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Research Report: ZLC-2016-1
Inventory Optimization as a Business Advantage
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Inventory Optimization as a Business Advantage

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Summary:

This thesis addresses the performance optimization of the supply chain network for a chemical company that has its manufacturing base in Europe and serves the customers in the Latin America. With an objective to achieve the right balance between net working capital and speed of response, the scope of the work includes studying the segmentation strategy, optimizing the inventory policy and modifying the supply chain network.

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KEY INSIGHTS

1. Scientific methodology and tools fit perfectly with business strategic evaluations, mainly due to the possibility of building simulation models and analyzing different scenarios to support the decision making process.
2. Discrete Event Simulation (DES) is a powerful tool to evaluate the performance of the network configuration in uncertainty given the complexity of the Latin American market leading to non-stationary demand distributions.
3. Operational and financial decisions, like finding the right balance between Net Working Capital (NWC) and speed of response, should be made simultaneously to maximize the value for shareholders.

Introduction

In the wake of the collapse of Lehman Brothers in 2008 and the subsequent economic crisis, the nature of supply chain planning (inventory stocks, in-transit inventory and free-up of working capital) is at a center stage as never before. These economic failures did not only eradicate equity wealth for unlucky or irresponsible shareholders but also imposed system-wide risks for the entire supply chain due to diminishing available external source of investment. Inventory management can play a role in terms of generating cash instead from internal operations optimizing available working capital. To this end, companies are advised to focus on the operational side of the supply chain as an effort to increase their available working capital in the area of inventory management. Typically, a considerable amount of working capital is locked in current inventories due to forecast inaccuracies and oversized service level targets. This in turn unveils the criticality of effective inventory management in securing working capital and synchronizing product flows in light of demand and supply variability. As such, working capital is inextricably connected to having the right amount of inventory in the right place at the right time. Within this setting, inventory management seems not only to promise strengthening the working capital but also acting as a safeguard for customer satisfaction, supply continuity and financial growth that are critical for long term sustainable success for any organization.

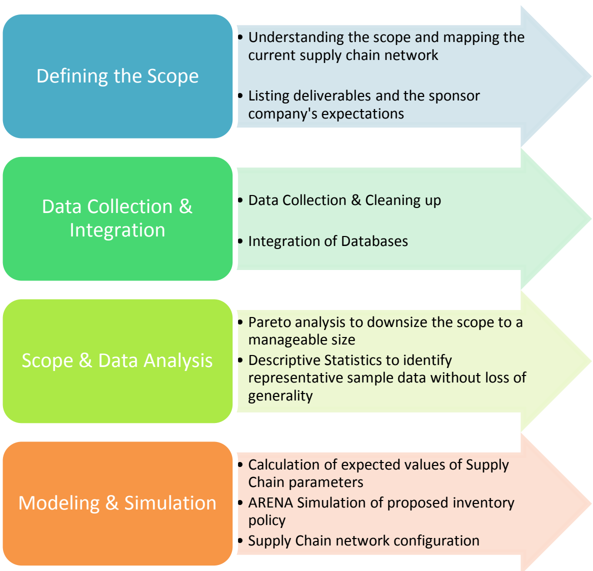
The sponsoring company of this thesis project is a leading manufacturer in chemical industry with Business-to-Business (B2B) worldwide operations. The focus of this thesis project is on their operations in Latin America of one specific Business Unit (BU). The problem that the company anticipates is that the replenishment process of the warehouses in all the regions lacks transparency and differs from region to region. This leads to firefighting situations and requires a lot of manual and time consuming efforts from the managers. Optimal inventory levels are not known in every location. The present work sets out to unveil how the company in case could optimally utilize the current network configuration to minimize supply chain costs and potentially investigate an alternative ('To-Be') supply chain network configuration. To this end, our two guiding research questions are as follows:

a. What are the key factors influencing safety stock placement in a single/multi-echelon network?

b. What is the right balance between Net Working Capital (NWC) and the speed of response?

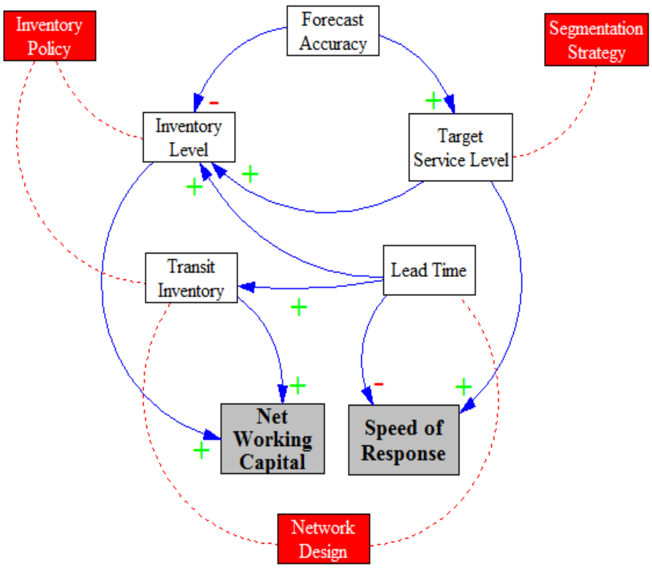
Methodology

Due to the large scope and multi-disciplinary aspect of the project involving data treatment, statistical analysis, mathematical modeling, stock policy development and simulation, a multi-stage roadmap was developed to tackle this problem and all steps to be followed are presented in the figure below.



The sponsor company's expectation is to find the right balance between net working capital and the speed of response that gives them a competitive advantage. As per the current business dynamics in a B2B environment, customer orders are either fulfilled on-time from available stock or with the arrival of the next replenishment shipment. While the former constitutes a faster speed of response, the latter represents a slower speed of response and might lead to customer dissatisfaction in the short term and potential loss of customer in the long term. In other words, speed of response is measured by the percentage of On-Time In-Full (OTIF) fulfillment of the customer's orders. Due to the large extent of this project, the scope has been limited only to Latin American markets, which is relatively small but also the most challenging from a supply chain perspective due to fluctuating demand, governmental regulations and macro-economic factors. There are 16 affiliate warehouses in 8 countries spread across Latin America to cater to demand from the respective regions. There also exists Global DCs in Europe which serve replenishment shipments according to the orders from affiliate warehouses in Latin America. The orders from the end-customers are directly shipped from the closest affiliate warehouse in Latin America. The scope of the project is confined to the replenishment strategy between Global DC in Europe to Affiliate warehouse in LatAm. This means, it is assumed that the manufacturing capacity is unconstrained within the scope of the project. Apart from optimizing the performance of Latin American supply chain network, the overall target of this project also includes preparation of a generic business model that will be utilized as a key value chain for a pilot business unit within the sponsor company.

A study was done to understand the interaction between the factors that impact NWC and Speed of Response. The factors considered are Forecast accuracy, Inventory Level, Transit Inventory, Target Service Level and Lead Time. The complex interactions between these factors are depicted in the below figure, which is the result of brainstorming sessions with supply chain experts. The arrow heads indicate the impact of the preceding factor on the succeeding factor and the symbol on top of the arrow head depicts the nature of impact. For example, improving forecasting system leads to higher forecast accuracy, which in turns reduces the uncertainty and hence the need to hold higher safety stock. Lower safety stock would lead to less capital tied in inventory thereby reducing NWC. Based on this study, we reached a conclusion that these factors can be directly controlled by three aspects of the Supply Chain – namely Segmentation Strategy, Inventory Policy (IP) and Network Design.



Segmentation

In order to differentiate the replenishment process for each SKU, the two factors considered are - importance of SKU in sales and the predictability of demand. In order to study the importance of a product in a region, all SKUs are sorted by their Contribution Margin (CoMa) and classified into three categories – A,B & C- based on their profitability. While 'A' class SKUs are highly profitable, 'C' class represents the least profitable. Similarly, all SKU's are classified into three categories – X, Y & Z – based on their forecast accuracy. While 'X' class represents most predictable SKUs, 'Z' class represents least predictable. The combination of these two classifications (A, B, C) & (X, Y, Z) results in 9 categories and their target service levels are present in the following table.

TARGET SERVICE LEVELS

	A	B	C
X	90%	75%	60%
Y	85%	70%	55%
Z	80%	65%	50%

The rationale behind these target service levels is to increase the net margin by increasing product availability for highly predictable SKUs while not holding too much of inventory as buffer stock for uncertainty. Hence, higher service levels are assigned to highly profitable and highly predictable(For example AX category) SKUs to generate higher net profits while lower service levels are assigned to least profitable least predictable SKUs to reduce working capital (for example, CZ category). It was learnt during the interviews with Sponsor Company personnel that, backorders do not become lost revenue and usually all backorders are fulfilled at a later date. The only risk is to lose the customer due to repeated delay in fulfillment of orders. Hence, within a profitability category (for example, Category A), precedence is given to the holding costs over underage costs (such as lost sales) – leading to assigning higher target service levels for AX when compared to AZ.

Inventory Policy (IP)

The inventory planning process establishes the optimal inventory levels that must be maintained at affiliate warehouse to meet expected service levels for demand fulfillment. The model used for modeling and simulation is the Order up-to level with a periodic review. Not only this is the best policy for a joint replenishment inventory systems (Viswanathan, S. 1997), but also the preferred mode of inventory policy from the sponsor company due to practical constraints on human resources and IT infrastructure. Descriptive statistics showed that the demand doesn't follow a normal behavior irrespective of aggregating on daily, weekly or monthly basis. Discrete Event Simulation (DES) model is built to examine various types of inventory policies in ARENA software. The inputs to the DES model include – demand, forecast, lead time and target service level. The model is configured to simulate three different types of inventory policies – Normality, Stationary optimization & Evolutionary optimization.

In an IP based on Normality, the demand is assumed to follow Normal distribution, in which case, important parameters can be calculated as given below.

σ_{L+T}	=	$\sigma_f * \sqrt{(L+T)}$
SS	=	$F\text{-}1(CSL;0;1) * \sigma_{L+T} * 1.25$
OUL	=	$D_{T+L} + SS$
Expected Transit Inventory	=	$D*L$
Expected Backorder	=	$\sigma_{L+T} * L(F\text{-}1(CSL;0;1))$
Expected On-hand Inventory	=	OUL - D_{T+L} + Expected Backorder

L : Lead time for replenishment

σ_{L+T} : Mean Absolute Deviation during L+T periods

T : Reorder interval

CSL : Cycle service level

D : Demand Forecast per unit time

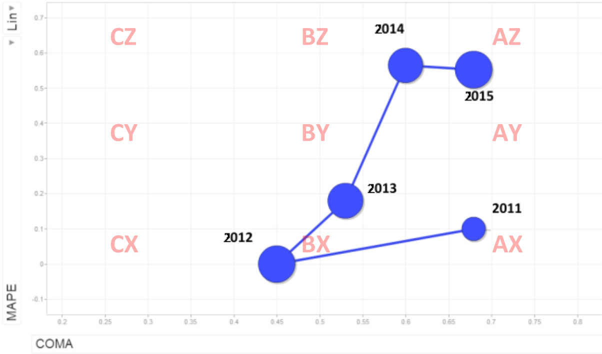
OUL : Order up to level

σ_f : Mean Absolute Deviation(MAD) per period

SS : Safety Stock

D_{T+L} : Mean demand during L+T period

An IP based on Stationary optimization, Opt Quest module, equipped with ARENA software, is used to perform non-linear optimization. The objective of the optimization is to arrive at the optimum safety stock while minimizing the Total cost, which is the sum of Inventory holding cost and Transportation cost, and meeting the target service levels. It is called as Stationary model because though the overall business of the sponsor company had gone through many changes with time, the SS remains constant across the time period of the simulation. But significant changes to business dynamics calls for changes in two keys aspects of the supply chain model – the segment the combination belongs to and the amount of safety stock. The change in segment over time in one case is illustrated in the figure below.



The size of the bubble represents the annual volume and it is plotted over Contribution Margin (X-axis) and MAPE (Y-axis). Hence the Cartesian plane is divided into 9 segments and we can see how the given combination jumps different categories in different years.

In an IP based on evolutionary optimization, SS is allowed to be updated on a periodic basis as we learn more about the business trends. It is worth noting that the number of decision variables significantly increase in evolutionary models when compared to a stationary model. This makes it not only computationally more challenging but also more time-consuming. There are two types of evolutionary optimization approaches. Multi-variate evolutionary optimization can be considered similar to running many stationary optimizations simultaneously for every period, as the SS is allowed to be updated. Whereas with the exponential-smoothing based evolutionary optimization, the only difference is that SS is a derived variable that is calculated by the equation below, unlike models where SS is an output of optimization.

$$SS = \alpha * SS_B + (1 - \alpha) * \varepsilon_{L+T}$$

Where:

SS = Safety stock for a given time period – a month in this case

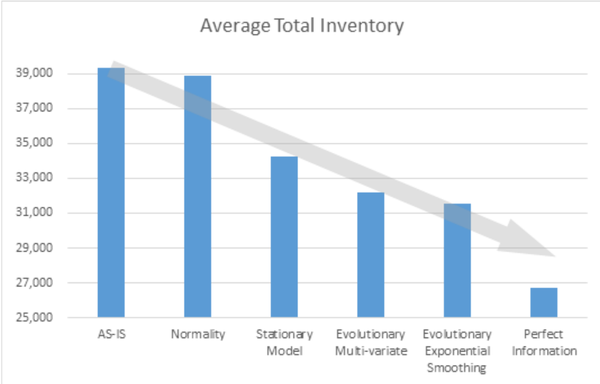
α = Exponential smoothing constant, a value between 0 and 1

SSB = Base safety stock, a constant

ε_{L+T} = Forecast error in the past (L+T) period

The two extremes of the proposed policy are when α = 0 or 1. When α = 1, SS = SS_B, which is a constant. In other words, α = 1 represents a passive stationary model where SS doesn't change with time. On the other hand, when α = 0, SS = ε_{L+T}. This indicates an extremely reactive model that updates SS every month according to the forecast error of past (L+T) periods. The proposed evolutionary model under exponential smoothing (where 0 < α < 1) is a middle ground between the two aforementioned passive-reactive extreme models. In this scenario, the Opt Quest module of ARENA is used to find optimum values of α and SS_B while minimizing the total cost under the constraint of meeting the target service levels for the given time period.

The figure below depicts graphically depicts the reduction in inventory levels in one case through adoption of different aforementioned models.



While AS-IS represents the current average annual inventory level held by the sponsor company, Perfect information represents the expected average annual inventory when we have perfect information of arriving demand, i.e. forecast = demand eliminating the need for safety stock. The objective is to get as close as possible towards average annual inventory of perfect information from the AS-IS scenario. More detailed results of the 20 combinations from all the models are compiled in the below table.

Average Total Inventory					
Combination	AS-IS (1)	Normality (2)	Stationary Model(3)	Evolutionary Model Multi-variate(4)	Perfect Information(5)
1	39,292	38,903	34,252	32,197	26,723
2	26,916	26,132	24,270	22,814	19,392
3	20,499	19,902	20,683	20,269	18,242
4	32,184	30,651	23,021	20,949	18,435
5	42,468	42,897	17,988	16,909	14,541
6	36,768	35,354	21,130	19,017	16,545
7	20,731	20,731	22,938	21,562	19,406
8	26,780	26,515	16,465	15,477	13,156
9	19,190	19,190	16,232	15,583	12,778
10	23,301	23,070	15,888	14,776	12,855
11	23,033	21,936	15,020	14,119	12,848
12	23,761	23,761	18,092	17,730	15,603
13	25,491	24,277	12,011	11,290	9,710
14	17,588	17,076	9,085	8,449	7,182
15	16,828	25,651	23,859	23,620	20,786
16	9,335	9,063	6,717	6,448	5,546
17	32,275	31,642	10,458	9,831	8,553
18	5,918	7,212	6,973	6,903	6,213
19	7,636	7,636	5,214	5,162	4,129
20	6,025	5,793	5,530	5,309	4,619
Total	**456,019**	**457,392**	**342,016**	**308,414**	**267,260**
% of AS-IS Inventory		100%	75%	68%	59%

While implementing normality-based inventory system might give marginal benefits from current inventory levels in certain cases, stationary & evolutionary models present much more benefits by reduction in inventory by over 25% and 32 % respectively from the current scenario.

Network Configuration

Simulations were run with the top SKU and stationary model is adopted to understand the impact of adding a DC on inventory levels and costs. Due to nature of the Sponsor Company's business model, adding a DC is not going to eliminate the need of running regional warehouses for two reasons. First, the regional warehouse serves all the Business Units of the Sponsor Company not just the one within the scope of this project. Secondly, serving end customers directly from DC is extremely difficult given the acceptable lead time to the customer is less than a week and it usually takes more than 10-30 days on average for custom clearances in Latin America. The results of the simulations are compiled in the following table.

	FACILITY	Replensihment from	Inventory			Cost		
			On-Hand	Transit	Total	Holding Cost	Transpn Cost	Total Cost
WITHOUT DC	Argentina	Europe	11,226	23,026	34,252	CHF 7,467	CHF 16,361	CHF 23,828
	Brazil	Europe	5,079	15,602	20,682	CHF 6,825	CHF 14,160	CHF 20,985
	Mexico	Europe	5,442	12,546	17,988	CHF 4,820	CHF 11,673	CHF 16,494
	Chile	Europe	1,342	3,408	4,750	CHF 1,249	CHF 3,071	CHF 4,321
	Colombia	Europe	1,105	2,224	3,329	CHF 755	CHF 2,406	CHF 3,162
			24,194	**56,806**	**81,001**	**CHF 21,116**	**CHF 47,671**	**CHF 68,790**
WITH DC IN MEXICO	Mexico DC	Europe	16,260	48,935	65,195	CHF 17,472	CHF 47,632	CHF 65,104
	Argentina	Mexico DC	13,449	6,012	19,461	CHF 5,215	CHF 16,821	CHF 22,037
	Brazil	Mexico DC	5,478	2,732	8,211	CHF 2,200	CHF 14,547	CHF 16,748
	Chile	Mexico DC	1,998	596	2,595	CHF 695	CHF 3,113	CHF 3,808
	Colombia	Mexico DC	1,095	455	1,550	CHF 415	CHF 2,368	CHF 2,784
			38,280	**58,730**	**97,012**	**CHF 25,997**	**CHF 84,481**	**CHF 110,481**

Though the amount of safety stock required at each facility has decreased by virtue of aggregation and reduction in lead times by adding a DC, we've observed an increase in total inventory levels and total costs after adding a DC when compared to before. This could be explained by two reasons. First, increase in inventory levels despite decrease in safety stock is attributed to increase in number of stocking locations. For example, inventory for catering to Argentinian demand is stored in both DC and then in the warehouse in Argentina. Secondly, increase in transportation costs is attributed to overall increase in ton-miles due to addition of another node in the supply chain network. Also, there would be additional costs of running a DC that are not captured in the simulation. From this analysis, we recommend against adding a DC in Latin America.

Conclusion

This thesis project emphasizes how multi-step approaches are able to breakdown larger problems and handle large amounts of data, whilst keeping the results accurate. In addition, it is evidence that scientific methods and tools such as discrete event simulation can not only be used to support or validate companies' decisions but also to optimize them. Throughout the thesis, many different tool and techniques such as probability distributions, demand aggregation, stock policies, discrete event simulation and non-linear optimization were used in order to handle the data and enable us to build models and propose recommendations. This clearly poses the multi-disciplinary aspect not only of our project, but also of many supply chain related challenges that companies need to meet on a daily basis.

Latin American market is relatively small but more challenging from supply chain standpoint due to complexity driven by non-stationary demand distributions. Descriptive statistics showed that the demand doesn't follow normal behavior irrespective of aggregating on a daily, weekly or monthly basis. The evolutionary inventory models and dynamic segmentation discussed in the thesis would help the sponsor company to plan better with these non-stationary non-normal demand distributions. Consequently, the output of the non-linear optimization of the DES Models presents the optimal safety stock for the Sponsor Company's current network. Three different models were discussed for inventory policy – Normality, Stationary & Evolutionary optimization each having not only increasing benefits of inventory levels and costs but also increasing difficulty in consistent implementation in large organizations. Our proposal to the company in the short term and long term will optimize their costs, however, preliminary results recommend against opening a centralized distribution center in Latin America due to the increase in both inventory levels and costs.

Cited Sources

Viswanathan, S. 1997. "Periodic Review (s,S) Policies for Joint Replenishment Inventory Systems." *Management Science* 43 (No.10): 1447-1454.