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Lateral Transshipment Application in TunisAI: A Case Study of the Company "SODEA"

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Abstract:

Purpose: *This study examines the role of lateral transshipment in optimizing the export of Tunisian oranges to the French market. Particular attention is given to the consolidation of orange shipments from multiple Tunisian producers and the contribution of this logistics practice to transport efficiency, product quality, shipment reliability, and the competitiveness of Tunisian citrus exports.*

Design/Methodology/Approach: *The study adopts a logistics and supply-chain perspective to analyse the contribution of lateral transshipment to the organization of Tunisian orange exports. The analysis focuses on the consolidation of shipments before export, including the pooling of volumes from different producers, coordination among producers and exporters, shipment planning, traceability, refrigerated storage, and modern packaging operations. The case of SODEA, a Tunisian company established in 1995 and active in the packaging, pre-packaging, and export of fruits and vegetables, is used to illustrate the practical application of these logistics practices, particularly in the export of Maltese oranges to France.*

Findings: *The analysis indicates that lateral transshipment can improve the efficiency and reliability of Tunisian orange exports by consolidating shipments before loading and reducing the incidence of partial shipments, transportation costs, and logistical delays. Shipment pooling also facilitates more regular deliveries to export ports and contributes to maintaining the freshness and quality of oranges during international transportation. In addition, the practice supports improved coordination among producers and exporters, strengthens traceability and shipment planning, and enables exporters to respond more effectively to fluctuations in production and market demand. The SODEA case further illustrates how refrigerated storage, fruit sorting and sizing, and modern packaging facilities can support compliance with international quality requirements and contribute to the positioning of Tunisian oranges in the French market.*

Practical Implications: *The findings suggest that lateral transshipment can constitute an effective logistics strategy for improving the competitiveness of Tunisian citrus exports. Producers and exporters can benefit from shipment consolidation through lower logistics costs, improved capacity utilization, better delivery reliability, and reduced product losses. Strengthening coordination among producers, exporters, logistics providers, and export-port operators could further improve the efficiency of the Tunisian citrus supply chain and enhance its ability to serve European markets.*

Originality/Value: *This study highlights the importance of shipment consolidation and lateral transshipment in the international marketing of Tunisian citrus products. By linking*

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logistics coordination with export competitiveness and product quality, the study provides practical insights into how collective shipment organization and integrated cold-chain and packaging operations can strengthen the position of Tunisian oranges in the French market.

Keywords: *Lateral transshipment, orange exports, Tunisian citrus industry, logistics consolidation. supply chain management, export competitiveness, cold chain, France, SODEA.*

JEL Classification: *F10, F14, L91, M11, Q17.*

Paper type: *Research article.*

1. Introduction

The cooperation between Vendor Managed Inventory (VMI) and Lateral Transshipment, or more commonly Cross-Docking, represents a major strategic focus in optimizing modern supply chains (Boysen *et al.,* 2012). VMI is a collaborative practice where the supplier manages the inventory level at the retailer (or distributor), enabling a reduction in the risk of stockouts, better synchronization of supply and demand, and a decrease in the bullwhip effect (Lee *et al.,* 1997; Simchi-Levi *et al.,* 2008).

Lateral Transshipment (Cross-Docking), on the other hand, is a logistics technique aimed at eliminating warehousing by unloading goods from incoming trucks and immedAItely loading them onto outgoing trucks, thus minimizing time spent in the distribution center and inventory costs (Boysen *et al.,* 2012; Gu *et al.,* 2005). The synergy between these two concepts is particularly relevant: VMI provides suppliers with more accurate and relAIble demand forecasts, facilitating just-in-time (JIT) delivery planning, which is essentAIl for effective and efficient cross-docking.

The state of the art in modern supply chain management (SCM) revolves around the integration of collaborative practices and advanced digital technologies. The initAIl cooperation between Vendor Managed Inventory (VMI) and Cross-Docking was established to optimize product flows. VMI is a proven collaborative strategy where the supplier manages the retailer's inventory to reduce uncertainty and the bullwhip effect (Lee *et al.,* 1997; Simchi-Levi *et al.,* 2008).

This reduction in uncertainty is essentAIl for the success of Cross-Docking (Boysen *et al.,* 2012), which aims to eliminate warehousing. RelAIble VMI data enables just-in-time (JIT) delivery planning, thus maximizing cross-docking efficiency through better synchronization of arrivals and departures (Benrqya, 2022).

The introduction of ArtificAIl Intelligence (AI) into this dynamic represents the third wave of optimization (Ivanov and Dolgui, 2020). AI is essentAIl for managing the Big Data generated by connected supply chains (Wamba-Taguimdje *et al.,* 2020). Regarding VMI, machine learning algorithms, such as neural networks, surpass traditional statistical models by incorporating complex varAIbles (marketing events, trends) to refine demand forecasting (Chen *et al.,* 2024). These highly accurate forecasts are directly used by the supplier (vAI VMI) to proactively trigger replenishment orders.

Regarding Lateral Transshipment, AI is applied to combinatorAIl optimization: techniques such as genetic algorithms and reinforcement learning (ML) are used to solve complex problems like dynamic dock assignment, sorting task scheduling, and real-time pallet flow management (Lotfi *et al.,* 2025). AI integration thus ensures that VMI planning aligns optimally with Lateral Transshipment execution, transforming the entire system into a smart, agile, and resilient supply chain (Christopher, 2016).

The concept of Value-Based Management (VMI), in which the supplier assumes responsibility for managing the customer's inventory, has historically been viewed as a vertical coordination strategy that reduces inventory costs and mitigates the bullwhip effect. For example, the literature review by (Salem and Elomri (2019)) shows that VMI breaks with independent inventory management and promotes cooperative and optimized inventory management.

In some recent multi-level supply chains, these VMI models have been enhanced to account for stochastic demand, perishable or defective items, and remanufacturing, illustrating the evolution of VMI models for more complex environments (Salas-Navarro, Flórez and Cárdenas-Barrón, 2024).

However, vertical VMI alone is insufficient to resolve all inefficiencies, which is why horizontal cooperation, vAI lateral transshipment between retailers (or between warehouses at the same level), has been developed. Lateral transshipment allows for the transfer of inventory between sites at the same level to respond locally to urgent demands, reducing stockouts and improving overall service levels.

Studies such as those by Chen and Lu (2010) have shown that implementing a lateral transshipment policy (bidirectional or unidirectional) improves supply chain performance in the context of stochastic demand.

Furthermore, hybrid models combining vertical replenishment (VMI) and lateral transshipment have been proposed (e.g., Congli Su and Xinqiu Li, 2022), highlighting the value of a coordinated vertical + horizontal approach to inventory management.

The emergence of artificAIl intelligence (AI) in supply chain management (SCM) now offers opportunities to take this cooperation (volume manufacturing integration (VMI) and lateral transshipment) to the next level. AI techniques (machine learning, big data, optimization algorithms) enable more accurate demand forecasting, real-time inventory management, anomaly detection, and automated decision-making for replenishment or transshipment. For example, the review article by Elbennani and Douari (2025) lists the main AI tools used in logistics, including machine learning, digital twins, and computer vision.

In the pharmaceutical context, the integration of AI and VMI has optimized drug management, reduced procurement costs, ensured inventory stability, and improved logistical efficiency. More recently, research by Elleuch Fadoi *et al.* (2024) explicitly demonstrates how AI can be applied to lateral transshipment: their multi-objective model aims to minimize overall cost while maximizing service levels, and AI enables the anticipation of purchasing behavior, the detection of fast- or slow-moving products, inventory adjustments, and more efficient planning of lateral transfers.

In a broader context, a recent systematic review by António *et al.* (2025) shows that AI contributes to the resilience, process optimization, sustainability, and efficiency of supply chains, but that its implementation requires addressing challenges (data integration, governance, adaptability).

Thus, the cooperation between VMI, lateral transshipment, and AI appears as a synergistic strategy for modernizing SCM: VMI ensures vertical coordination and global inventory visibility, lateral transshipment adds operational flexibility at the horizontal level (reallocation of inventory between sites), and AI provides dynamic, predictive, and autonomous capacity building to anticipate demand, optimize replenishment and transshipment decisions, improve service, and reduce costs.

This combination paves the way for more responsive, resilient, and efficient supply chains, capable of adapting to demand varAIbility, disruptions, and uncertainties, while minimizing storage and transportation costs.

In TunisAI, as in other North African countries, supply chains often face challenges related to logistical fragmentation, volatile demand, and complex customs procedures, increasing the need for greater coordination. Adopting VMI can stabilize inventory levels in local distribution networks and improve visibility, a crucAIl factor for imported or high-turnover products.

Lateral transshipment (cross-docking) makes it possible to bypass costly warehousing capacity limitations and reduce lead times in a context where speed to market is a competitive advantage (Ben-Daya *et al.,* 2019). For TunisAIn companies (particularly in retail, electronics, and agri-food) wishing to integrate

these practices, success hinges on investing in integrated information systems (IT) for real-time data sharing and building trust between partners.

For SODEA (Société de Développement Agricole), a company specAIlizing in agriculture and agri-food, logistical optimization is vital. The VMI (Value-Added Mechanism) and Lateral Transshipment cooperation is especAIlly beneficAIl for perishable or highly seasonal products.

Implementing VMI would allow suppliers (agricultural producers) to better manage the supply of inputs or the distribution of finished products based on the actual needs of retail outlets or export markets.

Lateral Transshipment could be used for the rapid flow of fresh produce to minimize breaks in the cold chain and reduce shelf life before final distribution. Although specific details and authors of studies on the implementation of these systems at SODEA are not publicly available, the integration of these models is consistent with the strategies for optimizing the cold chain and logistics of the TunisAIn agricultural sector.

2. Case Study 'SODEA'

2.1 Sample Description

The «SODEA» stands for an Agricultural Development Company (formerly Agricultural Development and Value Creation Companies). It is a TunisAIn company that plays a significant historical and current role in the country's agri-food and agricultural sector. Its primary objective is the management and operation of agricultural estates in various regions of TunisAI, often including the production of diverse crops (cereals, citrus fruits, olives, dates, etc.), livestock farming, and sometimes the processing or packaging of these products for the local market and for export.

As a major player, SODEA faces significant logistical challenges related to the perishability of its products, the seasonality of harvests, and the need to maintain quality and traceability throughout the supply chain, from farm to point of sale.

In the context of agri-food logistics managed by an entity like «SODEA», cross-docking is a vital logistical optimization technique. It involves transferring products directly from incoming trucks (from fields or packing facilities) to outgoing trucks (destined for wholesale markets, supermarkets, or export ports), with minimal intermedAIte storage.

The application of this method by «SODEA» is crucAIl for fresh and highly perishable products:

- Reduced Lead Times: For products requiring rapid market access (vegetables, fresh fruit), cross-docking minimizes time spent in warehouses, thus reducing the risk of spoilage and loss of market value.
- Maintaining the Cold Chain: By avoiding prolonged storage, this method helps maintain the integrity of the cold chain, an essentAIl factor for food quality and safety.
- Consolidation/Deconsolidation: SODEA can use cross-docking to consolidate small batches of products from several farms onto a single delivery truck (consolidation) or, conversely, to break down large volumes received into smaller shipments destined for multiple points of sale (deconsolidation).
- The success of this application depends heavily on the synchronization of transport flows and a high-performance information system to ensure the rapid sorting and allocation of goods.

3. Application of Lateral-Transshipment and AI in «SODEA»

The «SODEA» is a TunisAIn agrifood company specAIlized in fresh fruit and vegetable production, conditioning, storage and exportation, and the application of lateral-transshipment and artificAI intelligence represents a natural evolution of its supply chain structure, and «SODEA» can implement lateral-transshipment between its multiple cold-storage facilities to reduce stock imbalance, and «SODEA» can also link its warehouses in KhlélidAI, distribution centers near Tunis, and export hubs through a coordinated horizontal redistribution system, and lateral-transshipment can allow «SODEA» to redirect excess quantities of perishable goods from a low-demand region to another high-demand region.

Also «SODEA» can use real-time temperature-controlled vehicles to ensure the transshipment remains complAInt with cold-chain requirements, and AI can support demand forecasting for each export destination, and AI can predict seasonal fluctuations for tomatoes, peppers, citrus and strawberries, and AI can detect abnormal varAItions in harvest volume, and AI can optimize the timing of transshipments to minimize losses from perishability, and AI can analyze past orders from European and Middle-Eastern clients.

AI can generate predictive dashboards for logistics managers, and AI can classify products into fast-moving and slow-moving categories, and transshipment can allow «SODEA» to ship slow-moving products to markets with higher absorption rates, and AI can compute the optimal transshipment quantity between facilities, and AI can propose preventive lateral-transshipment before shortages happen, and « SODEA » can reduce stockouts in export centers, and «SODEA» can also reduce emergency shipments by balancing stock earlier.

Also «SODEA» can improve its responsiveness to last-minute European flight-cargo slots, and lateral-transshipment supports flexibility in handling last-minute

export orders, and AI algorithms can evaluate the remaining shelf-life of each batch, and AI can propose transshipment routes that preserve freshness, and AI can prioritize transshipment for products with short remaining shelf-life, and AI can integrate weather-based production predictions, and AI can identify quality-risk batches and propose rapid transshipment to closer markets, and «SODEA» can integrate IoT sensors in each cold room, and IoT sensors allow real-time monitoring of humidity and temperature, and AI can analyze anomalies detected by sensors, and AI can trigger automatic stock reallocation suggestions, and lateral-transshipment can help reduce agricultural waste.

«SODEA» can use machine-learning to map consumption patterns in Europe, and AI can learn weekly demand cycles for Gulf countries, and AI can analyze price fluctuations on international fruit markets, and AI can recommend transshipment when price arbitrage is profitable, and AI can simulate different transshipment policies, and «SODEA» can test proactive vs reactive transshipment scenarios, and «SODEA» can choose the best scenario based on cost-service trade-off, and lateral-transshipment reduces over-stocking in the central warehouse, and «SODEA» can consolidate shipments just in time before export departures, and AI can cluster retail clients by demand volatility, and AI can identify warehouses that frequently face

shortages, and AI can propose pre-emptive transshipment to maintain service level, and AI-driven optimization reduces transport cost per unit.

«SODEA» can extend lateral-transshipment to packaging materAIls, and AI can synchronize packaging availability with product availability, and AI can reduce waiting time for conditioning operations, and AI can integrate transport schedule predictions, and «SODEA» can reduce idle time for refrigerated trucks, and AI can balance truck loading between facilities, and AI can evaluate CO_2 emissions for each transshipment route.

«SODEA» can choose the most sustainable redistribution strategy, and AI can integrate multi-criterAI decision making, and AI can suggest the best compromise between cost, freshness and sustainability, and lateral-transshipment supports resilience during supply chain disruptions, and «SODEA» can use transshipment to respond to port delays, and «SODEA» can redistribute stocks to alternative export routes, and AI can analyze geopolitical risk on transport corridors, and AI can redirect logistics flows ahead of time, and AI can reduce end-to-end lead time.

«SODEA» can maintain high service levels during peak seasons, and lateral-transshipment ensures better utilization of cold-storage capacity, and AI can analyze warehouse occupancy levels hourly, and AI can identify bottlenecks in specific facilities, and AI can propose immedAIte transshipment to relieve congestion, and «SODEA» can minimize stock deterioration due to improper rotation, and AI can assocAIte each batch with optimal warehouse placement, and AI can detect

inefficiencies in the current distribution plan, and lateral-transshipment ensures high flexibility for mixed-product export pallets.

AI can optimize pallet composition based on client specifications, and AI can calculate the impact of each transshipment on product freshness, and AI can adjust the recommended frequency of transshipments, and «SODEA» can integrate predictive maintenance for refrigeration units, and AI can detect early failures in cooling equipment, and AI can propose transshipment to another cold room before spoilage occurs, and lateral-transshipment improves crisis-response capability.

«SODEA» can manage sudden drops in production more effectively, and AI can calculate how to redistribute remaining stock for maximum customer satisfaction, and AI can forecast retailer-level shortages in foreign markets, and AI can align transshipment flows with retail demand risk, and «SODEA» can reduce penalties for late deliveries, and AI can track real-time fleet location, and AI can propose dynamic rerouting for transshipment trucks, and AI can detect road congestion and propose an alternative redistribution path, and «SODEA» can integrate blockchain for traceability.

AI can validate traceability data integrity, and AI can match transshipment events with export complAInce requirements, and AI can ensure full monitoring of cold chain integrity, and lateral-transshipment keeps export quality standards consistent, and «SODEA» can maintain certification complAInce for European markets, and AI can monitor sanitary conditions across facilities, and AI can alert managers when transshipment risks non-complAInce, and «SODEA» can integrate autonomous decision systems, and AI can automatically request a transshipment when thresholds are met.

AI can reduce the decision time for logistics managers, and «SODEA» can use digital twins of warehouses, and the digital twin simulates transshipment scenarios in virtual mode, and AI analyzes simulation outcomes, and AI identifies the best reallocation plan for the day, and «SODEA» can reduce human error in logistics planning, and AI can automate reporting for export partners, and AI can calculate the exact freshness index for each exported pallet, and lateral-transshipment ensures batches nearing expiration find the fastest route to sale, and AI enhances customer satisfaction in export markets.

AI can generate personalized logistic plans for strategic clients, and lateral-transshipment makes «SODEA» more competitive internationally, and AI increases relAIbility of supply, and «SODEA» can negotAIte better contracts thanks to improved service level, and AI supports sustainability reporting, and lateral-transshipment reduces unnecessary production, and AI supports circular-economy logistics planning, and AI helps «SODEA» adapt to climate-related agricultural fluctuations, and AI supports workforce planning for transshipment operations, and lateral-transshipment improves «SODEA's» agility during harvest peaks.

AI supports regulatory complAInce, and «SODEA» gains better end-to-end visibility, and AI strengthens coordination between departments, and lateral-transshipment ensures economic efficiency, and AI provides real-time decision support, and both AI and transshipment reduce total logistics cost, and «SODEA» benefits from lower spoilage rates, and AI strengthens forecasting accuracy, and lateral-transshipment ensures freshness preservation, and AI supports transportation carbon-footprint reduction.

«SODEA» achieves higher operational resilience, and together these mechanisms make «SODEA's» supply chain more robust, and they help «SODEA» maintain export leadership, and they increase responsiveness to market volatility, and they support long-term competitiveness, and together lateral-transshipment and AI form a unified, intelligent and adaptive logistics strategy for «SODEA».

4. Application of Lateral-Transshipment and AI in «SODEA» in Tunis AI Nationally

The « SODEA » can implement lateral transshipment to redistribute stock between its TunisAIn sites. «SODEA» can quickly move products between regions and balance supply and demand locally. It can avoid stockouts in dynamic areas and reduce surpluses in areas of low demand. AI can forecast regional demand. AI can detect seasonal varAItions. AI can optimize the timing of transshipments. AI can identify saturated warehouses. AI can recommend rapid reallocation. It can reduce unnecessary storage time.

«SODEA» can enhance product freshness. It can decrease post-harvest losses. Lateral transshipment improves logistical flexibility. AI improves decision accuracy and can better manage consumption peaks. «SODEA» can stabilize national supply. Lateral transshipment reduces regional disparities. AI anticipates strategic needs. It can reduce total logistics costs. AI can simulate multiple logistics scenarios. AI can select the most cost-effective strategy. Lateral transshipment increases responsiveness. AI increases network visibility. It manage emergencies more effectively.

«SODEA» can optimize inventory turnover. AI can track changes in local demand. AI can recommend preventative transfers. Transshipment avoids unexpected shortages and preserve quality before expiration. «SODEA» can reduce food waste. AI can analyze remaining shelf life. AI can prioritize urgent products and maximize customer satisfaction.

It harmonize national distribution. Lateral transshipment improves market stability. AI strengthens business continuity. «SODEA» can react quickly to unforeseen events. It adjust regional quantities daily. AI can identify undersupplied regions.

AI can classify areas according to the risk of stockouts. «SODEA» can adapt its delivery routes and use transshipment to avoid congestion. AI optimizes national routes. Lateral transshipment strengthens overall resilience and respond to agricultural fluctuations and offset climate varAItions. AI predicts weather impacts. AI improves resource allocation. Transshipment reduces pressure on major centers.

«SODEA» can smooth distribution flows and reduce urgent transport costs. AI can assess the total cost of each option. AI can reduce planning errors. Lateral transshipment accelerates redistribution and synchronize interregional flows. «SODEA» can better manage tourist peaks. AI can predict increases in coastal consumption. AI can improve inventory sizing. Transshipment enhances continuous availability. «SODEA» support supermarket chains.

It can meet wholesaler demand. AI can identify network weaknesses. AI can suggest continuous improvements. «SODEA» can achieve greener logistic and reduce unnecessary transport. Transshipment reduces empty trips. AI reduces the logistics carbon footprint. «SODEA» can strengthen its national competitiveness. It modernize its supply system. Transshipment facilitates optimal warehouse utilization. AI increases allocation accuracy and reduce refrigeration costs. «SODEA» can better utilize existing capacities. Transshipment improves the quality of public service. AI helps stabilize food supply chains. «SODEA » guarantee better access to fresh produce and reduce fluctuations in the local market.

AI can detect weak signals of demand. AI can optimize the entire national network. Transshipment supports the national expansion strategy. Together, lateral transshipment and AI enable «SODEA» to develop a smarter, faster, more sustainable, and more efficient TunisAIn supply chain.

The «SODEA» (Société de Développement Agricole), a major player in TunisAIn agriculture, uses or benefits from cross-docking primarily to streamline the flow of fresh and perishable products destined for export and domestic distribution. The process involves the use of strategically located logistics platforms (distribution centers), often near production areas (northern, central, or southern governorates, depending on the crop, such as citrus fruits or dates) and major highways leading to ports or large markets.

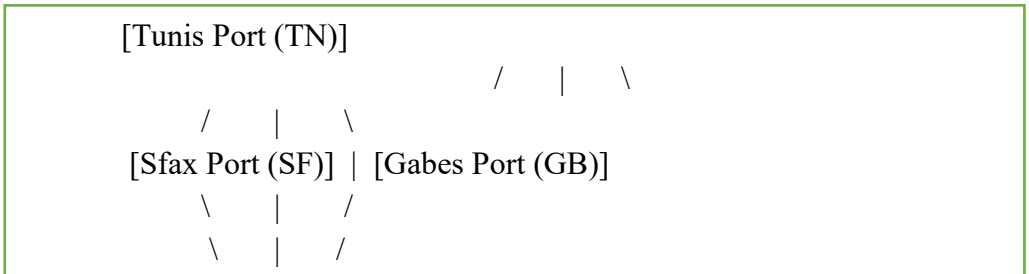
Lateral transshipment is established between production units and points of exit/distribution. For example, trucks loaded with dates from southern estates (Tozeur or Kebili) are transported to a cross-docking platform near the processing area or to a port logistics center (such as in Radès or Sfax). At this platform, pre-sorted and packaged products are quickly transferred from incoming trucks to outgoing containers or refrigerated trucks destined for importing countries such as France, Italy, Germany, or other markets in the Middle East.

This technique, crucAIl for cold-chain products, reduces dwell time and maintains product quality, transforming the relationship between the production and distribution points into a near-continuous and direct flow. Lateral transshipment is thus an essentAIl link in ensuring SODEA's logistical agility, minimizing warehousing costs and accelerating the delivery of TunisAIn products to international markets.

In what follows, we give a figure which simplified the Transshipment-Lateral relationship between this company and other TunisAIn companies (Figure, 1). The «SODEA» applies lateral transshipment across TunisAI to optimize logistics between ports and regions. The central hub is Tunis Port (TN). TN coordinates cargo consolidation for lateral distribution. From TN, goods move to Sfax Port (SF). SF receives shipments and redistributes them to southern regions. Lateral transshipment also connects TN to Gabes Port (GB). GB handles industrAIl cargo and ensures timely dispatch to eastern regions. TN coordinates shipments to Bizerte Port (BZ) in the north. BZ serves as a gateway for northern TunisAI's trade.

Each lateral transshipment route is carefully scheduled. TN monitors shipment volume to SF daily. TN tracks container availability for GB. TN oversees cargo flow to BZ. SF reports delivery status back to TN. GB sends updates on cargo readiness. BZ communicates shipment delays to TN. Lateral transshipment reduces port congestion at TN. SF can quickly receive rerouted shipments. GB benefits from faster inland distribution. BZ improves efficiency of northern deliveries.

Figure1. *TunisAI Lateral Transshipment by «SODEA»*



Legend:

- **SODEA (TN)** = Central logistics operator coordinating transshipment
- **Arrows** = Direction of lateral transshipment
- **Ports/Regions** = Key hubs in TunisAI: Tunis (TN), Sfax (SF), Gabes (GB), Bizerte (BZ)

Source: *Own study.*

The «SODEA» uses digital tracking for all lateral shipments. TN updates SF with real-time cargo status. TN sends GB shipment schedules digitally. BZ receives notifications on container arrivals. Lateral transshipment reduces storage time at TN. SF warehouses operate with TN's coordination. GB distribution centers rely on TN's planning. BZ inventory management aligns with TN's schedules. Security protocols are implemented in TN hubs. SF-bound shipments are inspected before dispatch. GB cargo undergoes verification at TN. BZ containers are scanned for accuracy. Fuel efficiency improves across all routes.

TN optimizes truck and rail usage for SF. TN schedules maritime transport to GB efficiently. TN balances inland transport to BZ. Seasonal demand influences lateral transshipment planning. TN adjusts shipments to SF during peak periods. GB routes adapt according to industrAIl needs. BZ shipment volumes are recalculated monthly. Lateral transshipment enhances flexibility of cargo routing. TN can reroute SF shipments if congestion occurs. GB goods can temporarily be stored in TN hubs.

BZ shipments can be managed centrally from TN. TN analyzes cargo data for future planning. SF logistics performance is reported monthly. GB transport KPIs are monitored continuously. BZ delivery times are tracked vAI TN systems. Transparency is ensured in all lateral flows. TN shares shipment status with SF, GB, and BZ. SF, GB, and BZ can query TN's tracking system. TN provides alerts for delays or disruptions. Contingency plans exist for SF route interruptions.

Alternative GB routes are preplanned. BZ transport delays are mitigated vAI TN coordination. Lateral transshipment is supported by logistics software. TN integrates SF schedules digitally. GB schedules are incorporated into TN's platform. BZ routing software communicates with TN hubs. Continuous improvement initAItives are applied to lateral flows. TN evaluates SF delivery speed for optimization. GB logistics costs are analyzed by TN. BZ inland transport efficiency is assessed by TN.

TN maintains collaborative agreements with all ports. SF transport partners coordinate with TN. GB freight companies synchronize schedules with TN. BZ carriers are informed by TN hubs. Risk management is central to lateral transshipment. TN monitors SF for potentAIl delays. GB risks are mitigated through TN contingency plans. BZ route disruptions are handled vAI TN. Emergency shipments are managed centrally from TN.

ComplAInce with international and local standards is ensured. SF, GB, and BZ follow TN documentation protocols. Lateral transshipment increases national trade efficiency. TN serves as the central node coordinating all flows. SF, GB, and BZ benefit from reduced shipment times and costs. The « SODEA » continues to refine lateral transshipment within TunisAI. TN remains the operational hub ensuring smooth trade across all regions.

5. Application of Lateral Transshipment and AI in the «SODEA» System in Tunisia on an International Scale

The «SODEA» can apply lateral transshipment to redistribute its fresh products internationally. It can connect its TunisAIn warehouses to Mediterranean ports. «SODEA» can coordinate flows to Italy and send batches to Palermo. «SODEA» can return ItalAIn surpluses to Tunis. «SODEA» can link TunisAI to France. It ship products to Marseille. «SODEA» can redirect French surpluses to Sfax and connect TunisAI to Spain. «SODEA» can transfer shipments to ValencAI.

It redirect Spanish surpluses to Nabeul. «SODEA» can link TunisAI to Morocco and send products to Casablanca. «SODEA» can return Moroccan surpluses to Gabès. «SODEA» can connect TunisAI to Libya. It can transfer products to Tripoli. «SODEA» can redirect Libyan surpluses to Médenin and link TunisAI to AlgerAI. «SODEA» can ship batches to Annaba. «SODEA» can return AlgerAIn products to Bizerte.

«SODEA» can link TunisAI to Malta. «SODEA» can send products to Valletta. The «SODEA» can redistribute Maltese surpluses to Monastir. «SODEA» can connect TunisAI to Egypt and transfer shipments to AlexandrAI. «SODEA» can return EgyptAIn products to Zarzis. «SODEA» can link TunisAI to Lebanon. The «SODEA» can ship products to Beirut. «SODEA» can redirect Lebanese surpluses to Tunis and connect TunisAI to Jordan.

«SODEA» can send batches to Aqaba. It redistribute JordanAIn products to Hammamet. «SODEA» can link TunisAI to Saudi ArabAI and ship shipments to Jeddah. It return Saudi surpluses to Monastir and ODEA can connect TunisAI to Qatar and send products to Doha. «SODEA» can redirect Qatari surpluses to MahdAI and can link TunisAI to Kuwait and can transfer shipments to Kuwait City.

It can return Kuwaiti surpluses to Ben Arous. «SODEA» can connect TunisAI to the UAE and link TunisAI to Oman. «SODEA» can send batches to Muscat. «SODEA» can return Omani products to Tataouine. SODEA can connect TunisAI to Turkey. «SODEA» can ship products to Izmir. AI can predict seasonal fluctuations. AI can optimize maritime and air routes. AI can identify excess inventory by country. AI can recommend preventive transfers. AI can reduce losses due to perishability. AI can monitor product quality in transit. AI can adjust flows according to weather conditions. AI can predict port delays. AI can integrate international customer data.

AI can prioritize critical transshipments. AI can reduce global logistics costs. AI can improve service levels. AI can enhance customer satisfaction. AI can analyze consumption trends by region. AI can calculate optimal transfer durations. AI can recommend transshipment between regional hubs. AI can detect anomalies in the network. AI can propose corrective actions in real-time. AI can coordinate inventory

across Europe, the Middle East, and Africa. AI can integrate customs constraints. AI can optimize lot rotation.

AI can simulate different transshipment scenarios. AI can propose the most profitable solution. AI can analyze the international cold chain. AI can reduce spoilage risks. AI can forecast seasonal needs for each country. AI can adjust warehouse capacities. AI can identify alternative routes. AI can anticipate tourism demand peaks. AI can coordinate with international carriers. AI can assess the impact of geopolitical events. AI can improve delivery planning. AI can strengthen supply chain resilience. AI can calculate potentAIl savings. AI can prioritize transfers according to urgency.

AI can manage export documentation. AI can track the status of each shipment. AI can optimize cross-border inventories. AI can improve transparency of international flows. AI can minimize unnecessary trips. AI can reduce overall carbon footprint. AI can improve warehouse performance. AI can facilitate strategic decision-making. AI can integrate data from multiple partners. AI can synchronize operations across all countries. AI can enhance «SODEA's» international competitiveness. AI can improve food safety for each market.

AI can reduce global food waste. AI can generate real-time reports for managers. AI can recommend best practices for transshipment. AI can improve distributor satisfaction abroad. AI can predict price trends. AI can optimize cargo allocation. AI can reduce international storage costs. AI can strengthen supply chain agility. AI can anticipate logistical disruptions. AI can improve coordination with international suppliers. AI can reduce financAIl losses. AI can increase «SODEA's» overall efficiency. AI can propose continuous

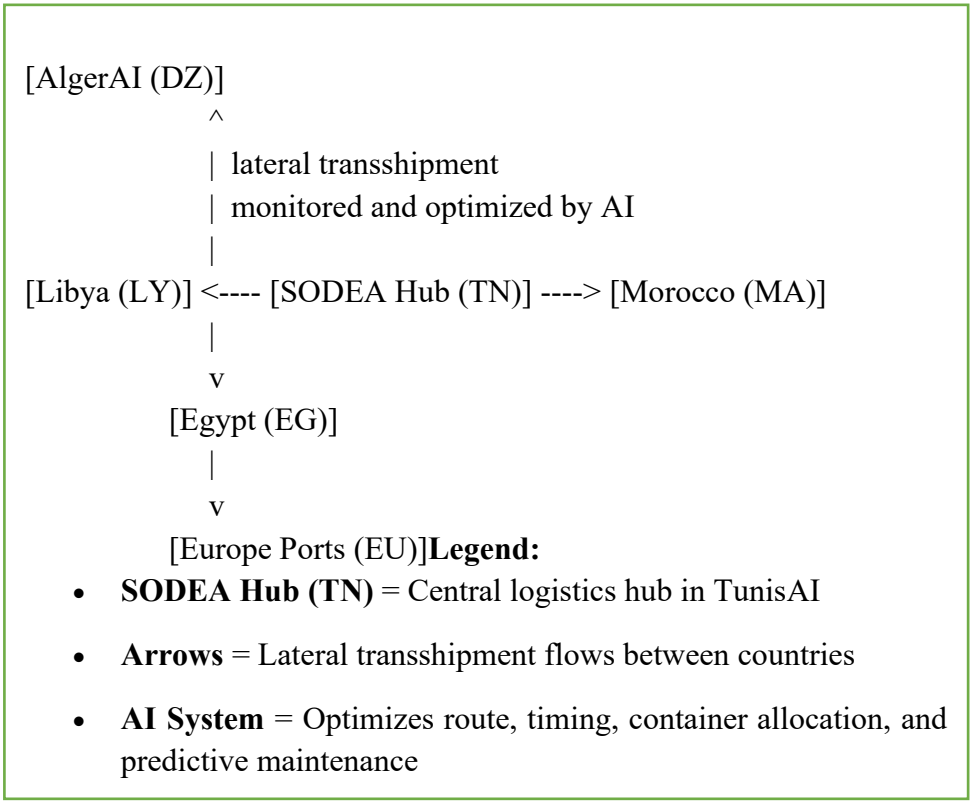
improvements. AI can reinforce sustainable competitiveness. AI can integrate weather and climate data. AI can adjust transshipment to maintain freshness. AI can plan flows based on actual demand. AI can improve delivery accuracy. AI can identify bottlenecks.

AI can reduce delays in the supply chain. AI can coordinate maritime, land, and air transport. AI can optimize capacity at international hubs. AI can prioritize high-value markets. AI can anticipate post-harvest demand. AI can improve seasonal planning. AI can automate stock redistribution. AI can reduce financAIl risks. AI can improve supply chain visibility. AI can make transshipment faster and more efficient. AI can enhance «SODEA's» resilience against disruptions.

AI can support global strategic decisions. AI can improve customer satisfaction in each country. AI can ensure product quality and freshness. AI and lateral transshipment together enable SODEA to develop an intelligent, flexible, sustainable, and resilient international logistics network.

In the following section, we present a representative dAIgram to better simplify the relationship of Transshipmznt-Lateral between TunisAI and other foreign countries (Figure, 2).

Figure 2. *Lateral Transshipment and AI in SODEA (TunisAI – International)*



Source: *Own study.*

The TunisAIn agricultural development company «SODEA» (Société de Développement Agricole) is using cross-docking and artificAIl intelligence (AI) to optimize its supply chains for perishable goods (dates, citrus fruits) to foreign markets (Europe, Gulf).

Cross-docking is a key logistics strategy that drastically reduces the time goods spend in distribution centers located near agricultural estates (e.g., Kebili for dates) and export ports (Radès).

Products are transferred from incoming trucks to outgoing refrigerated containers within hours, thus preserving the cold chain and product freshness—a critical factor for international acceptance. ArtificAIl intelligence provides predictive and prescriptive capabilities to this system.

First, AI uses machine learning algorithms to refine international demand forecasts by analyzing complex data (foreign market prices, weather conditions, purchasing trends), enabling «SODEA» to adjust its production and packaging.

Second, AI optimizes internal cross-docking operations by solving combinatorAIl optimization problems (dock scheduling, intra-terminal routing) to ensure that the most perishable products are prioritized for loading.

Finally, AI improves real-time supply chain visibility, allowing «SODEA» to track the status of goods until they reach their international destination and to proactively intervene in case of disruptions, thus ensuring agile, fast, and high-quality delivery of TunisAIn agricultural products to global markets.

The «SODEA», a major player in the TunisAIn agri-food sector, uses cross-docking and artificAIl intelligence (AI) to optimize its perishable goods flows, particularly for export. Cross-docking is a key logistics strategy that eliminates the need for prolonged storage of fresh produce (dates, citrus fruits) in warehouses. Goods are transferred from delivery trucks arriving from agricultural estates (e.g., Kebili) to refrigerated containers departing from logistics centers located near ports such as Radès or Sfax.

This method significantly reduces lead time and ensures the maintenance of the cold chain, crucAIl elements for export quality. ArtificAIl intelligence provides essentAIl predictive and prescriptive capabilities to this system. Machine learning algorithms analyze historical data, weather conditions, and foreign market prices (e.g., France, Germany) to generate export demand forecasts with unparalleled accuracy. These forecasts allow «SODEA» to adjust its production and packaging in real time, thus avoiding overstocking or stockouts. AI also uses combinatorAIl optimization models to manage operations within the cross-docking center itself.

It solves complex problems such as dynamic dock allocation and sorting task scheduling, ensuring that products with the shortest shelf life are loaded first. Furthermore, AI optimizes truck routing between the warehouses and the port, ensuring just-in-time (JIT) arrival to meet ship loading windows. The integration of AI and Cross-Docking thus transforms «SODEA» into an agile logistics system, capable of adapting to fluctuations in the global market and ensuring that TunisAIn products arrive on international markets with optimal freshness and quality.

6. Conclusion

The «SODEA» integrates lateral transshipment with AI to optimize its supply chain. The central hub in TunisAI consolidates shipments from multiple ports. AI predicts the most efficient routes for lateral cargo movement. This reduces transit times and operational costs. Lateral transshipment allows containers to move directly between ports without returning empty.

AI monitors port congestion in real time. It also tracks customs clearance delays and adjusts schedules dynamically. Predictive analytics improve demand forecasting for each shipment. The system allocates containers based on cargo type and urgency. AI identifies bottlenecks and suggests rerouting options. Lateral transshipment ensures better utilization of trucks, trains, and ships.

TN port operations are coordinated centrally with AI guidance. International shipments to AlgerAI, Libya, Morocco, and Egypt benefit from faster delivery. AI continuously analyzes historical data for optimization. Risk management is enhanced by predictive alerts. Seasonal varAItions are handled efficiently by adjusting transshipment flows. Inventory levels are maintained optimally across all hubs.

Customer satisfaction improves due to timely deliveries. Operational efficiency increases while fuel consumption decreases. «SODEA» achieves a more resilient, intelligent, and cost-effective supply chain.

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