Balancing Product Flow and Synchronizing Transportation

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Summary: Traditionally, production and transportation planning processes are managed separately in organizations. In such arrangements, order processing, load planning, and transportation scheduling are often done sequentially, which can be time consuming. Establishing a proactive steady flow of products between two nodes of a supply chain can bypass this order-plan-ship process. A steady flow of products can reduce transportation costs, increase cross-dock productivity, and reduce bullwhip effect upstream in the supply chain. This thesis develops an analytical framework to calculate this steady flow. The methodology developed in the research also presents the opportunity for new and innovative contract types with transportation providers.

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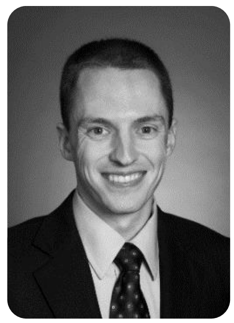

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KEY INSIGHTS

1. The traditionally independent production and transportation planning processes can lead to excessive lead times and added variability in the supply chain.
2. Despite variable demand, a steady flow can be viable for many SKUs with a variety of characteristics.
3. Having a steady flow of products can yield major benefits in transportation and cross-dock savings.

Introduction

Products flow through any shipper's network based on customer demand. For a given product, that demand typically fluctuates over time. Many Stock Keeping Units (SKUs) may be fast-moving and always have demand, whereas other SKUs may have more sporadic demand cycles. When a product's demand is higher, and more frequent, that product is shipped consistently. Most commonly, shipment of products from the plant to the warehouse entails three activities: order, plan, and ship. The warehouse places an order to the plant for products in accordance with actual customer orders as well as forecasted demand. The placing of an order triggers the load planning or load building process that entails deciding which SKUs should be placed on a single truck constrained by weight and volume limitations. After load planning is completed, the shipment process begins. Transportation carriers are then contacted to request for required capacity. Upon acceptance of the load by a carrier, load pick-up planning is done. Subsequently, the load is picked up and transported to the warehouse.

Instead of waiting for orders to be placed, would it be beneficial to ship a certain amount of the expected demand for that product proactively? Both financial benefits and risks are associated with setting up this type of distribution structure. The focus of this thesis is to provide an analytical framework to maximize the benefits while minimizing the risks. Some benefits include shorter lead-times, decreased transportation costs, and warehouse cross-docking. The major risk is the potential to increase inventories and consequently the inventory holding costs. To take advantage of the savings while managing the risks, the framework determines which SKUs are eligible and how much of each SKU should be shipped proactively.

Methodology

The focus of this study is a plant-to-warehouse lane. To determine the optimal steady flow on the plant-to-warehouse lane, the demand data from the warehouse out to the customers was utilized. This data was aggregated to a weekly level, and the unit of measure for time used in this model was a week. The overall approach that was developed to determine the steady flow is shown in Figure 1.

The process is as follows. Starting in boxes 1 & 2 (Figure 1), SKU level forecast and historical data are used to characterize the demand. First, descriptive statistics (box 3) of the demand are calculated. In order to do this, a determination needs to be made as to how much data would be used for these calculations.

In other words, how many weeks of historical data (say, *H weeks*) and forecast data (say, *F weeks*) should be used? The number of weeks for each are input parameters that can be tuned. The calculated statistics from the specified timeframe (*H weeks* + *F weeks,* henceforth called "model horizon") include mean of demand, standard deviation of demand, coefficient of variation (COV) of demand, minimum demand, as well as percentage of weeks with demand (non-zero values). Only weeks with demand (non-zero values) are used to calculate the mean, standard deviation, COV, and minimum demand to ensure the statistics were not affected by weeks without shipments. Next, a forecast check is performed (box 4) by analyzing the full length of available forecast data to determine the percentage of forecast weeks with a non-zero demand. This check is performed to filter out any SKUs that are being phased out of production.

These summary statistics are then used to determine whether the SKU is eligible for steady flow (box 5). If the SKU is found to be ineligible, it is marked as such and disregarded (box 6). If a SKU is found to be eligible, its optimal steady flow is then calculated (box 7). The optimal steady flow is chosen by maximizing total savings, which includes transportation savings, cross-dock savings, and cost of excess inventory. Figure 2 shows the calculations used.

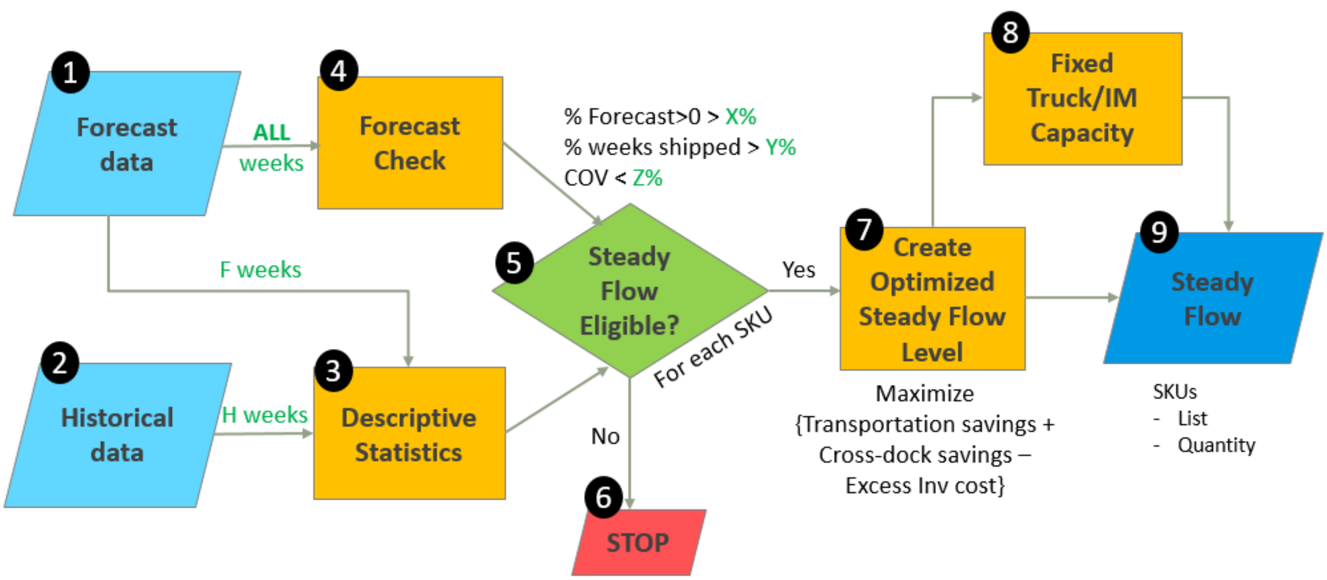

Figure 1 – Steady Flow Calculation Framework

$$Total\ Savings = Transportation\ Savings + Crossdock\ Savings - Excess\ Inv\ Cost$$

$$Objective\ function: MAXIMIZE\ Total\ Savings$$
$$Decision\ Variable: Number\ of\ Pallets\ on\ Steady\ Flow\ (s)$$

$$Transportation\ savings = \sum_{i=1}^{n} (\mathrm{s} * \mathrm{j} * \mathrm{p})$$

$$Crossdock\ savings = \sum_{i=1}^{n} Min(s,\ d_i) * c_s * c_e$$

$$Excess\ Inv\ Cost = \left\{ \sum_{i=1}^{n} \mathrm{Max}((e_{i-1} + s - d_i),0) * j * h * v \right\} + \{\mathrm{Max}((e_{n-1} + s - d_n), 0) * j * v * r\}$$

Figure 2 – Steady Flow Optimization Framework

Definitions (units)
n = # weeks in model horizon (weeks)
s = number of pallets on steady flow (pallet)
j = % of truck that a pallet represents – based on weight and volume (truck/pallet)
p = transportation savings per truck ($/truck)
d_i = demand for week i (pallet)
c_s = cross-dock savings per pallet ($/pallet)
c_e = cross-dock eligibility: $0 \le c_e \le 1$ (dimensionless)
e_{i-1} = excess inventory running total in week i-1; e_0 = 0 (pallet)
h = inventory holding cost ($/$/weeks)
v = inventory value ($/truck)
r = end of period risk factor (%)

Optimal steady flow is calculated for every eligible SKU. An optimization is then performed to select the best mix of SKUs that maximizes total savings while conforming to a minimum vehicle capacity utilization constraint. This collection of SKUs and their corresponding quantities for steady flow is the model's final output and recommendation (box 9).

The first six months of weekly steady flow is studied to calculate the average and minimum number of trucks/containers required for the steady flow of products. Once the steady flow of containers is determined, it is used as an additional constraint in the final SKU selection process (box 8).

Test Lane Results

The methodology developed was tested using data from the sponsor company's North American operations. One high volume plant-to-warehouse lane with more than 1,000 SKUs was chosen to calculate the steady flow using a set of input parameters, and the impact on the model's performance when changing those parameters was studied. Figure 3 shows the optimization result for a sample SKU. As the steady flow increases to up to 9 pallets a week, the transportation and cross-dock savings continue to rise without incurring noticeable excess inventory costs. However, as the steady flow is increased beyond 9 pallets per week, the excess inventory costs rise rapidly. The total savings are maximized at 11 pallets per week. The optimal steady flow determined for this SKU was in between the minimum pallets shipped and the mean pallets shipped over the model horizon.

It was observed that as a SKU's COV gets higher, the optimal steady flow moves closer to the minimum of the demand. As the variation in demand goes up, a higher steady flow increases the excess downstream inventory risk.

As the percentage of weeks with demand decreases in the model horizon, the steady flow also gets closer and closer to the minimum. In other words, the more weeks that have zero demand for any given SKU the closer the steady flow will be to the minimum amount of demand.

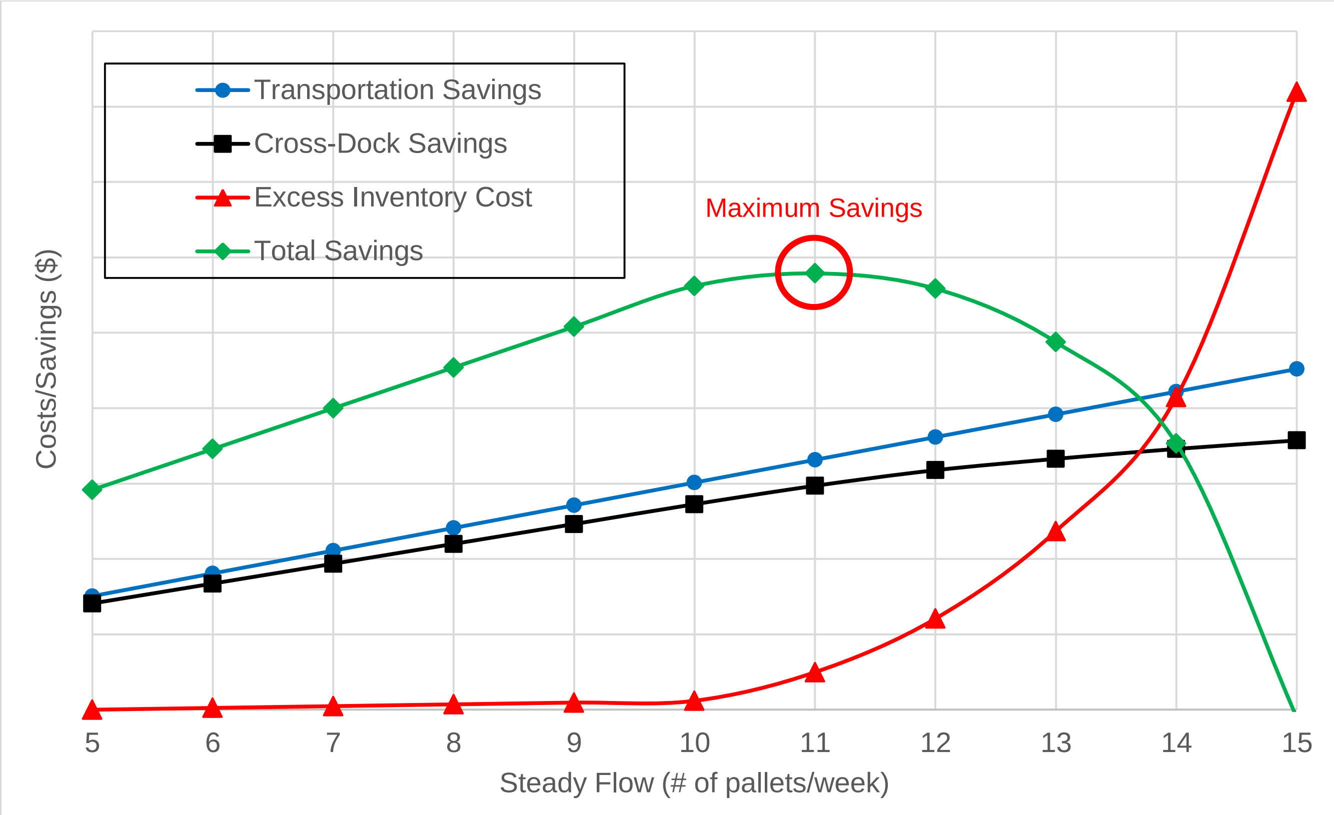

Figure 3 - Sample SKU Savings Optimization

Conclusion

The goal of this thesis was to develop an analytical framework for determining the products that could flow on an intra-company lane regularly. This steady flow of products between supply chain nodes can lower transportation costs, increase cross-dock productivity, as well as dampen the bullwhip effect upstream in the supply chain. This research was done in the context of a plant-to-warehouse lane of a fast moving consumer goods company.

The methodology developed in this research utilizes historical and forecast data to characterize the demand. Descriptive statistics are used to determine whether a SKU is eligible for steady flow. Subsequently, transportation cost savings, cross-dock savings, and excess inventory considerations are used to optimize the quantity of each eligible SKU on steady flow. The model considers additional business constraints of vehicle capacity utilization and then recommends a final list of SKUs and quantities for the steady flow. This methodology was tested on a high volume plant-to-warehouse lane. Insights about the relationship between the variation in demand and steady flow were presented. As the coefficient of variation decreases, the optimal steady flow moves closer to the mean of the non-zero historical demand and selected forecast over the model horizon.

Areas for future enhancements to this framework include optimal data aggregation, forecast accuracy implications, expansion of cost considerations, and implications on DRP. This research opens up the possibility of realizing cost savings by decreasing transportation costs and improving warehouse productivity, paving the way for innovative contract types with transportation providers. This framework allows shippers to bridge the gap between steady flow theory and implementation.