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Optimizing Inventory Management at SABIC

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The need for a more cost competitive approach in the petrochemical supply chain of SABIC is rising, because of strong competition from the Middle East. Companies in the Middle East benefit from a cost advantage in feedstock prices, which becomes larger when the oil price increases. Using the better margin as a means, companies in the Middle East are expanding their capacity. At the same time, the annual growth in the ethylene demand has come to a halt. As a result companies outside the Middle East, such as Europe, are struggling to keep up with the Middle Eastern competition.

Reducing inventory levels is a common practice to free up working capital and consequently reduce costs in a supply chain. On the other hand, managing inventories wrongfully can have very costly consequences through possible non-optimal production (e.g. reduced production rates) and an unbalanced materials flow resulting in penalty costs for ships that are waiting to load or unload the material. How to optimize the inventory levels at SABIC was a long-standing challenge from SABIC’s Supply & Inventory Manager in the UK, who graduated from TU/e a number of years ago. It is the commercial team however, which has the largest influence on stock levels, by determining the levels where sale orders are being made. Optimization of stocks had traditionally not been on their agenda. Hence, the Supply & Inventory Manager needed a strong and convincing approach to show the commercial team how to optimize their inventory levels, subject to the risk of adjusting production plans as well as to the costs of working capital.

Eindhoven University of Technology was called to assist SABIC. SABIC’s request was to develop a comprehensive model for stock optimization. A project was defined that was aimed at finding the most cost effective stock level given current and future supply and demand patterns, and certain constraints.
The petrochemical supply chain of SABIC consists of multiple production plants that are decoupled through (large) storage tanks. The decoupling is necessary because the output of the production plants is not completely predictable. This explains why production of an intermediate product is not synchronized with the usage of that intermediate of the downstream plant. Without storage tanks, plants would be fully dependent on the lowest production rate in the chain. Furthermore, it would be impossible to have maintenance actions carried out without closing down the entire chain.

There are several reasons why there are fluctuations in demand and supply from the plants. Firstly, the composition of the input material (feedstock) can vary. Secondly, there can be technical disturbances in the plant itself. Thirdly, the plan that is made by the SCM department can contain errors, leading to a different output being generated than expected. Lastly, SCM may decide to change the feedstock mix based on the purchase costs of feedstock and the prices of the products it will yield at that specific moment, i.e. margin optimization. The combination of these uncertainties have been measured and analyzed in order to statistically capture these uncertainties altogether.

The products that are used and produced by SABIC are traded on the global market (commodities). This implies that most of the products of SABIC can always be purchased or sold; however, the price depends on the current market situation. The commercial team that purchases feedstock material, together with SCM, tries to anticipate on these price fluctuations; however, product price volatility has not been included in the study.

Figure 1 shows an example of a storage tank that is situated between two plants. Demurrage is a common way in the shipping domain to charge ship waiting costs. The storage tank serves as buffer to compensate for the fluctuations in demand and supply. However, additional demand and supply can be generated by shipping material in or out of the tanks. Other buffer situations that are in scope of the study are ones where there is only the possibility to have extra demand, or only extra supply. This is often determined by the technical capabilities of a plant or site. Besides buffers (plant-tank-plant), here are also tanks for feedstock (ship-tank-plant) and end products (plant-tank-ship).
The decisions that can be made in the supply chain to influence the inventory levels in a tank, besides adjusting the production and usage rates of the plants, are to order extra supply and to generate additional sales. The level in the storage tank that should trigger getting additional supply is denominated as $S_p$ (p for purchase) and the level that triggers extra sales is $S_s$ (s for sales). The amount that is purchased or sold is denominated by a fixed quantity $Q$. A normal situation should lead to a sawtooth stock level profile as shown in Figure 2.

Fluctuations in demand and supply, as well as uncertainty in ship arrival times, can lead to problematic situations as shown in Figure 3. Late ship arrivals can cause stock levels to rise further than anticipated (longer production before material is taken out of a tank). Furthermore, varying production rates may cause stock levels to rise more quickly or more slowly than expected. The uncertainties in production rates and arriving vessels introduce the probability of:

1. Tanks being completely full (blocking of supplying plant)
2. Tanks being completely empty (starvation of consuming plant)
3. Tanks having insufficient material available for the ship to load (ship has to wait)
4. Tanks having insufficient space for a ship to discharge its cargo (ship has to wait)
As blocking directly forces the plant upstream of the tank to stop production, starvation forces the plant downstream to stop production. These risks come with large financial penalties in terms of margin losses. Furthermore, the probability that ships have to wait before they can (fully) load or unload comes at a financial penalty as well, which is referred to as demurrage. The challenge of inventory management is to keep the stock level as low as possible while at the same time buffering against such uncertainties. Furthermore, building and maintaining storage capacity is very capital intensive and should be avoided when possible. SABIC aims at optimizing the working capital in its operations by trading off possible production margin losses, logistics costs such as demurrage and working capital. However, it was not explicitly known what inventory level was needed to buffer against the uncertainty in the supply and demand for a given storage tank. The commercial team sometimes argued that the storage capacity could be utilized to anticipate on price increases. However, price speculation should not be a criterion for stock management, as SABIC does not have trading as a core competence. The costs associated with having high inventories, including demurrage of ships not being able to discharge, were not at all explicitly known to the team. The Supply & Inventory Manager saw the need for a scientific approach to convince the organization to optimize stocks, which is why a project was started to create a formal model for this.
A stock optimization model was constructed to generate the optimal sales and/or purchase levels ($S_s$ and $S_p$) for a given stocking point and a given ship size $Q$. The model is a Monte Carlo based path simulation model, implemented in R-code, combined with MS Excel to get a more user-friendly simulation tool. The cost and input parameters are combined into cost curves, from which the optimal sales and purchase cost boundaries can be determined. The following cost elements have been modeled in the stock optimization model:

- Working capital costs for the inventory in the storage tank
- Loss of margin as a result of blocked/starved plants
- Logistical costs
- Demurrage costs when ships need to wait to be (dis)charged

The cost levels at different sales or purchase levels are calculated by means of the simulation model. An example of a cost curve that is generated using the model is given below. TRC stands for total relevant costs, which is the sum of all relevant cost components.
This cost curve applies to the situation where a storage tank is situated between two plants, say plant A and plant B, where A is supplying B, but A has a lower production rate than B (short, unbalanced buffer). Additional supply can be delivered by ships, and the model determines the optimal stock level where a quantity Q needs to be purchased. As can be seen in the figure, the costs vary with the purchase level (S_p) that has been set. When the purchase level is too low (the left side of the graph), the costs rise exponentially because the downstream plant B is starved. When the purchase level rises, an area of the curve is reached where the costs rise proportionally, mainly because the excess stock leads to extra working capital costs. When the purchase level rises even further, the costs rise again exponentially because the ships that are ordered cannot discharge Q into the storage tank immediately, which means that SABIC needs to pay demurrage costs to compensate for the waiting costs.

The study has shown that the shape of this curve as shown above is very typical for situations where the tank storage size is large enough, which is indicated by the middle section of the graph. If the tank is too small, the linear (middle) part of the curve is compressed and the cost curve is lifted, indicating SABIC cannot run the plants without the risk on margin losses and/or demurrage. This means that the inventory optimization tool can also be used to calculate the required tank size, as the resulting curve should have the middle section in order to get an acceptable cost level.

The first time the draft model was presented to SABIC’s management, it was greeted with enthusiasm. The management of the different businesses was immediately interested in the project and several members proposed to have a pilot in their part of the business. They recognized that their sales managers had a lack of guidelines to manage stocks, and perceived the tool as a means to objectively set a stock level.
Queuing Theory

The stock levels were determined using a mix of queuing theory and simulation modeling. In the simulation, the stock level is varied and the effect on the costs is calculated by calculation of the queuing effects. Moreover, the results of the simulation model were validated with transient queuing theory. This transient queuing model calculates the costs for specific inventory levels analogously to the simulation model and indeed shows that it fits the simulation based model quite well, confirming the validity of the approach. This implies that, although a transient approach presents some mathematical challenges, the study has proven the applicability of the transient queuing theory in such a practical context.
Together with SABIC, the inventory optimization tool has been implemented for a number of products in SABIC’s UK production site. The tool offers graphical support to the commercial team, clearly showing the optimal sales and/or purchase levels. Figure 5 shows the inventory level of one of the products in the pilot before and after the tool had been implemented.

The green area in the graph indicates the bandwidth for the decision makers for the preferred stock level. The choice was made explicitly to offer some freedom in determining the exact reorder level – the green area represents the size of a ship.
The pilot study shows the applicability and the positive financial effects of applying the tool. Besides a step change in the stock position (very significant reduction in the average inventory level), the team also noticed a more rhythmic planning of outgoing vessels. This lead (as expected) to a reduction of margin losses due to less changes in the production plans. Furthermore, it lead to a more efficient planning system, in which there was less ‘fire-fighting’: Less short term repair actions had to be carried out. In these competitive times, where there is a strong focus on reducing inventories, it is key to explicitly know how much stock is actually needed for an integral cost optimal supply chain.

The graduate student that carried out the project was offered a job at SABIC, which he accepted after graduating with honors at the Eindhoven University of Technology. One of his first assignments is to implement the stock optimization policy, using the tool that was developed during the graduate assignment. It is expected that the tool will eventually be implemented in the SAP APO planning application by SABIC.
The roll-out of the inventory optimization tool started for SABICs production site in the UK for one product group. The first results showed that the quantitatively determined sales and purchase levels match the expectation of the experienced members of the commercial and the supply chain team, and therefore make clear that the model captures the planning complexity rather well. The graph in Figure 6 shows the results of the stock optimization tool for the product groups where it has been applied.

The graph shows that for most situations, the inventory level has been reduced significantly by the new approach. For some products, the inventory has raised slightly, which means that the inventory level was probably too low, resulting in starvation or demurrage costs.

SABIC has experienced that the inventory management tool, which translates the quantitatively determined sales and purchase levels in an intuitive, graphical way, makes the decision about stock levels much more explicit. Consequently, it makes it very transparent when risks on margin losses and/or demurrage are being run, as well when inventory levels are unnecessarily large.

The following quote was taken from SABIC’s Supply & Inventory Manager: “the pilot shows step change in stock management and subsequently improvement in business performance. The optimization tool has led to reduced margin losses caused by empty or full tanks, while the costs for repairing infeasible plans have been significantly reduced. Next to that, in some product groups the overall
working capital position has reduced significantly. In addition, from a planning perspective, the benefits in planning efficiency are not to be missed. The implementation of the stock policy has reduced the amount of difficult discussions about sales decisions to be made and the planners can focus on their plan instead of on being in firefighting mode all the time.”

The tool can also be applied in assessing the storage capacity needs for a particular product or feedstock – a question that is commonly struggled with. SABIC developed a slightly adjusted version of the model, also taking into account the capital spent on maintaining tanks, which allows them to quantify the added value of having one additional tank. This proved to be very useful in justifying the necessity of additional storage capacity of feedstock storage.

The roll-out and refinement of the optimal stock targets has become one of the top priorities of the Director Supply Chain Chemicals Europe, showing the relevance and the support for the approach on senior management level.

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**About SABIC**

The Saudi Basic Industries Corporation (SABIC) was founded in 1976 by Royal Decree to convert oil by products into useful chemicals, polymers and fertilizers. SABIC is a diversified manufacturing company, active in chemicals and intermediates, industrial polymers, fertilizers and metals. It is the largest public company in Saudi Arabia as listed in Tadawul, but the Saudi government still owns 70% of its shares. Private sector shareholders are from Saudi Arabia and other countries of the six-nation Gulf Cooperation Council (GCC).

SABIC is the largest company in the Middle East. Production in 1985 was 6.5 million tons, five years later production rose to 13 million tons and by 2003 production had risen to 42 million metric tons. SABIC employs above 30,000 people globally and has 60 manufacturing and compounding plants in more than 40 countries.
References


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