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Raw Material Order Strategy and Total Landed Cost Optimization in Consumer Foods

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***Abstract*— A strategy for raw material order is too frequently based on one key criterion—purchase price per unit. Purchase price alone will not be enough for determining the sourcing, routing, and replenishment of raw materials for the consumer foods industry, concludes this paper, and Total Landed Cost (TLC) would provide a better and more robust decision-making lens. The paper contrasts the two predominant inbound approaches of Direct Ship and Order Consolidation with a broader range of approaches that includes min-max replenishment, request-for-quote (RFQ) sourcing, vendor-managed inventory (VMI), and make-and-ship. The added warehousing and handling cost is negligible compared to the freight efficiency and truckload utilization. The analysis indicates that Order Consolidation will be demonstrably superior to Direct Ship by a significant amount once freight efficiency and price-tier discounts are appropriately considered, even with the added warehousing and handling cost. Three benefits for businesses that make using TLC as the decision lens their priority: There is greater order-fill and service performance, there is closer inventory and working-capital efficiency, and there is a defensible, repeatable way to take advantage of procurement and logistics savings that a price-only comparison will not address.**

***Keywords*— Direct ship, inventory carrying cost, order consolidation, total landed cost, truckload utilization.**

I. Introduction

Consumer foods supply chains have a challenging mix of constraints, and order strategy for raw materials is not as straightforward as it may appear on a spreadsheet. Completed good/service expectations are also high and rigid—retail customers have very strict in-full-on-time expectations and will initiate chargebacks for these. Even if the aggregate level of demand remains stable, at the stock-keeping unit (SKU) level it can be volatile due to promotional activity, seasonality, and changing consumer preference [1]. Many of the raw materials involved — dairy solids, fruit concentrates, certain flavor systems, and some functional ingredients — are perishable or quality-sensitive, which limits how much safety stock a plant can responsibly hold.

The inbound complexity is layered on top of this—multiple vendors offering the same or interchangeable materials, multiple plants with varying consumption rates, and freight networks, where lane cost, mode, and frequency are all playing an intertwined, non-obvious role [3].

Aside from that, there is a continuing and expensive assumption about the sourcing of raw materials that occurs in many cases: the lowest quoted unit cost is the "cheapest" raw material [2]. This assumption falls apart when freight mode, shipment frequency, and consolidation opportunity are taken into account, as well as warehousing, handling, and inventory-carrying cost. A vendor with a slightly higher unit cost but with an efficient freight lane can easily have a lower cost to serve than a cheaper vendor with an inefficient freight lane, e.g., or a lower cost to serve than the nominally cheaper vendor who carries too few items on his/her freight lane to realize the benefits of scale. Purchase price is one input to a cost equation, not the equation itself.

The objective of this paper is to establish the case-study framework for the evaluation of raw material order strategies using the Total Landed Cost approach and, using that framework, to provide a defensible basis for determining when a consumer foods company should order from Direct Ship or Order Consolidation or one of the other order strategies discussed in Section 2. The aim is not to announce a stand-out winner of the strategies (in fact, this is one of the key findings of this paper—that there is no universal winner) but to provide a repeatable approach to strategy decision that can withstand challenges from finance, supply chain and sourcing disciplines equally.

A. Research Questions

Primary question.

How can total landed cost be used to improve raw material order strategy decisions in a consumer food supply chain?

Secondary questions

When would Direct Ship be better than Order Consolidation?

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How can the price tiers, freight rates, and shipment frequency impact the choice of strategy?

What are the service-inventory implications of a change of strategy?

How can strategy advice be translated into sourcing and supply processes?

II. Order Strategy Landscape

There are usually five practical strategies (approaches) for ordering raw materials that a consumer foods company can follow. These have different profiles of trade-offs in terms of lead time, service risk, system visibility, vendor dependency, truck load utilisation and write-off exposure.

A. Min-max replenishment

With min-max, a Plant or Distribution Point has fixed minimum and maximum inventory stock levels for a material, and the inventory on hand (plus on order) that is less than the minimum will cause an order to be placed automatically [4]. While easy to administer and providing planners with a set of predictable rules to follow to place orders, min-max is plant-local logic—that is, it does not inherently incorporate consideration of freight efficiency/cost or consolidation opportunity across the entire network—and it does not lead you to optimize your truckload utilization for lower-volume materials in the first instance.

B. Order Consolidation.

In this situation, instead of being shipped directly to the consuming plant, shipments from one or more vendors are sent to an intermediate consolidation point (usually a regional warehouse or cross-dock). Consolidation enhances inbound visibility (all volume is centralized and measured at a single location before it progresses onwards) and can also significantly improve truckload utilization by consolidating smaller volume shipments from vendors into full load shipments for the last mile to the plant [5]. This added cost and time of warehousing and handling is the trade-off and the carrying cost of the inventory located at the consolidation point.

C. Request for Quotation (RFQ)-based sourcing.

A request-for-quote sourcing re-competes a sourcing item's supply base periodically (annually or when it reaches a certain volume) to obtain the best commercial terms. Though not necessarily a physical-flow strategy, RFQ is still a sourcing-side input to the price-and-freight-term inputs that are part of any TLC comparison [6].

The major danger that exists is that the evaluation process will be based on price and no consideration will be given to the vendor's landed price, which may be higher when freight and handling costs are added on if the vendor is chosen.

D. Vendor-managed inventory (VMI).

With VMI, the vendor keeps track of the position of the plant (or an intermediate station) and replenishes against a service level agreement, sometimes holding the stock until consumed (consignment) [7]. While it may be useful to the buying company to have all of its planning work done for it, it also makes the vendor more reliant on the service and demands that the vendor be more system-mature and storage-capable to deliver the service with consistency.

E. Make-and-ship "Make-to-Order."

In a make-and-ship arrangement, the vendor will actually make the product to order instead of to a forecast, and very little or no finished inventory of the product will be in the vendor's possession, and the product will be shipped shortly after production [8]. This reduces the buying company's exposure to write-off inventory of non-perishable or slow-selling materials because there is no inventory built up in advance of confirmed demand, but it increases lead time and thus service risk because there is little protection to buffer against a spike in demand or a disruption in supply from the vendor.

Order Consolidation vs Make and Ship are useful contrasts: Order Consolidation is all about not only network visibility but also the utilization of trucks, regarding the efficient handling of known volume [9]. Make and Ship is about the reduction of the amount of inventory present in the system, at the cost of responsiveness.

While the strategies listed above are not mutually exclusive—for example, a company might pursue Order Consolidation for a "family" of high-volume ingredients and Make-and-Ship for a slow-moving, high write-off-risk specialty flavor—none of the strategies can be meaningfully ranked or combined without a common cost basis that accounts for freight, warehousing, handling, and carrying costs as well as price. That common basis is the Total Landed Cost, which is developed in the next section.

III. Total Landed Cost Framework

Total Landed Cost is the total cost of a unit of raw material after it has been received, including any respective prices, transportation costs, insurance, import duties, etc [10]. It includes materials costs, inbound transportation, warehousing and handling (if applicable), and carrying costs (capital) to the inventory between steps.

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The general TLC formula in terms of units can be written as the following (refer to Figure 1 explaining how the four distinct cost terms combine to give a per-unit cost):

$$TLC = P + F/Q + (H \times D) + (C \times P \times T)$$

Where:

- P = purchase price per unit (net of any volume/tier discount)
- F = freight cost per shipment
- Q = units per shipment (so F/Q is the per-unit freight allocation)
- H = warehousing and handling cost per unit per day of dwell (applies only where a consolidation step exists)
- D = average dwell time in days at the consolidation point
- C = annual inventory carrying cost rate (expressed as a decimal, typically 18–25% for consumer foods raw materials, reflecting cost of capital, insurance, obsolescence, and shrink risk)
- T = average days of inventory held across the flow, expressed as a fraction of a year (days ÷ 365)

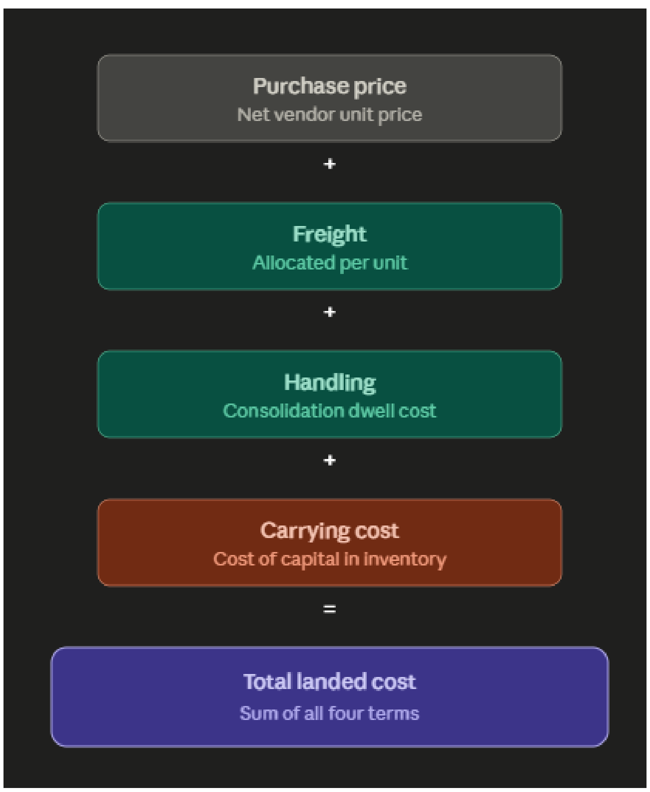

FIGURE 1. TOTAL LANDED COST BUILD-UP

This Figure illustrates that there are four distinct cost terms that combine to give a per-unit cost. Purchase price sits at the base, followed by freight, then handling, then carrying cost, each stacked as an addition rather than treated as a standalone number. The visual reinforces the paper's central argument: none of these terms alone tells you the true cost of a material, and price-only comparisons ignore three of the four layers entirely. This last line is a highlighted 'Total landed cost' block, which means that this is the result of the whole calculation, not another line item within a price.

From the formula, if it's a Direct Ship flow, T equals the carrying cost of the plant's safety stock and cycle stock, and H and D are set to zero (no intermediate warehousing step). In an Order Consolidation flow, H and D are enabled terms that represent the warehouse dwell, and T is an enabling term that represents carrying cost throughout the consolidation point and plant.

Decision variables that feed into the model, in addition to the terms of the formula, are material and its perishability/shelf-life profile; vendor and its production/storage capability; receiving plant and consumption rate; demand volume and demand volatility; contracted (typical) lead time; minimum order quantity (MOQ); freight lane cost structure (rate per mile, freight mode, accessorials); the achievable utilization of the truckload under each strategy; the carrying cost rate attaching to inventory and the type of strategy (whose terms are active in the formula).

In practice, the basic comparison comes down to the two per-unit calculations that are performed side by side on the same combination of material and vendor and plant:

- Direct Ship TLC = vendor-to-plant freight (allocated per unit) + plant-held carrying cost, added to price.
- Order Consolidation TLC = vendor-to-warehouse freight + warehousing/handling cost + warehouse-to-plant freight (allocated per unit, typically at a much better truckload utilization because volume from multiple vendors or shipments is combined) + warehouse-held carrying cost + plant-held carrying cost, added to price.

Applying this framework consistently across the material portfolio has several practical consequences, such as bringing service risk into play as a real cost or a real dollar delta—not a mere abstraction—with the ability to prioritize materials that should be revisited first through a focus on those where the expected delta between truckloads and inventory is largest.

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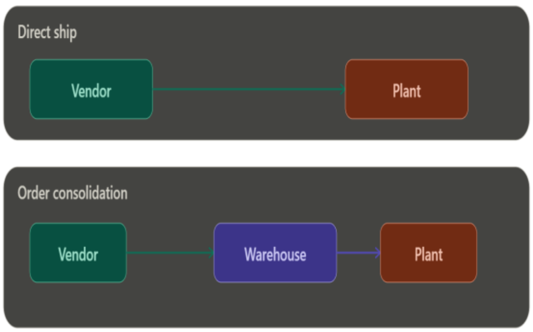

FIGURE 2. DIRECT SHIP VERSUS ORDER CONSOLIDATION FLOW

In this diagram, the two physical routing strategies of the paper are compared. Direct Ship (shown at top) is the case where the material is transported directly from the vendor to the plant. The second one represented is Order Consolidation, where material moves from the warehouse to the plant via an intermediate warehouse, thereby introducing a node but permitting shipments to be combined. Having both flows displayed on the same canvas immediately shows the structural difference: one extra stop, one extra cost layer, potentially better utilization of trucks. It provides a "map" of the mind to readers before they get to the numeric comparison in the case study.

IV. METHOD/ANALYTICAL APPROACH

This paper is based on an industry case study approach, rather than on a controlled experiment or a large-sample statistical study, supplemented by scenario analysis and strategy simulation. This design decision is appropriate because the nature of the decision being studied is one that is evaluated combination-by-combination (a specific material, from a specific vendor, into a specific plant) and the appropriate comparison is among a small number of clearly defined alternative strategies for that combination, rather than a population-level inference.

The unit of analysis is therefore the material–vendor–plant combination. It's the same as the operational "Order Consolidation as company policy," which a sourcing or network team makes at the business level, not because it is "Order Consolidation as company policy," but because the facts of the specific freight lane and the volume and freight price of the specific ingredient from the specific vendor and feeding plant yield this recommendation. A different vendor for the same ingredient, or the same vendor feeding a different plant, may reach the opposite conclusion.

The analytical steps followed for each material–vendor–plant combination under review are:

- Create a baseline cost profile of the current strategy, including actual pricing, freight terms, number of shipments made, and existing warehousing/handling costs; define the current stock-in-transit and stock-on-hand implied inventory carrying cost for the current strategy.
- Recalculate TLC, all other variables being equal, while replacing the freight, handling, and carrying-cost terms that would apply under the alternative flow.
- Compare the inventory impact, service risk, and savings between the baseline and alternative(s) (both in dollars per unit and dollars/year against real units).
- Consider opportunities by their value and feasibility, as not all opportunities with a positive TLC delta are equally feasible—vendor storage capacity, terms of the contract, and system constraints all impact feasibility.
- Record restrictions and the justification for the recommendation, including the requirements on which it is based (e.g., "sustains a minimum 3-pallet shipment size from vendor") and the governance path that is needed to implement the recommendation.

This approach deliberately restricts the unit of analysis (UoA) to a narrow focus and sets the basis for the comparison (TLC) to be the same for each combination being evaluated, which makes results from different materials and vendors comparable and prioritizable on a common basis.

V. CASE-STUDY ANALYSIS

For purposes of illustration, this paper applies the framework to an illustrative flavoring-ingredient segment, liquid flavor concentrates, that are used in a range of finished goods, from three vendors to two consumption plants. Below are the figures created to represent typical consumer food sourcing economics and are illustrative, not based on any specific disclosed company's ledger, and are made on that assumption throughout this section.

Baseline: Vendor A, Direct Ship To Plant 1. Vendor A has quoted the price to be \$4.10 for every unit. Direct Ship ships in a dedicated truck with an average truckload utilization of 60%, with a \$2,200 per shipment freight cost and 8,000 units per shipment, an allocated freight cost of \$0.275 per unit. Plant 1 has 21 days of average safety and cycle stock for this material.

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At a carrying cost rate of 22% annually, T = 21/365 = 0.0575, giving a carrying cost component of 0.22 × \$4.10 × 0.0575 ≈ \$0.052 per unit. Baseline TLC = \$4.10 + \$0.275 + \$0.052 ≈ \$4.427 per unit.

Alternative 1: Vendor A, routed via Order Consolidation. However, in the regional consolidation warehouse, the same Vendor A material is mixed with shipments of other ingredients that are shipped to the same network of plants. The freight from vendor to warehouse is reduced to \$0.14 per unit (larger, better-utilized shipments), and the warehouse-to-plant freight is reduced to \$0.09 per unit (since now the warehouse costs are combined with other volume, the utilization of the trucks increased to 85%). Carrying cost is for both warehouse dwell and plant-held stock, which is \$0.22 × \$4.10 × 0.0329 = \$0.0297 per unit when the consolidation point acts as a buffer. Alternative 1: TLC = \$4.10 + \$0.14 + \$0.12 + \$0.09 + \$0.0297 ≈ \$4.480 per unit.

Alternative 2: Vendor B, Direct Ship to Plant 1. A freight allocation of \$0.41 per unit at 45% truckload utilization is quoted for Vendor B, which is operating from a freight lane that is less efficient and a smaller drop-off size. Vendor B quotes a lower unit price of \$3.95, but they have a less efficient freight lane and smaller drop-off size, resulting in a freight allocation of \$0.41 per unit at 45% truckload utilization. Plant inventory is similar to the Vendor A Direct Ship case (at 21 days) for a carrying charge of 0.22 × \$3.95 × 0.0575 ≈ \$0.050 per unit. Alternative 2: TLC = \$3.95 + \$0.41 + \$0.050 ≈ \$4.410 per unit.

Alternative 3: Vendor B, routed via Order Consolidation. The same consolidation logic as in Alternative 1 is applied to Vendor B's lower price (freight per unit from vendor to warehouse \$0.16); handling per unit @ 4-day dwell: \$0.12; freight to warehouses from plant: \$0.09; carrying cost 0.22 × \$3.95 × \$0.0329 ≈ \$0.0286 per unit). Alternative 3 TLC = \$3.95 + \$0.16 + \$0.12 + \$0.09 + \$0.0286 ≈ \$4.349 per unit. Figure 3 illustrates the total landed cost (TLC) per unit of all four scenarios explored in Section 5.

TABLE I
SUMMARY OF THE ALTERNATIVES

Scenario	Price	Freight	Handling	Carrying cost	PLC per unit
Vendor A, Direct Ship (baseline)	\$4.100	\$0.275	\$0.000	\$0.052	\$4.427
Vendor A, Order Consolidation	\$4.100	\$0.230	\$0.120	\$0.030	\$4.480
Vendor B, Direct Ship	\$3.950	\$0.410	\$0.000	\$0.050	\$4.410
Vendor B, Order Consolidation	\$3.950	\$0.250	\$0.120	\$0.029	\$4.349

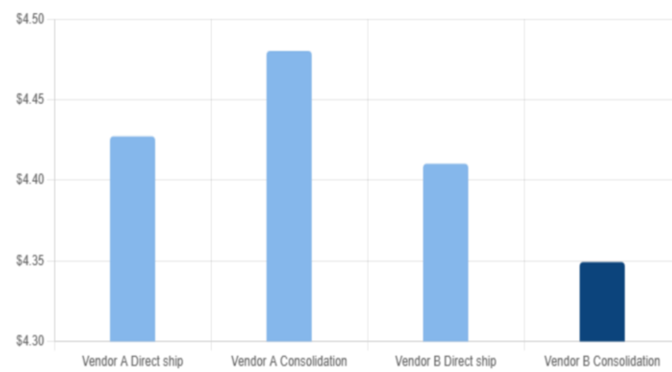

FIGURE 3. CASE STUDY TLC COMPARISON CHART

This bar chart illustrates the total landed cost (TLC) per unit of all four scenarios explored in Section 5: Vendor A—Direct Ship and Order Consolidation and Vendor B—Direct Ship and Order Consolidation. The spread between the bars is relatively narrow (\$4.35–\$4.48), which is interesting in one aspect—that the relative difference between bars in terms of dollars and cents becomes large with volume.

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The darkest bar represents Vendor B under Order Consolidation (OC), which is the best scenario that was found in the analysis. Comparing the size of the gap between best and baseline is easier by visualizing the comparison in parallel with the table, rather than linearly reading the four numbers.

While the savings from Volume Consolidation are merely discounted by the Vendor's B freight lane inefficiency of $0.15 per unit (and only achieved when consolidated freight volume moves through the Vendor's freight lane), the savings realized for this material are not reflected in the price difference between vendors A and B ($0.15 per unit), as it becomes visible at an annual volume of approximately 1.2 million units at Plant A.

The case also provides examples of when each strategy is successful. The second significant way Order Consolidation affects Vendor B more than Vendor A is that Vendor B's Direct Ship freight lane was the least efficient of the four options (45% utilization of truckloads), which therefore allowed for more inefficiency to be recovered. The improvement in freight, the reduction in carrying costs, and the slight saving in handling costs that consolidation brings result in a marginal advantage to Direct Ship versus a marginal disadvantage to consolidation when considered alone for Vendor A, where the Direct Ship lane is already reasonably efficient (60% truckload utilization). The main area where Order Consolidation wins comes where freight inefficiency and/or price-tier effects are big enough to more than compensate for the increased warehousing and handling cost, and when Direct Ship is competitive, it is when the freight lane in question is already competitive.

Risk of service also varies by the four scenarios. Order Consolidation introduces a node in the network and will consequently also introduce a small amount of lead time (the dwell time in the node) and a dependency on the operational reliability of the consolidation point itself; in this example, the added lead time is a minor risk as the concentrate is non-perishable and moves very quickly. This is not necessarily true of a material that is very perishable or has a short shelf life: If dwell time is added, that can create the risk of write-off; a pure TLC calculation, done mechanically, may underestimate this risk.

When it comes to the Vendor B Order Consolidation scenario, the carrying-cost terms are identical; although it introduces a small buffer at the consolidation point, it reduces the plant-held inventory (from 21 to 12 days), resulting in a slight net decrease in total system inventory dollars for this material when the consolidation level is considered an effective shared buffer across multiple ingredients instead of a dedicated buffer for this one. Sensitivity check emphasizes the conclusion.

The freight allocation of Vendor B's Direct Ship lane would need to drop from $0.41 to approximately $0.24, an increase in truckload utilization from 45% to about 77%, to become equal to the Direct Ship TLC of $4.349 that the vendor had for that lane due to Order Consolidation. But Vendor B didn't prove itself to be the one with the volume to warrant that price differential, so the only viable option is to consolidate. This type of sensitivity view is a valuable addition to the fundamental TLC comparison, as it not only provides a sourcing team with insight into today's strategy's winners, but it also gives the team an idea as to how susceptible or resilient the winning strategy is likely to be should there be any change in freight rates, dwell time, or vendor shipment discipline during the contract's term.

VI. OPERATIONALIZATION

However, a TLC recommendation means nothing unless it is actually put into practice, and this means a clear action plan from analysis to execution. That journey takes a typical consumer foods organization from an analyst who creates and validates the TLC comparison through a network lead who evaluates the recommendation under the broader network constraints (other materials sharing the same consolidation point, warehouse capacity, and carrier contract terms) to the Strategic/Supply Allocation and Replenishment Manager (SARM) or equivalent supply planning owner who reviews service risk and inventory implications in respect to the plant's production plan and, finally, to the buyer who has the commercial relationship with the vendor and must validate that the vendor can and will support the operational terms the recommendation assumes (shipment size, frequency, and consolidation point routing) [12].

Approval checkpoints are established at each handoff, and a new strategy change that impacts a material shared across multiple plants or business units is generally called out for additional review by a more senior decision maker, as is a change that requires a new consolidation point/carrier contract instead of existing infrastructure, a change with an annual savings impact that exceeds a policy-defined materiality threshold (typically tens of thousands of dollars or more), or a change that raises the service risk of the associated material, which has a documented history of stockout or quality problems.

After the recommendation is approved, the next step is to implement the recommended changes into the system to be executed, typically within the systems, applications, and products (SAP) system or other equivalent Enterprise resource planning (ERP), which would include the following:

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1) Ensure the new factor and delivery routing (consolidation point instead of direct plant delivery) is reflected in the updated source list and info record; 2) Update planning parameters (such as safety stock, reorder point, shipment lot size) to account for the new delivery lead time and shipment size; 3) Update the freight/shipping condition records to mirror the new factory point routing (consolidation point instead of direct delivery); 4) Ensure the vendor shipping instructions and any EDI/ASN setup are updated accordingly [11].

The reason this workflow is important is that an analytically correct TLC recommendation that ends with a spreadsheet result is not a result of any savings whatsoever. The worth of the framework in Section 3 is dependent on having a repeatable process that takes a recommendation all the way through the approval process and into the transactional systems, which in fact rule the movement of material and the assignment of a cost.

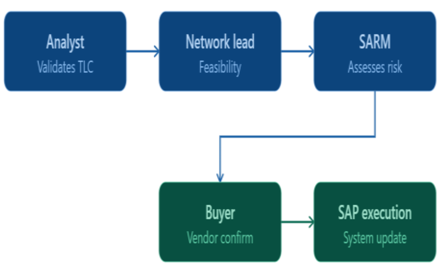

FIGURE 4. OPERATIONALIZATION APPROVAL WORKFLOW

This flowchart illustrates the steps from analysis to action for a TLC recommendation. it gets initiated when the cost comparison is done by the analyst and then moved to the network lead for a feasibility check, then to the SARM for a risk assessment, and finally the cost is moved to the buyer to get vendor confirmation and then finally to SAP for the system execution. The curve in the road following SARM illustrates the transition from the evaluation to commercial and system execution. The diagram has been designed to convey a point that has been made in the text: a TLC that is correct has no meaning or value unless it passes through this entire chain.

VII. FINDINGS

A. Cost Findings

Structured TLC modeling revealed material advantages to Order Consolidation over Direct Ship, especially in situations where the vendor's freight lane is inefficient (low truck utilization) and where price-tier effects make the benefit that a lower-priced vendor can obtain only when the freight is optimized for consolidation (as illustrated in cases in Section 5). On the other hand, when Direct Ship is still the better option, TLC modeling comes to the fore, helping to shield the organization from defaulting to consolidation [13].

B. Service Finding

No one technique is always right for all materials. It is a matter of the stability of demand for the particular material, the storage and production capacity of the particular vendor, the flexibility of the consuming plant's production schedule, and the constraints of execution like minimum order quantity (MOQ), etc [14]. This is an immediate result of the material–vendor–plant as a unit of analysis, as opposed to a company-wide approach.

C. Process Findings

Strategic decisions that are swift and consistent, and decisions that have material impact on the successful implementation of the strategy, can be made more quickly and standardized and are more likely to be implemented, with defined roles and checkpoints for approval as defined in Section 6.

VIII. PRACTICAL IMPLICATIONS FOR CONSUMER FOODS COMPANIES

Practical application of the framework should be done as a process that considers Total Landed Cost as the key decision-making parameter for raw material order strategy to replace price comparisons as the only parameter in sourcing and network decisions. There are two criteria for segmenting strategy choice: material behavior and network role (perishability, volume, demand volatility, and criticality to production), but this choice should not be dictated by an overall company policy, as Section 5 demonstrates; even two vendors supplying the same material can be inclined towards different strategies.

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Efforts to improve savings should be targeted to high volume and high freight first, because the dollar benefit of a particular effort to improve per-unit savings increases with volume, so that these product combinations are the most beneficial combinations to begin analyzing efforts to save dollars with TLC. The operationalization pathway (Section 6) is the pathway through which an "Analytical Finding" becomes a "Realized Saving," and this pathway should be shared with clear "Workflow Ownership" among sourcing, inbound supply/network planning, and buying. Lastly, money must be allocated to develop repeatable approval and system-execution pathways, such as an approval of a recommendation being stored in an SAP source list, an SAP info record, and a planning parameter update, which should then become 'sticky' rather than resetting when a new contract is signed, or a new employee joins.

A. The Role of AI and Machine Learning in TLC Optimization

The approach outlined in this paper is well-suited for augmentation by artificial intelligence and machine learning, as the scope of material–vendor–plant combinations to be considered expands beyond the manual workload that cannot be addressed. There are currently a number of ways in which this is already taken forward in the supply chain for consumer foods.

These model-based inputs can be improved using machine learning techniques, such as historical consumption, promotional calendars, and seasonality signals to predict demand at a finer level of detail than what can be achieved at a plant-level average (which could be an average of the most popular items), building more accurate safety-stock and dwell-time inputs to the TLC formula than static planning parameters. Likewise, predictive models using historical freight data can approximate the freight allocation term (F/Q) for different lane and shipment sizes, allowing a sourcing team to run freight utilization scenarios (FTUs) before deciding on a routing, rather than relying on a single historic average.

Another way to accomplish an automated combination-by-combination search is for a combination of optimization algorithms, especially linear and mixed integer programming, often in conjunction with machine-learned cost estimates, to conduct this search across the entire material–vendor–plant database and automatically identify the highest-value TLC opportunities, rather than having an analyst select the combinations to review first.

This directly contributes to the prioritization step in the method (Section 4) and the "high volume, high freight materials first" guidance provided in Section 8 of this method.

In the operationalisation layer (Section 6), anomaly detection models can be used to warn when a vendor deviates from the conditions used to justify a change in strategy based on the historical size, dwell time, and freight cost of the actual shipment data, thus filling the gap between analytical rigour and realised savings (Section 9). With NLP tools, the vendor's responses can be read and commercial terms extracted and normalized across all responses, thereby ensuring that the amount alone is not the only factor to be overlooked and that the RFQ results are not completely overlooked.

These alternatives do not replace a judgment-based feasibility and service-risk assessment, as described in Sections 6 and 9, but extend the analytical reach of the TLC framework without taking away governance of the resulting recommendations from the human domain.

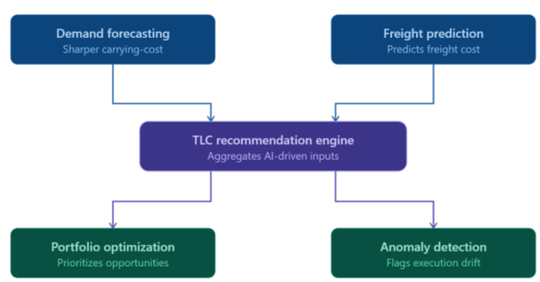

FIGURE 5. AI AND MACHINE LEARNING INTEGRATION IN THE TLC FRAMEWORK

This figure illustration depicts the integration of AI and machine learning into the TLC framework instead of replacing it. There are two predictive inputs: demand forecasting and freight prediction, which run through a central TLC recommendation engine, fine-tuning the carrying-cost and freight-allocation terms in the formula over static planning parameters. The engine, in turn, powers two downstream processes — portfolio optimization, which automatically processes the material–vendor–plant combination to decide on the best opportunities, and anomaly detection, which tracks execution against the assumptions a recommendation relied on. The architecture clearly reflects that AI serves to complement analysis and monitoring while human interpretation plays a crucial role in the feasibility and risk decisions made.

IX. LIMITATIONS

Each material, vendor, and plant combination will have a different savings percentage, as the results of this framework are variable by material category, freight lane structure, and supplier capability—the savings percentage indicated in the Section 5 case study should not be interpreted as an expectation for every material and should only be used in conjunction with each material-vendor-plant combination. In part, these are judgment-based decisions by supply planning and sourcing professionals, and not just a result of the cost model—for instance, if a material has a history of quality or availability issues, it may be advisable to use a more conservative approach than a TLC-based approach. Lastly, even if the underlying analytical case is a positive one, organizational resistance to introducing a change in a proven vendor relationship, insufficient system updates, or failure to maintain the volume/shipment size assumptions upon which the analysis was based can all lead to a positive analysis result that fails to meet the organization's expectations when implemented.

X. CONCLUSION

The main idea of this paper is that raw material order strategy should be considered as a network optimization problem, and it should be evaluated in combination with the price, freight, warehousing, handling, and carrying costs and evaluated on a whole network level, not on a local purchasing level. The Total Landed Cost approach provides a more compelling and more real basis on which to make choices among the various approaches covered in this paper, namely, Direct Ship, Order Consolidation, and the broader approach of Total Landed Cost, and the illustrative case study in Section 5 demonstrates, very realistically, how such comparisons can result in savings—and risk—to be found that are not apparent from a price-only perspective. Yet the value of the framework is more than just a mathematical exercise; as Sections 6 and 9 demonstrate, the TLC model's value lies only when it is integrated with a disciplined and repeatable operational and governance process and supported by a recommendation from analysis to approval into the transactional systems that actually move material. Consumer food companies that couple the analytical discipline of Total Landed Cost with the same process discipline stand a better chance of capturing the savings, service, and inventory benefits that this paper has outlined.

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