

Optimization of inventory level at Oilfield services: Case Study

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Abstract— This work is done at ABC in Supply Chain domain. ABC is the world's leading product and service provider to customers working in the oil and gas industry worldwide. The objective of this project is to ensure that optimal level of inventory is held, balancing the needs of maintaining high service levels needed to support operations, versus the working capital and costs associated with carrying the inventory. This was done by analysing the historical inventory data of past two year and figuring out the trends. The information obtained helped in establishing minimum, maximum and target levels for the ordering of all reoccurring stocked inventory. The scope of project is restricted to Inventory Management of ABC-Well Services.

Index Terms— Inventory, Lead Time, Oil fields, Service level

1 INTRODUCTION

The intricate nature of the oil and gas industry offers a classic model for inventory control and management techniques. This industry is spread over the world in various geographic locations to tap the oil and gas reserves at lowest possible cost, as a result a large number of oilfield service companies are increasing their global footprint in order to support these worldwide operations. The typical business cycle in the oil and gas industry starts at the exploration phase and passes through various phases such as production, refining and marketing before it reaches the final customer. Such an interface between various phases represents different companies where output of one phase is connected to next phase leading to formation of a forward linkage. In this regard the efficiency of a supply chain can be crucial to the success of any company. Inventory management plays a critical role in success of such a unique supply chain.

ABC provides integrated project management, information solutions and technology to its customers working in the oil and gas industry worldwide. It has a wide product and service portfolio covering seismic and geophysical services, drilling, production, business solution, well services etc. Out of many business functions, ABC- Well Services function was chosen for purpose of study. Due to uncertain business environment demand for products and spare parts vary significantly thus the challenge of avoiding stock out while encumbered by high inventory costs has been a continuing problem. While uncertain about demand significant fluctuation in lead time, ABC- Well Services is simultaneously experiencing fluctuation in lead time.

The main emphasis of this paper is to optimize and align their (ABC Asia Services Ltd - Well Services) inventory deployment with desired service levels. The paper recommends a systematic approach towards the management of inventory

based on the framework of a Min-Max model, which will improve control and management practices of inventory. Section 2 discusses work of various researchers related to inventory optimization and control under different circumstances. Section 3 discusses the methodology adopted to optimize inventory levels. Section 4 discusses the results which would be obtained after implementation of proposed inventory planning. Section 5 summarizes the entire work done in paper and defines future scope

2 LITERATURE REVIEW

Various researchers worked on issues related to inventory optimization and control. The research work done is highlighted as follows-

Scarf provided mathematical foundation to Min-Max modelling technique in [1] used in present oilfield services case. Silver in [2] identified that a gap exists between theory and practice of inventory management in many organizations and suggested for bridging this gap through use of operations research techniques. Skouri and Papachristos studied continuous review inventory model in [3]. They considered five significant costs: deterioration, opportunity cost, shortage, holding due to the lost sales and the replenishment cost per replenishment and developed a model which ensured the existence of a unique optimal policy and proposed a mathematical algorithm to find it. Chima investigated in [4] the role of managing the supply chain in the petroleum industry and discussed the application of the Uniform Commercial Code to address supply-chain management issues. Soshko and Vjaks in [8] presented a case study of Latvian Distribution Company on enhancing inventory management by focusing on application of different modelling techniques in inventory management under uncertainty, namely inventory models, simulation models and

optimization models. Liao and Chang proposed in [9] the use of metaheuristic combined with exponential smoothing methods to forecast future demands and to determine the optimal inventory policy based on historical demand without the need of any prior knowledge about the demand distribution. Chalapong and Lazarus explored in [5] efficiency gain via supply chain optimization through examining and assessing opportunities for ABC Company to employ statistical inventory models, understand a variety of factors influencing inventory levels and costs, and improve its network structure. King in [6] facilitated understanding and determination safety stock amid uncertainty regarding lead time and demand. Sicilia, Febles-Acosta, & Rosa in [7] discussed deterministic inventory to optimize total inventory cost for business enterprises where both holding cost and deterioration rate are dependent on time.

3 METHODOLOGY

The main aim of project was to create a model to optimize ABC- Well Services' current inventory requirements and provide a Min/ Max and target average level on per SKU. After analysing the current process, it was decided to identify fast moving items on which Min-Max planning would be carried out as fast moving items formed bulk of inventory. Fast moving items were identified using historical consumption pattern as they had consistent use over time. The figure 1 depicts general demand pattern of a runner item. Runners have consistent usage for a period.

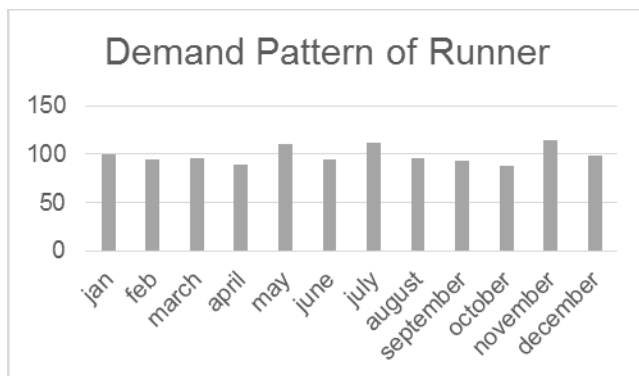


Fig 1 Demand Pattern of Runner

Min-Max planning is the preferred method of planning and procurement of regularly used items. Min-Max planning system sets predetermined ranges within which the inventory position should fall. During the planning phase, the minimum and maximum levels were set in the store for identified part to guide the store manager. There are six key inputs like historical usage, lead time parameters, demand forecast, price of unit item, ordering constraint, inventory on hand for establishing minimum and maximum levels. Key inputs to

setting minimum and maximum levels are as depicted in diagram:

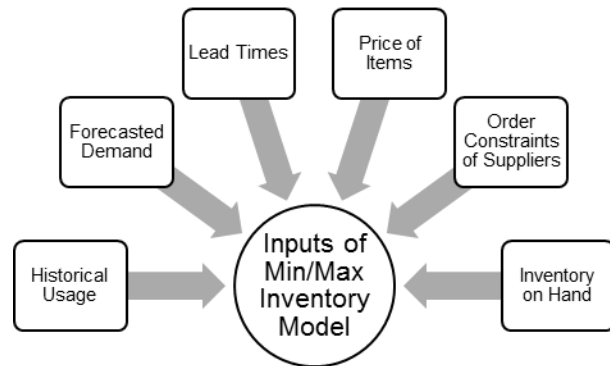


Fig 2: Inputs to Min-Max planning (ABC)

Min-Max planning comprised of a minimum value (or reorder point) and a maximum value. The minimum value is made up of two parts: safety stock and demand during lead-time (average lead-time in days multiplied by the average demand in days). This will allow to account for the materials' lead time and demand variability. Maximum value comprises of minimum value and EOQ/optimum quantity.

Once fast moving items were identified their corresponding lead time calculations were done based on historical data i.e. using purchase order (PO) creation date and good receipt note (GRN) date and current RDC (regional distribution center) lead time data. In absence of Goods receipt note date on certain occasions logistics tracker sheet containing custom clearance date and delivery date was used as a proxy for GRN date. Following sub-sections compute lead time parameters and perform ABC classification which are used to estimate safety stock levels.

3.1 Lead time calculations

Lead time calculation method

- Obtain records of all Purchase orders raised in the previous 2 years for all inventory items under consideration.
- Obtain GRNs records for all POs raised.
- Calculate the average lead time, standard deviation and coefficient of variation of lead times for each item from PO and GRN records.
- Since historical lead times were not an accurate reflection of future lead times on account of recent development of RDC, obtained the newly documented average lead times from RDC catalogue for each item.
- Used the historical coefficient of variation of each item to calculate the standard deviation of lead time

for each item based on the newly obtained average lead times.

3.2 ABC Analysis

Categorizing inventory levels into an ABC classification system was next critical step in managing inventory. An ABC analysis is performed to better understand inventory within the store.

12-month usage value (\$) of each item was determined by using historical consumption data of past 1 year to find out how much a particular item was consumed in last 12 months and corresponding price of that item. Classification criteria is mentioned in Table 1.

Table 1: Classification criteria

12 Month Usage Value (\$)	Rank
Top 70%	A
Next 20%	B
Last 10%	C

Results of classification done as per mentioned criteria is shown diagrammatically in Fig 3. 59% of total items belong to "C" category, 28% of total items belong to "B" category and 13% of total items belong to "A" category.

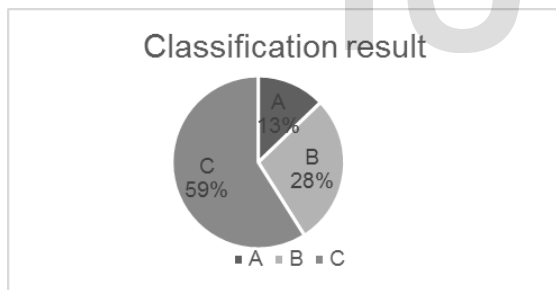


Fig 3 Classification Result

3.3 Safety Stock

Once average lead time calculations and inventory classification was carried out, safety stock on SKU level was calculated. The more inconsistent or uncertain demand becomes, the more safety stock is needed to buffer against changes in demand. The same applies for lead-time.

Safety stock equation used is given by expression below from [10]

$$SS = k * \sqrt{\mu_{LT} * \sigma_u^2 * \mu_u^2 * \mu_{LT}^2} \quad (1)$$

- μ_u = Average usage (per day)
- μ_{LT} = Average lead time (in days)
- σ_{LT} = Standard deviation of lead time in day

- σ_u = Standard deviation of usage
- k = Service level factor

The k-factor is z value taken from the normal distribution Table 2 and chosen based on the exhaustive empirical calculations of total cost associated with inventory (addition of carrying cost, ordering cost and cost of inventory) performed for targeted service levels of the inventory item through sensitivity analysis.

Table 2: Service levels

Category Ranking	Service level	k value
A	80%	0.842
B	75%	0.674
C	70%	0.524

3.4 MIN-MAX Levels

Once the optimal safety stock had been defined, the minimum stock level was calculated as:

$$\text{Min Stock Level} = \text{Safety Stock} + (\text{Daily Demand} * \text{Lead-time in Days}) \quad (2)$$

Calculated min level should be rounded off to next higher multiple of Minimum order quantity (MOQ) for ordering purpose. Min level served the purpose of Re-order point (ROP). It should be noted that adjustments to safety stock and minimum stock levels need to be made on a periodic basis and when large changes in consumption are forecasted. Once the actual order quantity has been defined, the maximum stock level was calculated as:

$$\text{Max Stock Level} = \text{Min Stock Level} + \text{Economic Order Quantity/Optimal quantity} \quad (3)$$

The EOQ calculation is used to find the optimal balance in cost between carrying stocks of the inventory and the transaction cost associated with making an order. The EOQ will define the optimal order size, according to the following equation:

$$EOQ = \sqrt{\frac{2 * \text{Annual usage} * \text{Order cost}}{\text{Carrying Cost} * \text{Unit Cost}}} \quad (4)$$

Where:

- EOQ = Economic order quantity
- Annual Usage = The forecast yearly usage at the location for the SKU
- Order Cost = Transactional cost associated with the order
- Carrying Cost = Annual carrying cost per unit expressed in terms of percentage of price of item.

Theoretically calculated EOQ in most cases was not exact multiple of MOQ and in certain cases EOQ was bound by shelf life constraints of items. Thus calculated EOQ was

adjusted using MOQ, MULT and shelf life of items to overcome such practical constraints.

Basic assumptions of simple EOQ model from [10] are:

- A continuous, constant, and known rate of demand
- A constant and known replenishment or lead time

There were certain items which were not following above mentioned assumptions on account of absence of demand for those items in a particular quarter or high standard deviation of lead time. Also certain items were having significantly higher lead time as a result a major component of Min level i.e. demands during lead time was substantially higher than corresponding EOQ. This violated the underlying purpose of having Min level (ROP) as EOQ was smaller than demand during lead time it would fail to trigger ROP after first order cycle.

To solve the above mentioned problem use of EOQ was forgone. A new strategy was adopted to place order of optimal quantities i.e. to place order of quantity by rounding off demand during lead time to immediate higher multiple of Minimum order quantity (MOQ). Then ordered quantity was subtracted from respective forecast of that quarter to get residual quantity, if this quantity was still greater than demand during lead time then same process would be repeated else residual quantity was rounded to immediate higher multiple of MOQ. Flow chart in Figure 5 depicts above mentioned process.

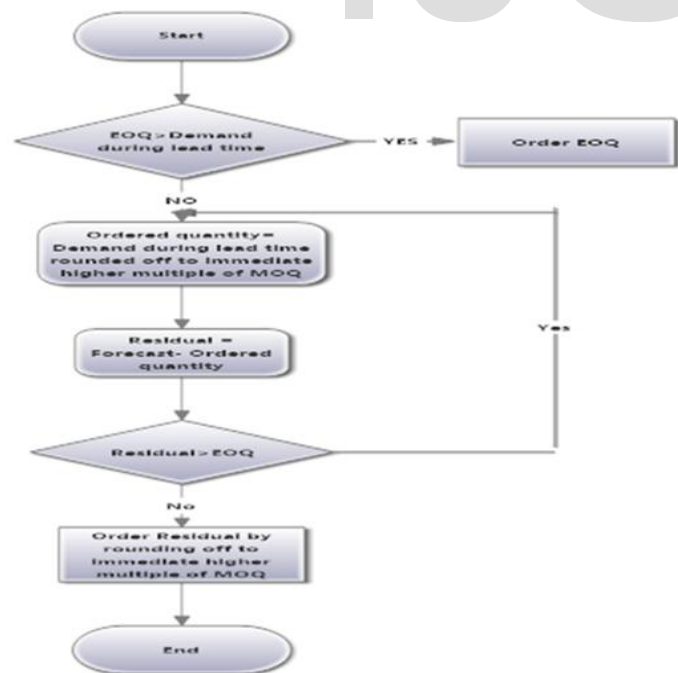


Fig 5: Optimal quantity ordering

Say for example if demand during lead time for item X is 110 units, forecasted quantity is 180, EOQ is 100, MOQ is 20 and safety stock for X is 30. Then optimal ordering quantity would

be 120, residual would be 160-120=40 thus next optimal quantity order would be 40. For few items on account of high lead time and high standard deviation of lead time Min level was greater than forecasted demand for the respective quarter. This resulted in holding higher inventory than desired level. In such cases respective forecast of that quarter was rounded to its immediate higher multiple of MOQ.

The setting of Min-Max levels allows for the projection of target inventory levels based on the minimum and the maximum. Figure 3 shows a general Min-Max cycle. The formula to calculate the target average inventory value based on Min-Max levels is below:

$$\text{Target Average Inventory} = 0.5(\text{Max}-\text{Min}) + \text{Safety Stock} \quad (5)$$

3.5 TOTAL RELEVANT COST

Finally TRC (Total relevant cost) i.e. carrying cost + holding cost was computed on quarterly basis for identified items using following equations from [10]:

$$\text{TRC} = A * \left(\frac{D}{Q}\right) + vr * \left(\frac{Q}{2} + SS\right) \quad (6)$$

Where:

- A= Setup cost
- D/Q = No. of times order is placed per annum
- v= holding cost per unit per annum
- r= unit cost of item
- Q= EOQ/ Optimum quantity
- SS= Safety stock

To function correctly, there are four key requirements of a Min/Max level planning system

1. **Physical count accuracy:** A Min/Max planning system is dependent upon the accuracy of the stock levels. In a Min/Max system, inaccurate stock counts will drive the procurement of unnecessary materials or insufficient materials.
2. **Regular review of Min/Max levels:** Min/Max levels must be reviewed, at minimum, quarterly, and should be reviewed more frequently if the activity level varies significantly. Not reviewing these levels regularly in-line with activity level changes will lead to excess inventory or stock-outs.
3. **Regular review of inventory position to calculate an order:** An order is calculated based on the relationship between the inventory position and the Min/Max levels. Inventory position is estimated using quantity on order, stock on hand and allocated issue quantity data.

$$\text{Inventory position} = \text{Quantity on order} + \text{Stock on hand} + \text{Allocated issue quantity} \quad (7)$$

Excess inventory or stock-outs will occur if the entire inventory position is not taken into account.

- 4. ABC Classification:** An ABC analysis helps to set safety stock levels based on service levels corresponding to each of category ranking.

4 RESULTS & ANALYSIS

This work was done from strategic point of view and its objective was to optimize inventory level so as to reduce overall cost associated with inventory and at same time ensuring desired service levels are met. After adopting this model there would be significant reduction in quantity of inventory held on quarterly basis as well as on annual basis and its associated cost as per theoretical calculation performed. Suggested model will obviate the need to hold unnecessary inventory. This model will increase the ordering cost but at same time significantly reduce holding cost, storage cost and cost of capital thus enhancing operating liquidity. The proposed model was initially applied on second, third and fourth quarter respectively since first quarter had already taken place. To gauge the benefits in terms of how efficiently inventory levels are optimized and its associated monetary impact same model was applied to the first quarter. There was 13% reduction in cost associated with inventory i.e. TRC in first quarter. Table 3 shows Min-Max, Target average level and TRC for six items from second quarter.

Table 3: Min-Max, Target average level and TRC

Item	Category	Forecast Quarter 2 (lb)	Min Quarter 2 (lb)	Max Quarter 2 (lb)	Target Average Level Quarter 2 (lb)	TRC per item Quarter 2 (\$)
ABC	A	5799.71	2702.86	3750	3779.57	272586.21
LMN	A	7967.28	3275.43	6595.772	6660.66	170260.84
XYZ	B	8387.56	3448.22	7114.889	2958.33	54519.18
JKL	B	72832.85	32832.54	63639.54	21924	69773.87
DEF	C	74157.95	52413.33	61219.67	4403.16	24101.33
PQR	C	6846	2815.71	5222.667	3861.48	3972.42

5 CONCLUSION

Inventory management is required within a location, plant, or distribution network to ensure the optimal level of inventory is held, balancing the needs of maintaining high service levels

needed to support operations, versus the working capital and costs associated with carrying the inventory.

A Min-Max model presents many opportunities for inventory optimization that the Well Services may pursue to reduce holding cost, cost of capital and obsolescence cost.

In this work we optimized inventory levels for the Well Services Function of ABC. This inventory model we recommended has the potential to offer significant cost savings.

6 FUTURE SCOPE

We discussed this work from single store for a single field perspective but it is found that there are many fields operating each with its dedicated store in a specific location. For increasing the efficiency we can club fields in nearby locations to form a unified regional market. This unified regional market can be served by a regional distribution center (RDC). RDCs would achieve the goal of aggregating “demand signals” from the downstream location stores to pass a consolidated demand to the upstream suppliers. Aggregated, these signals would less volatile, than those from individual location stores, thereby allowing the internal or external suppliers to plan professionally. The RDCs, could be strategically located in close proximity to regional market, cut down lead-time and variability in lead-time, thus helping safety stock at field locations to be reduced.

6.1 Inventory Classification And Tiering

Inventory would be classified using the methodology detailed in the Inventory classification Section, but at the aggregated location store level. In addition to location store level classification, a tiering analysis based on the number of locations actively consuming each item would be performed. Regional inventory tiering analysis would allow RDCs to set criteria for items to be considered for inclusion into any RDC. Only items falling in tiers 1 through 4 will be considered for inclusion in any RDC, barring few exceptions. A general guideline for tiering is below.

Table 4: RDC Tiering

Tier	Store Level Classification	Location using items within regional market
1	C	>= 4
2	AB	>= 4
3	C	Between 2 and 4
4	AB	Between 2 and 4
Single	Any	Only used in one location in the regional market
Dead	C	Items not consumed within regional market in last 12 months

6.2 Min/Max Level Planning For RDC

Details and formulas of the Min/Max level planning systems are described in more detail in Section D. However, the RDC should only use a minimum stocking level. All orders above a minimum stocking level will be driven by field order demand represented by POs placed to the RDC.

6.3 Setting Field Min/Max Levels for RDC Items

When there is a supporting RDC for a field location, the service level used to calculate safety stock for the field store level Min/Max items may be less than the service level for non-RDC supported items regardless of ABC classification. This is because the inventory is stocked in expectation of field demand at a logistically closer point. The variation of lead-time is less due to centralized stocking. Expediting is also simplified and less costly when centrally stocked.

6.4 Multi-Echelon Approach

Once RDCs are setup to serve regional markets Multi-Echelon approach could be used for optimization of entire network inventory level. The primary objective of using Multi-Echelon approach is to minimize the total inventory in all echelons (the RDC and all location stores) while meeting service commitments to end customers. Along with inventory, warehousing and transportation cost also are kept in check, because their cost factors are also considered in optimization process. Using multi-echelon approach, decisions regarding inventory replenishment and forecasting of demand are made in a single optimization exercise rather separately at location stores and at RDCs.

Multi-echelon approach should consider following points

- The primary field demand and other information at the location stores should drive the forecasts in all echelons.
- In each echelon, lead times and lead time variations should be accounted in replenishment decisions of all upstream suppliers, not just the immediate suppliers.
- The factors causing demand distortion should be identified and possible corrective actions should be taken
- Visibility of inventory i.e. inventory position throughout the demand chain improves demand requirements projections and reduction of safety stock levels
- Synchronizing the ordering cycles at the location stores with RDC operations reduces lead times and

lead time variation between the location stores and the RDC. Multi-echelon models can evaluate the impact on both echelons of different synchronization strategies.

- The RDC can provide different service levels (for the same items) to different location stores. A multi-echelon approach makes this possible by controlling how and when a product enters and leaves the RDC

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