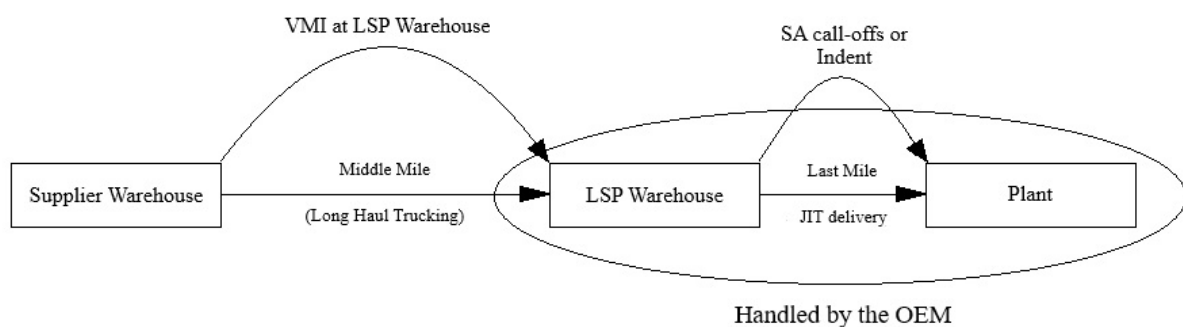


Figure 3. LSP-Integrated VMI

Due to the short lead time between the LSP warehouse and the plant, it is practical to treat them as a single operational unit. Materials can be pulled during the shift as needed, similar to a Consignment VMI model.

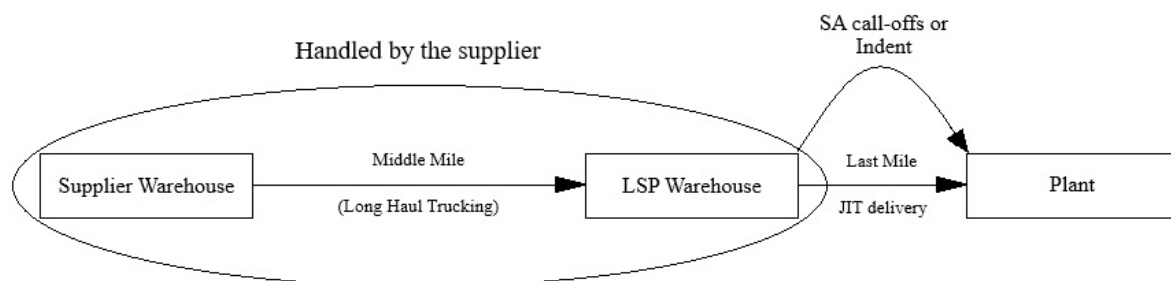
Table 1. Comparison of LSP-Integrated VMI and Consignment VMI

Feature	Consignment VMI	LSP-integrated VMI
Invoicing Trigger	Supplier is invoiced only for the quantity consumed by the customer.	Supplier is invoiced for the quantity inwarded into the plant.
Replenishment Decision Authority	Replenishment decisions are made by the supplier.	Replenishment decisions are made by the supplier.
Inventory Control Policy	Both lower and upper inventory limits are defined and monitored by the company.	Only the lower inventory limit is defined and monitored by the company.
Inventory Storage Location	Inventory is stored at the customer's premises.	Inventory is stored at the LSP-operated warehouse.
Material Consumption Flow	Inventory is consumed directly by the customer as needed.	Inventory is inwarded JIT by the OEM for each production shift.
Inventory Ownership Model	Ownership remains with the supplier until the material is consumed by the customer.	Ownership remains with the supplier until the material is consumed by the customer.
Data Sharing	Real-time consumption data is shared with the supplier.	The MRP system runs weekly; the MPS is shared with suppliers.

The system in place exhibits several key features of a consignment VMI model, with notable adaptations. Unlike traditional consignment VMI, where inventory is stored at the customer OEM site, replenishment here occurs at the LSP warehouse. While standard VMI practices involve maintaining inventory within predefined minimum

and maximum limits to balance stockouts and carrying costs, this model enforces only a minimum threshold. This is primarily because holding costs are absorbed by the LSP, and space availability at the LSP warehouse is not a constraint for the OEM.

Perspective 2: Supplier Extends Inventory Closer to OEM

**Figure 4.** Supplier Extends Inventory Closer to OEM

In this view, the supplier—unable to deliver materials to the plant JIT due to long lead times—extends their inventory to a location near the OEM (i.e., the LSP warehouse) to facilitate JIT deliveries. However, this perspective does not fully apply in the current scenario, as the OEM is actively involved in middle-mile processes, such as overseeing inventory at the LSP warehouse and sharing demand data with the supplier to support replenishment decisions. This level of involvement shifts the model closer to a consignment VMI structure, making Perspective 1 more accurate and appropriate for this case.

6. Existing Inbound Supply Chain Buyer

A buyer plays a pivotal role within the procurement department, being responsible for the inward movement and management of stock for specific parts and raw materials assigned to them. Each buyer is allocated a distinct set of materials and is tasked with overseeing their procurement while maintaining effective relationships with various suppliers [29]. For example, consider a buyer named Alex, who is responsible for managing the stock of materials A, B, and C. Each of these materials may be sourced from multiple

suppliers, requiring Alex to make informed decisions regarding procurement quantities from each supplier and to coordinate and manage these supplier relationships effectively [30].

The buyer's responsibilities are multifaceted and include several key functions. These include ensuring adequate stock levels by collaborating with suppliers to maintain sufficient inventory at the LSP warehouse, thereby preventing material shortages that could disrupt production. Buyers also manage the movement of materials from the LSP warehouse to the plant, ensure that suppliers meet production targets to avoid stock levels falling below critical thresholds, track in-transit inventory, and regulate in-plant stock to stay within optimal limits [31]. A critical aspect of the role involves managing multiple suppliers for the same material [32]. Buyers must

strategically balance these relationships to mitigate risks and maintain procurement flexibility [33]. This approach prevents overreliance on a single supplier.

6.3 Geographic Supplier Clustering

The company has categorized its suppliers into four distinct clusters based on geographic regions within India. Each supplier has been assigned to one of these clusters as follows:

Cluster 1: Suppliers located in and around Chennai.

Cluster 2: Suppliers from other parts of South India but outside a 300 km radius of Chennai.

Cluster 3: Suppliers from the western region (e.g., Pune and Aurangabad).

Cluster 4: Suppliers from northern India (e.g., Faridabad and Gurgaon).

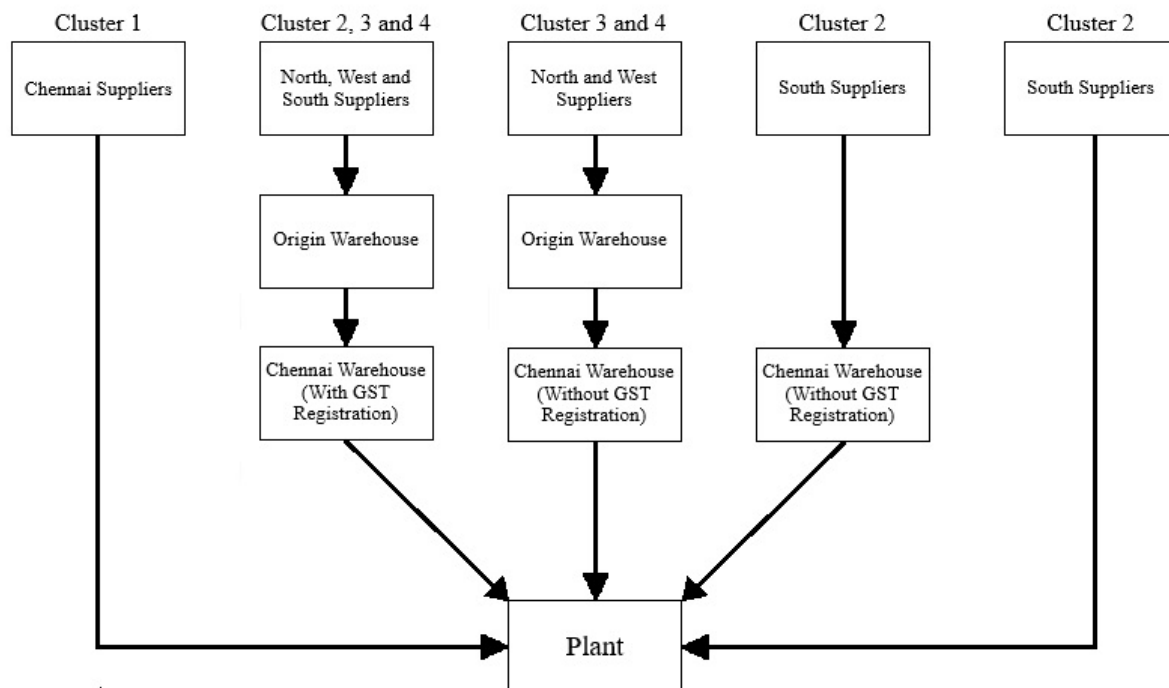


Figure 5. Geographic Supplier Clustering

6.4 The LSP Network

Suppliers from Clusters 2, 3, and 4 are geographically distant from the plant, making it impractical to deliver materials daily due to the high lead times. Additionally, the plant's storage capacity is limited, preventing bulk inwarding of materials. To address these challenges, a system leveraging LSP warehouses located in and around Chennai has been established. In this framework, suppliers from Clusters 2, 3, and 4 dispatch their inventory to the respective LSP warehouses with

which they have partnered, following a monthly plan provided by the company. The scheduling of deliveries—including the timing, quantity, and frequency of inventory inwarding—is coordinated between the suppliers and their partner LSPs.

However, buyers are responsible for ensuring that inventory levels at LSP warehouses do not fall below predefined thresholds, as this could lead to material shortages and potential production stoppages. LSP warehouses hold

inventory until it is needed for production. Based on the shift-wise material requirements outlined in the Final Assembly Schedule (FAS) provided by the Production Planning and Control (PPC)

department for the next three days, buyers coordinate material transfers from the LSP warehouse to the plant using schedule agreement call-offs.

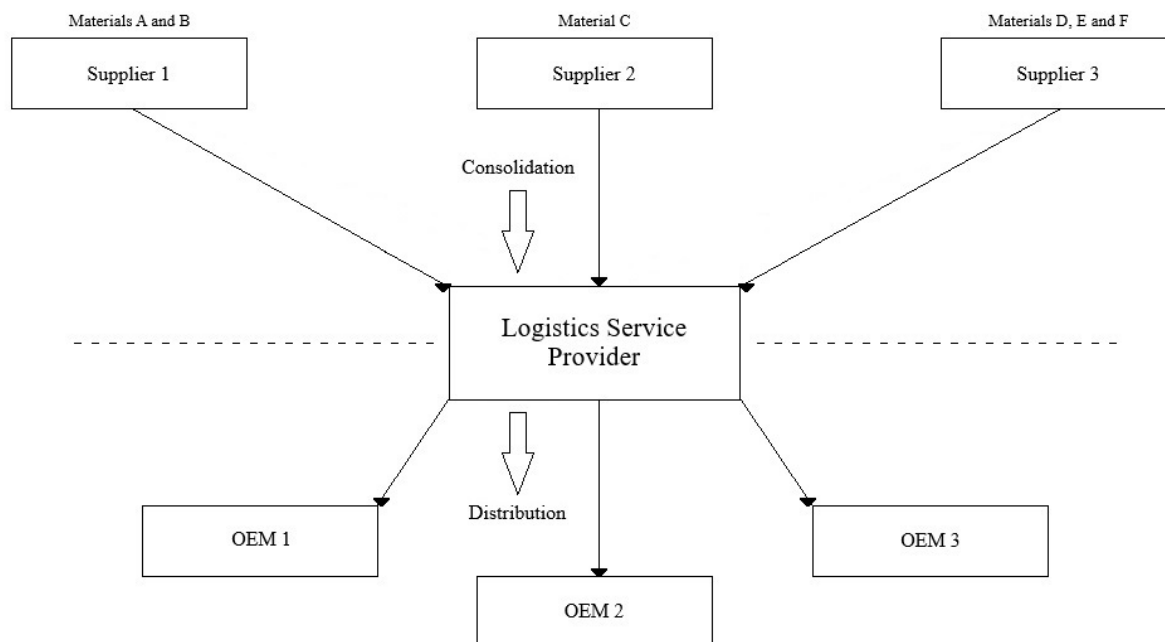


Figure 6. Logistics Flow from Suppliers to OEMs via LSP

Multiple suppliers of different materials often store their inventory in the warehouse of the same LSP with whom they have partnered. While the specifics are determined by agreements between each supplier and the LSP, the common practice is for the LSP to use its own fleet of trucks to collect materials from various suppliers and consolidate them at its warehouse. This milk run strategy significantly lowers logistics costs for suppliers, as direct Less Than Truckload (LTL) shipments from distant locations to the LSP warehouse would be considerably more expensive.

The same LSP is also responsible for delivering materials to multiple OEMs, as a single supplier may provide materials to several OEMs. Consequently, inventory for multiple OEMs is often stored within the same LSP warehouse. In such cases, the LSP typically consolidates materials for different OEMs in the same truck and delivers them to their respective destinations. However, for this specific company, strict protocols are in place to prevent materials intended for other OEMs from entering the plant premises. As a result, only materials designated for this OEM are loaded onto the truck and delivered exclusively to the company.

6.5 Challenges in the Existing Network

The current network faces several operational challenges. One major issue is the combined load pattern, where materials from multiple LSP warehouses are consolidated into a single truck for delivery to various departments, such as the fabrication shop and vehicle assembly line. This multi-stop delivery significantly increases the TAT for vehicles, as trucks must queue and unload at multiple departmental stores, delaying the timely unloading of materials from other LSPs. When inventory levels drop too low, any delay in unloading essential materials can result in assembly line stoppages. Another contributing factor is the lack of prioritization during loading; LSPs, often unaware of the urgency of specific materials, may load critical items at the back and less essential ones at the front, further delaying access to high-priority materials. Additionally, the rising volume of inbound vehicles is causing severe traffic congestion within the plant. Some suppliers also dispatch shipments based on truckload capacity rather than actual daily requirements, leading to excess materials at the plant. This contributes to improper storage practices, increasing the risk of workplace incidents and complicating inventory

tracking and management [34]. These inefficiencies also impact reverse logistics operations. The absence of a Warehouse Management System (WMS) further exacerbates the situation, as continued reliance on spreadsheets undermines stock accuracy and real-time visibility. Inventory in transit and at local warehouses is tracked manually through transporter-shared files, which are not

integrated with the Enterprise Resource Planning (ERP) system. Moreover, a critical communication gap exists between the procurement and Inbound Logistics Control (ILC) departments. Collectively, these issues result in excess inventory, fragmented visibility, and prolonged vehicle turnaround times.

7. Centralized VMI Approach

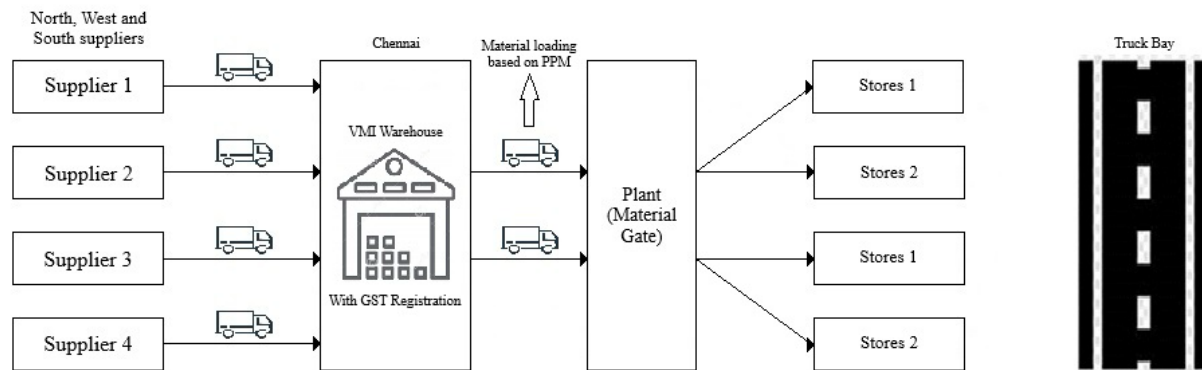


Figure 8: Centralised VMI Framework

7.2 The Framework and Its Benefits

The company identified VMI as a strategic solution to its challenges and implemented it by requiring suppliers from the North, West, and South regions to consolidate their inventory at a company-owned VMI warehouse. Under this model, suppliers were responsible for managing their inventory at the warehouse in accordance with pre-agreed norms, while the company intervened only when inventory levels breached control limits. Ownership of the materials remained with the suppliers until the goods were inwarded into the plant. To ensure regulatory compliance and prevent the expiry of e-way bills, each supplier was required to register their Goods and Services Tax (GST) individually at the VMI warehouse. A cost-sharing model was established to distribute the operational expenses of the warehouse among the suppliers. Expenses related to rent, handling, and transportation were allocated proportionally based on the tonnage of materials supplied and the space occupied within the warehouse. This reduced the financial burden on individual suppliers and encouraged more efficient use of warehouse resources.

Since VMI is implemented only at the central warehouse, it would logically be expected to address only middle-mile challenges. However, the centralization also contributed to eliminating last-mile delivery issues. Coordination among

multiple suppliers using different LSPs was simplified, eliminating congestion caused by scattered and uncoordinated deliveries to the plant. To ensure efficient warehouse operations, the company partnered with a Third-Party Logistics (3PL) service provider. Material loading was now based on the Parts Purchase Market (PPM), meaning that a truck would carry material for only one departmental store at a time. A combined load pattern was used only if PPM-based loading resulted in a LTL shipment. This approach eliminated truck queues at individual PPMs that previously arose from combined load patterns and the resulting multi-stop deliveries. The company also introduced shuttle-based truck operations to transport materials from the VMI warehouse to the plant in alignment with daily production requirements. These measures collectively reduced truck TAT and prevented the inwarding of excess material into the plant.

7.3 Issues Encountered

Despite the potential benefits of the VMI framework, several challenges emerged during implementation, limiting its effectiveness and increasing operational costs. A key issue was the existing supplier-LSP agreements, as many suppliers had long-term contracts with their respective logistics partners. This complicated their onboarding into the new VMI model and led to resistance, hindering full participation.

Additionally, rising transportation costs became a major concern. The company had to arrange dedicated trucks to transport materials from distant supplier warehouses to the VMI facility, resulting in significantly higher logistics expenses compared to traditional methods. Previously, transporters could consolidate shipments from multiple suppliers, including those catering to other

companies, enabling more cost-effective operations. The loss of this consolidation advantage placed financial strain on the company. As a result, the organization was compelled to reconsider this VMI model and explore alternative strategies to address the challenges more effectively.

8. VMI Adoption in LSPs

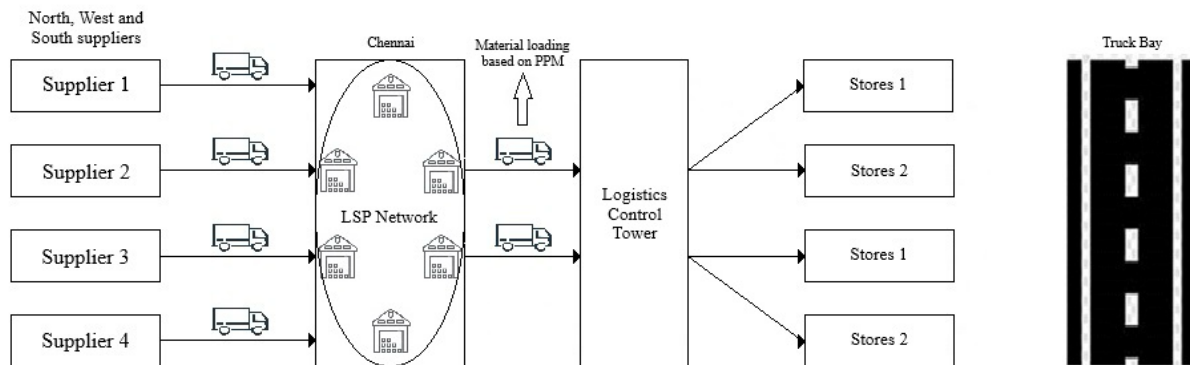


Figure 9. LSP-Integrated VMI Framework

The supplier partners were already utilizing local transporter warehouses near the plant. The company discovered that by integrating LSPs with well-established logistics networks into a unified system and onboarding additional suppliers to these LSPs—thereby reducing the overall number in the network—the core requirements of the VMI framework, as outlined in Table 1, could be effectively met without relying on a centralized VMI warehouse. This decentralized approach offered a cost-efficient solution to the challenges encountered in the initial VMI model.

8.2 Last Mile Delivery: From LSP Warehouse to Plant

This VMI model also addressed last-mile delivery challenges, similar to those in the previous centralized VMI setup. Additionally, a LCT was established to ensure better coordination [35]. The LCT enabled the company to send indents to suppliers, specifying the required materials and quantities based on real-time needs. Previously, buyers were responsible for maintaining stock records, monitoring inventory levels for each shift, and manually issuing call-off orders as per the existing schedule agreement. A major limitation of this system was the lack of direct communication between the procurement team and the ILC. The LCT bridged this gap by acting as an interface between the procurement department and the ILC. It also reduced the administrative burden on buyers

and resolved the issue of inwarding excess materials into the plant.

8.3 Activities Undertaken

Initial discussions were held with local transporters that had well-established logistics networks. The primary objective was to reduce the number of LSPs involved by connecting suppliers with a select group of reliable transporters. Transporters were receptive to this proposal, as it offered several benefits: the company would bring them more customers, and the TAT of their trucks would be reduced in this setup, resulting in cost savings. In parallel with transporter engagement, suppliers were asked to obtain local GST registrations at the LSP warehouses. This was crucial for ensuring regulatory compliance and preventing the expiration of GST e-way bills, which had been a recurring issue under the previous system.

8.4 Efficiency Improvements

The LCT connected with all local warehouses through a daily indent mechanism supported by a robust SAP interface extension. This eliminated communication gaps between the procurement team and the ILC, while also reducing the administrative burden on buyers. To enhance visibility, transporters were required to update stock information directly in SAP, enabling tracking of materials both in transit (middle mile) and at local warehouses, replacing the earlier

manual process using transporter-shared files. Suppliers obtained local GST registrations and vendor codes, ensuring regulatory compliance and minimizing the risk of e-way bill expirations. Schedule agreements were redirected to these new vendor codes. To facilitate smoother coordination, the logistics team was designated as the Single Point of Contact (SPOC) for linking supplier partners with inbound warehouses. The revised VMI framework kept transportation costs minimal by leveraging existing LSP infrastructure and eliminating the need for dedicated trucking arrangements. These changes significantly improved efficiency, reducing the TAT for LSP trucks from approximately 8 hours to around 4 hours.

9. Conclusion

The strategic implementation of VMI in the inbound logistics network of the motorcycle manufacturer helped address several longstanding challenges. While the initial centralized VMI model encountered issues such as supplier resistance and increased transportation costs, transitioning to an integrated VMI framework embedded within LSP operations proved to be a more adaptive and cost-effective solution. By decentralizing inventory storage—while retaining the core principles of consignment VMI, including supplier-managed replenishment, inventory monitoring, control limits, and data sharing—the company was able to optimize truck turnaround times and minimize production disruptions.

Though the implementation of VMI within the LSP network was primarily intended to address middle mile issues and maintain optimal stock levels at LSP warehouses, it also had a significant positive impact on last mile delivery. Notably, enabling suppliers to obtain vendor codes for the LSP warehouse prevented the expiry of e-way bills and ensured regulatory compliance. Moreover, transporters began updating in-transit and LSP warehouse stock directly in SAP, which significantly improved stock accuracy. The introduction of the LCT further bridged the operational gap between the procurement and ILC teams. This facilitated better coordination and resolved several last mile issues, such as excess material inwarding and inefficient combined load patterns.

A major achievement for both the OEM and the LSP was the reduction of high truck turnaround time—from 8 hours to 4 hours. The findings of this study provide valuable insights for manufacturers aiming to enhance their inbound logistics strategies, demonstrating how a well-designed VMI model can effectively balance operational efficiency, cost control, and supplier collaboration within complex manufacturing environments.

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