

MULTI-LEVEL PRODUCTION PLANNING FOR MULTI-LOCATION
CHEMICAL COMPANY

by

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ABSTRACT

MULTI-LEVEL PRODUCTION PLANNING FOR MULTI-LOCATION CHEMICAL COMPANY

We investigate the decision-making process at a chemical company which is a major soda manufacturer having three production facilities in different countries. The company is one of the top ten largest soda producers in the world and serves as a major supplier to the global market with sales to over 50 countries. Complex sales and operation structures of company require synchronization of optimized decisions. Our study focuses on optimizing decisions from various levels which are strategic, tactical, operational and synchronizing them within and among organizations. In order to reach this purpose, we designed an integrated solution platform based on various optimization models. We fully implemented and deployed the solution platform, which has been used since 2020.

ÖZET

ÇOK ULUSLU KİMYASAL ŞİRKETİNDE ÇOK SEVİYELİ ÜRETİM PLANI

Bu çalışmada kimyasallar sektöründe faaliyetini sürdüren ve 3 farklı ülkede soda üretim tesisleri bulunan bir şirketin karar alma süreçlerini analiz etmekteyiz. Şirket dünyanın en büyük on soda üreticisinden biri olarak global pazarda 50'den fazla ülkeye ürün sağlamaktadır. Şirketin karmaşık satış ve operasyonel yönetim ağı farklı seviyelerde eniyelenmiş kararlara ihtiyaç duymaktadır. Bizim çalışmamız stratejik, taktik ve operasyonel kararların eniyelenmesine ve eniyelenmiş kararların organizasyon içinde ve farklı organizasyonlar arasında senkronize edilmesine odaklanmaktadır. Bu amaçla, herbiri kendi içinde eniyileme modelleri içeren entegre çözüm platformları dizayn ettik. Dizayn ettiğimiz çözüm platformları 2020 yılından itibaren aktif olarak kullanılmaktadır.

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LIST OF ACRONYMS/ABBREVIATIONS

BP	Budget Planning
BL	Bucket Length
CIF	Cost Insurance & Freight
CH	Customer Hierarchy
Ctr	Country
Cus	Customer
D	Day
DOH	Days on Hang
DSS	Decision Support System
FC	Forecast
Freq	Frequency
ERP	Enterprise Resource Planning
FOB	Free On Board
GUI	Graphical User Interface
KPI	Key Performance Indicator
M	Month
MRP	Material Requirement Planning
OP	Operational Planning
PF	Product Family
PF3	Third Product Family
PH	Product Hierarchy
SCDT	Supply Chain Development Team
SKU	Stock Keeping Unit
SP	Strategic Planning
S&OP	Sales and Operation Planning
TB	Time Bucket
W	Week
Y	Year

YTD	Year To Date
YTG	Year To Go

1. INTRODUCTION

In this study, we developed an integrated planning tool for a chemical company producing soda ash products. The company has three production facilities in different countries and serves in the global market as a major supplier. We initiated analyses and design processes in 2019. In 2020, we fully implemented four platforms, which are integrated with each other, enabling users to manage decision-making processes. The integrated platform has over 500 user interfaces and over 70 active users.

1.1. Challenges

First, soda ash is a commodity good whose price is typically determined by the market. The company can turn its stocks to sales immediately. Although the profit margin is dependent to the market and time, the company could always sell its products with a positive profit margin. Therefore, the company always aims to maximize production and sales to maximize its revenues.

Second, the company has multiple production facilities and customers in over 50 countries. One of the major challenges of the company is optimizing sourcing decisions. A customer can be supplied from a single factory or multiple sourcing units. If products are sold to right markets at the right time from the right location, profit and revenue could be maximized with given capacities.

Third, the company has been continuously growing with investments and acquisitions. Although volume growth is always an advantage, capacity increments should be planned in the right locations and for the right packaging technologies. If investments are managed efficiently, the company could grow in highly profitable markets with lower manufacturing and logistics costs.

Briefly, one of the primary goals of the company is to grow continuously by increasing profitability. This could only be achieved with correct strategic decisions in the long run. On the other side, the company has overly complex sales and supply chain infrastructures. Thus, realizing strategic decisions at a lower level is still significant challenge. This can be achieved with efficient and synchronized decision-making systems at the tactical and the operational level.

1.2. Roles and Responsibilities

In this section, we will mention roles and responsibilities of stakeholders using the platform as active user.

Supply Chain Development Team (SCDT) defines and manages the supply chain road map of the company. The team ensures supply chain capabilities can meet business requirements and takes required actions to reach this objective. During mid & long-term planning operations, the team gathers input from sales and planning teams, then analyzes the data, proposes scenarios over them, and shares the results with the leadership team. The leadership team makes final decisions based on the data provided by SCDT. When decisions are fixed, SCDT coordinates the business by providing an alignment between sales and planning teams.

Sales Team is responsible for developing customers, proposing contracts to customers and projecting all sales activities. In the long term planning, the team shares existing and proposed contracts, anticipates volume and price scenarios for future customers. These predictions are based during the strategic decision-making process. In mid term, sales team manages contracted and spot market sales. They ensure projected sales plan is parallel to long-term objectives. In operational planning, they are responsible for forecast netting and leading the planning team to prioritize shipments.

Planning Team defines the available capacity and aggregated production volumes for product families in the mid-term and the long-term. In short term, the team

is responsible for doing production plans, calculating promised dates of orders and handling material requirement planning. The team has close collaboration with sales and manufacturing teams. If there are changes in production or satisfaction plan, the planning team makes related adjustments to coordinate all stakeholders.

1.3. Structure of Study

In this paper, we focus on various decisions and discuss how they can be managed and synchronized among each other. In Section 2, we mention literature that contributes to our study. In Section 3, we describe decisions and their impacts on business. In Section 4, we define an aggregation methodology to group decisions. The aggregation enables us to manage decisions with a suitable level of detail and efficient data flow among decisions from different complexity levels. In Section 5, we propose solutions for each aggregation level and describe data flow among different levels. In Section 6, we discuss details of mathematical models for each level. In Section 7 and 8, we discuss the results of the deployment and conclusion.

2. LITERATURE REVIEW

In this section, we will refer to the literature contributing our study. In the study, we aimed to implement an integrated DSS platform to manage decisions throughout the organization. We also planned to use aggregate production models to optimize decisions from various levels. Thus, our review involves decision & planning domain classification, interactive DSS implementations and aggregate production models. Since the chemical company has multi-facilities, we also reviewed papers specifically focusing on multi-site and chemical industries.

Several authors classify production-planning problems into strategic, tactical and operational problems. Readers are referred to Anthony (1965) [1], Salomon et al. (1991) [2], McDonald and Karimi (1997) [3], Min and Zhou (2002) [4], Gupta and Maranas (1999,2003) [5,6]. Jerbi et al (2012) [7] provide a detailed description for different levels of planning and decisions. He also emphasizes data flow among different levels of decisions.

Many valuable developments regarding these decisions are present in the literature. Simchi-Levi et al. (2004) [8] propose optimization techniques for strategic decisions. He focuses on production and distribution systems, pricing to improve supply chain performance and supply chain design models. Chopra and Meindl (2013) [9] work on analyzing supply chain decisions with the classification of strategic & tactical & operational, designing supply chain networks, coordinating supply and demand and managing cross-functional drivers. Shapiro (2003) [10] evaluates strategic planning problems in terms of four categories of modeling and organizational imperatives. Fleischmann et al. (2006) [11] focus strategic decision-making process in multi-facility environments. He aims to improve the efficiency of investment decisions among 12 facilities of BMW. Díaz-Madroño et al. (2013) [12] review discrete-time optimization models for tactical production planning. In the paper wide range of optimization models, aggregation levels and solver performances are discussed regarding tactical planning. We

refer readers to analyze Madroño's paper to identify main research trends regarding optimization of tactical decisions.

There also exists the significant number of studies regarding interactive DSS implementations. Jozefowska et al. (2005) [13] presents a DSS for short-term production planning. Jozefowska evaluates operational decisions in his work. Taskin and Unal (2008) [14] investigate tactical level planning problems in float-glass manufacturing industry. They implement a decision support system improving the efficiency of S&OP processes. The DSS enables users to handle more detail and increase output. Although scope of our study is wider, there are common purposes and similar implementation concepts between our studies. For this reason, we benefited from the paper significantly. Teksan et al. (2013) [15] implements production planning, shift planning and detailed scheduling systems in a tissue paper manufacturer. The paper provided us with ideas to synchronize decisions. Taşkin et al. (2015) [16] develop and implement a DSS for an electronic device manufacturer. The paper also discusses challenges of S&OP regarding volatile demand, long lead time of materials. We also analyze papers of Silvaa [17] and Maturana [18]. Silvaa develops a system for aggregate production plan. Maturana proposes a system with a database, solver and GUIs.

We also analyzed studies focusing on chemical industry. Kallrath (2000) [19] compares performance of various optimization techniques in chemical production planning problems. There are limited DSS applications in optimization literature regarding the chemical industry. Yang et al. (1993) [20] develop and implement a decision support system in one of the largest chemical dye plants in China. Lee and Chan (2002) [21] develop production planning optimization tool in BASF by formulating with MILP.

It is also significant to interrelate optimized decisions. Otherwise, optimized strategic decisions cannot be applied to lower levels. Ivanov (2009) [22] studies interlinking supply chain decisions from strategic to operational ones. He also presents a mathematical model based on his proposal. He aims to contribute to developing methodical basics and practical tools for planning. Disaggregation is an important concept

for alignment of decisions for different levels. Axseter and Jonsson (1984) [23] have a study regarding aggregation and disaggregation in hierarchical production planning. Ozdamar et al. (1996) [24] implement a hierarchical decision support system (HDSS) including aggregate production models and disaggregate algorithms.

We also reviewed aggregate production planning literature. Mula et al (2009) [25] provide a literature search regarding production planning and applied mathematical models. Basic production planning models utilize resource capacities to satisfy demand assuming demand and capacities are deterministic [26–28]. There are also extension studies about multiple objectives, maximization gross profit, minimization of lateness [29–31]. Finally, there are multi-site extensions in the literature. Leung et al. (2006) [32] present a multi-site aggregate production planning model in the lingerie industry. We also analyzed papers of Akbalik and Penz (2011) [33], Timpe et al. (1998) [34], Lan et al. (2011) [35] and Drechsel and Kimms (2011) [36].

3. DECISION MANAGEMENT

3.1. Decisions

In Section 2, we mentioned that several authors, classify planning problems into strategic, tactical and operational problems. As shown in Figure 3.1 presented by Jerbi et al (2012) [7], first, strategic planning models cover up to ten-year horizon. It deals with long term decisions like where to invest for production facility or long term technology investments in the network. Second, tactical planning models deal with medium term decisions whose horizons are mostly less than a year. They aim to manage materials flow, inventory levels, capacity utilization and maintenance activities. Tactical planning uses strategic decisions as input and act according to given framework. Finally, operational levels are related to short term decisions covering a horizon from hours to several weeks. Scheduling, sequencing, order promising are some examples in the domain of operational planning. Similarly, operational plans base tactical decisions and have purpose to be aligned with higher level decisions.

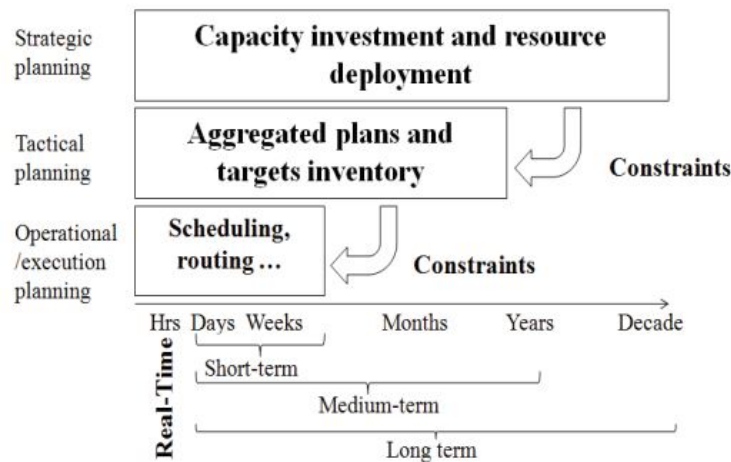


Figure 3.1. Decision Types.

Decisions which are made in corresponding planning cycle will be named with the class name of the planning cycle. Management team of the company gets strategic, tactical and operational decisions in yearly planning cycle to manage the complex sales

and supply chain network which mentioned in Section 1. If and only if all types of decisions are optimized and synchronized with each other, long term targets can be accomplished. Decisions which are made in yearly planing cycle are summarized in Table 3.1.

Table 3.1. Decisions in Planning Cycle.

Strategic Decisions	
Decision 1	Sourcing Decision
Decision 2	Capacity Investment
Decision 3	Sourcing Decision
Tactical Decisions	
Decision 4	Setting Mid Term Growth Targets
Decision 5	Inventory Policy
Decision 6	Setting Short Term Growth Targets
Decision 7	Maintenance & Shutdown
Operational Decisions	
Decision 8	Sales Adjustments
Decision 9	Customer Prioritizing
Decision 10	Material Inventory Policy

3.1.1. Strategic Decisions

Decision 1 clearly define volume & price increments in each region for five-year horizon. Targets might vary for different product families. Growth targets are major driver of the business. Sales & Marketing teams realign their activities according to growth targets. They update customer mix, build new pipelines and try to gain new shares in focus markets. On the other side, supply chain teams design and implement capacity increment plans based on targeted sales volume which is derived from growth targets as well.

In order to set valid growth targets, management team needs unconstrained demand forecast and capacity projection for each production facility. Management team is also supposed to simulate different scenarios based on price change. For this reason, sales team prepares multiple forecast scenarios based on different price levels. Supply chain team is responsible for validating how much forecast could be satisfied and calculating respective cost.

Decision 2 defines capacity investments and projected capacity in the next five year for each packaging group in each factory. Most of capacity investments cost significant amount of budget. Budgeted investments require detailed analysis, online tenders, shutdowns and major modification in production facility. For this reason, depending on size, lead time of an investment might take up to 2-3 years.

It is very critical to decide where and when to invest. Surely, increment in a capacity has a positive impact regardless of the location and type of product family. Because, as mentioned above, soda is a commodity good and capacity determines the sales amount. However, correct investments can still generate significantly higher return than inefficient ones. For this reason, unconstrained sales forecast, type of invested product family, additional logistics cost, and gross margin of incremental sales are all important parameters for the investment decision. Therefore, capacity investment decisions cannot be considered as independent from other strategic decisions.

Decision 3 corresponds sourcing decisions. Demands of a customer can be assigned to a specific plant or, alternatively, can be partially satisfied from different locations. Sourcing decisions match sourcing units and customers for the next 2-3 years. During the operation, some shipments can be planned over alternating facilities; nevertheless, long term decisions are made based on the sourcing decision.

It is significant to assign customer demands to reasonable sourcing units so that associated manufacturing and logistics costs are minimized. When sourcing decision is given, contracts are sealed with customers. More than 80% of total sales comes from

contracts whose horizon are mostly one year. Since international shipments require certain paperwork, once a contract is sealed, sourcing is fixed and not updated except extreme cases. Moreover, specification of products might slightly vary among different factories. Therefore, some customers may have constraints about sourcing units. Supply chain team is responsible for minimizing total cost and balancing volume for each factory by obeying operational constraints.

3.1.2. Tactical Decisions

Decision 4 defines targeted volume and prices for the next year in monthly split. It also includes SKU and customer detail distinctly from strategic decisions. This decision is a baseline for the next year. Monthly targets are expected to be parallel to strategic decisions. Otherwise, compliance to long term targets cannot be possible.

In order to set valid monthly targets, monthly sales and production capacities should be estimated precisely. Based on sales input, SCDT and planning teams calculate satisfied customer demand, period ending stock and production plan in SKU detail. If there occurs backlogs or unsatisfied demand, sales team is informed and they are expected to update quantity or due dates of contracts. This process might be repeated several times. In order to manage the process efficiently, planners and sales team should be able to run these operations fast and systematically.

Decision 5 defines safety, cycle and target stock levels for finished good and materials. Inventory policy is a key input of planning because both short and long term production and demand satisfaction decisions base inventory policy.

As mentioned above, soda is used as a raw material in various industries. Delays in soda shipments cause customers to encounter with significant problems resulting penalty for the company. For this reason, company should keep safety stock in finished goods to compensate possible problems in manufacturing. Overstocks could be sold in the spot market even if it causes margin dilution in some cases. Therefore, company

aim to maximize production of finished goods. At this point, if safety stocks are over-defined, company may need to shift contracted sales to spot market which cause negative impact in profitability. If safety stocks are under-defined, resulting shortages cause loss of goodwill with customers.

Based on sales targets, company may adjust risk preferences in yearly basis. Planners need to run multiple scenarios with different safety stock levels to be able to explain impact of each decision. The company needs a platform calculating cost and benefit of various stock policies immediately.

Decision 6 corresponds short term growth targets. Organization takes actions in a regular basis to be aligned with mid-term targets. Year to date (YTD) realizations might have variations with mid-term targets which are given in the last quarter of the previous year. At this point, year to go (YTG) plan is updated and monthly targets are revised so that targets can still be achieved at the end of the year. In this process, production & sales quantities, product-mix, sales-mix can be updated.

The sales team considers multiple criterion throughout the process. First sum of realizations and revised sales should be parallel to mid-term targets. Second, sales volume of customers having strategic priority cannot be reduced even if they contribute lower gross margin. On the other side, revised capacities must be enough to satisfy the revised demand and reach target stock levels. In order to manage this complex process, the sales team need a system that can calculate impact of possible scenarios promptly.

Decision 7 defines how much of total capacity will be used in the following months. Normally, this decision is roughly made while defining mid-term growth decision; nevertheless, final decisions are made within the year according to inventory position, compliance to targets and backlog quantity.

SCDT and planning teams might increase or decrease production capacity by using these instruments. Related actions must be managed according to revised sales plan of following months. Otherwise, there will be inconsistency between sales and production plan causing disobedience to short term growth targets.

3.1.3. Operational Decisions

Decision 8 corresponds sales adjustments. Planning team uses customer orders and net forecast as input during the production planning process. Sales adjustments define volume and quantity changes in forecast within the new two months.

Since most of sales come from contracted sales, it could be expected that forecasts are mostly fixed. However, especially in short term, forecast could fluctuate significantly. Customers might shift shipment plans, increase or decrease volumes based on their own material requirement plan. At this point, the sales team must be flexible to net forecasts and customer orders. If there is an excess net requirement, some forecasts should be postponed or removed. On the other side, demand satisfaction could turn infeasible state depending on variation in production plan. In case of a supply problem, sales and planning teams are supposed to collaborate and come up with a solution plan. In any case, supply and demand need to be balanced over the production planning horizon.

The process above is a daily repeating cycle. Thus, forecast netting, satisfaction plan and forecast adjustment processes must be managed regularly and promptly. If feedback mechanism among the departments have inefficiencies, promised due dates fluctuate and that results customer dissatisfaction in the long run.

Decision 9 defines satisfaction time of orders in system. If volume of open orders is more than expected forecasts or production performance is realized with low efficiency, there occurs delays and unsatisfactions in orders. Even if supply and demand is balanced regularly over the production planning horizon, these variations cause

unbalances in short term.

In case of excess demand over a certain period, customers are prioritized and organization decides which customers will be served lately. This process is checked in daily basis and planning and sales teams try to keep due dates fixed as much as possible. In case of delays, teams are supposed to agree on the prioritization. Afterwards, production plan should be adjusted accordingly and customers should be informed on time. Efficient communication with customers mitigates negative impacts of tardiness in shipments.

Decision 10 defines safety, cycle and target stocks of materials. Since maximizing production is essential, stoppage due to lack of material is not acceptable. This results a high safety stock levels for materials. However, it is also important to keep material stock in a reasonable level due to cash impact.

Planning team is responsible for setting and obeying these targeted inventory levels. In order to obey these targets, stock projections must be updated and monitored according to adjustments in finished production plan. Since this operation repeats in daily basis, MRP calculations must be managed efficiently.

3.2. Aggregation Methodology

In this study, we aim to design solution platforms to evaluate and support decisions in Section 3.1. Solution platforms should include mathematical models which optimize the decisions. Unfortunately, it is not possible to optimize every decision with only one mathematical model since decisions posses various complexity levels. For instance, a procurement action regarding material inventory policy should be considered in daily basis and in SKU detail. On the other side, long term growth target, which is one of the strategic decisions, cannot be analyzed in daily basis. For this reason, growth and procurement decisions must be evaluated in different mathematical models.

At this point, it is also critical to synchronize the decisions. If they are optimized independently, there might occur some conflicts among decisions. Operational and tactical decisions should support strategic decisions. Otherwise, the system cannot be optimized as a whole. Therefore, proposed system should optimize group of decisions and then transfer optimized outputs to other sets as input. In this way, system could ensure that decisions are optimized for each group and interrelated among the different groups.

Here, another question arises, how can decisions be grouped? If number of mathematical models are maximized, namely each decision is defined as a new group, combination of sub-optimal solutions is diverged from global optimum solution. Furthermore, synchronizing decisions will be more challenging process. As mentioned above, it is not possible to optimize all decisions in one group. Thus, number of group should be minimized; but at the same time each set of decisions should have similar complexity level so that they can be optimized together. In order to illustrate complexity level, in this study, we classified decisions based on five different categories which are frequency, horizon, bucket length, product hierarchy and customer hierarchy as shown in Table 3.2.

Table 3.2. Aggregation Complexity-1.

Complexity Type	Complexity Level	Sample Decision
Frequency	Daily, Weekly, Monthly, Yearly	1/Y
Horizon	Day, Week, Month, Year	3Y
Bucket Length	Day, Week, Month, Year	Y
Product Hierarchy	Product Family, SKU	PF
Customer Hierarchy	Country, Region, Customer	Ctr

Based on these factors an example decision aggregation can be defined as following. SampleDecision (Per:1/Y, H:3Y, BL:Y , PH:PF, CH:Ctr) means that decision is made once a year. It covers three-year horizon. Time aggregation unit is one year. Products and customers are aggregated as family and country respectively.

Finally, decisions are analyzed based on these criterion and following figure is created. Table 3.3 shows corresponding values of decisions for each classification level. In Section 4, we will discuss how these decisions can be grouped and solution platforms can be designed.

Table 3.3. Aggregation Complexity-2.

Decision	Freq.	Horizon	TB	PH	CH
Long-Term Growth Targets	1/Y	5Y	Y	PF	Ctr
Capacity Investment	1/Y	3Y-5Y	Y	PF	NR
Sourcing Decision	1/Y	2Y-3Y	Y	PF	Ctr
Mid-Term Growth Targets	1/Y	1Y	M	SKU	Cus
Inventory Policy	1/Y	1Y	M	SKU	NR
Short Term Growth Targets	1/M	1Y	M	SKU	Cus
Maintenance & Shutdown	3-4/Y	1Y	M	NR	NR
Sales Adjustments	1/D	1M-2M	W	SKU	Cus
Customer Prioritizing	1/D	2W-4W	D	SKU	Cus
Material Inventory Policy	1/D	1M-2M	D	SKU	NR

4. SOLUTION ARCHITECTURE

In this section , we will first group decisions based on their complexity level. In the second step, we will propose solution platforms for each group of decisions. Third, we will define data flow among group of decisions. Eventually, an integrated platform will be proposed.

4.1. Grouping Decisions

4.1.1. Frequency

In the first step, we will primarily focus on frequency classification of decisions because readjusting frequency of a decision is very challenging. For example, capacity investment decisions are made in yearly basis. If it is converted to a monthly decision, all input set need to be prepared in a monthly basis, which is not possible in practice. Therefore, increasing frequency of capacity investment decision is not feasible.

There are yearly, monthly, weekly and daily decisions. We will first discuss defining specific platforms for all frequency types. In this case, frequency of strategic, tactical and operational decisions will be yearly, monthly and daily respectively. Strategic decisions are already made yearly so this part is acceptable. Similarly, all operational decisions have daily frequency.

Tactical decisions are mixed in terms of frequency. Mid term growth, inventory policy decisions are made once in a year while others are made monthly. Unfortunately, it is not reasonable to convert yearly decisions to monthly basis because it is going to be non-value adding and require too much effort. As a result of the analysis, either yearly decisions will be merged with the strategic decisions or a new group will be defined. We will select one of the options based on other characteristics. For now, let us propose the minimal set including three platforms (See Table 4.1).

Table 4.1. Solution Platforms-1.

Group	Platform	Frequency
Group1	Strategic Planning Platform	1/Y
Group2	Tactical Planning Platform	1/M
Group3	Operational Planning Platform	1/D

4.1.2. Horizon

Strategic decisions have horizon between three and five years. It is reasonable to extend horizon of all decisions to five years. Actually, it is not easy to estimate sourcing and capacity investments for five years; nevertheless, a rough estimation can be used to set growth target.

Tactical decisions have one year horizon in common. In frequency part, we discussed whether some decisions can be transferred to strategic solution platform or not. At this point, horizon of these decisions cannot be extended to five year. Thus, we need to define a new group for decision whose both frequency and horizon is a year. We will call these decisions as budget decisions. Other group of tactical decisions will be named as Sales and Operations Planning (S&OP) decisions.

Operational decisions have maximum two month horizon. Therefore, it is reasonable to define horizon as two month. So far, we defined four groups for decisions as in Table 4.2. We will evaluate these groups for other characteristics as well. As mentioned above, we aim to minimize number of groups and ensure each group has similar decisions in terms of their complexity level.

4.1.3. Time Bucket

Strategic decisions have yearly time bucket in common. Budget and S&OP decisions have monthly time buckets. Operational decisions are made daily except forecast

Table 4.2. Solution Platforms-2.

Group	Platform	Frequency	Horizon
Group1	Strategic Planning Platform	1/Y	5Y
Group2	Budget Planning Platform	1/Y	1Y
Group3	S&OP Planning Platform	1/M	1Y
Group4	Operational Planning Platform	1/D	1M-2M

adjustment decisions. However, it is possible to run mathematical model daily by using weekly forecast. Surely, this cause loss of detail in operational plan since weekly forecast must be assigned to a specific day; nevertheless, in short term, most of forecasts is already transformed to an order which has a specific requested date. Proportion of forecasts in first 3-4 weeks is low compared to orders. Therefore, loss of data for two month is acceptable as well. At this point, current groups are suitable for time bucket classification.

4.1.4. Product Hierarchy

Current groups have same values for each decision in terms of product hierarchy. Strategic decisions will be analyzed in product family detail. All other groups will have SKU detail.

4.1.5. Customer Hierarchy

Current groups have same values for each decision in terms of customer hierarchy. Strategic and budget decisions will be analyzed in customer group detail. S&OP and operational decisions will have customer detail.

As a result of this study, proposed system will include four solution platforms having following aggregation levels as in Table 4.3. In the next section, we will explain each solution platform in detail.

Table 4.3. Solution Platforms-3.

Platform	Freq	Horizon	TB	PH	CH
Strategic Planning	1/Y	5Y	Y	PF	Ctr
Budget Planning	1/Y	1Y	M	SKU	Cus
S&OP Planning	1/M	1Y	M	SKU	Cus
Operational Planning	1/D	1M-2M	D	SKU	Cus

5. PROPOSED SOLUTION

Decisions are classified into four main classes in Section 4. In the next step we will design specific platforms for each decision set. Each platform should include required detail of information for each decision in the group.

5.1. Platforms

5.1.1. Strategic Planning Platform

Strategic platform is designed for management of strategic decisions which are capacity investments, growth and sourcing decisions. Figure 5.1 represents flow diagram we designed for strategic platform. Basically, in the first step, sales team is responsible for forecasting and planning team is responsible for estimating capacity. In the second step, an optimization tool determines which orders will be satisfied from which plant by considering inputs and business constraints. Strategic platform enables users to do what-if analyses, optimize each scenario and evaluate consequences of decisions simultaneously.

Note that, in the figure, rectangles represent a processes which include algorithms or intelligence. Cylinders correspond to input or output data. Rectangles with dashed lines show decisions. Throughout the study, we will use this notation in figures.

Platform provides an interface where sales team could enter yearly sales forecast in year, product family and country detail. 2022-Italy-DenseSoda-200K is an example of a forecast line. In ERP, past sales data is kept in SKU and customer combination. Our tool automatically aggregates past sales to product family and country level. Afterwards, aggregated numbers are matched with corresponding forecasts so that users can immediately see past volume & financial figures of each line. User is expected to

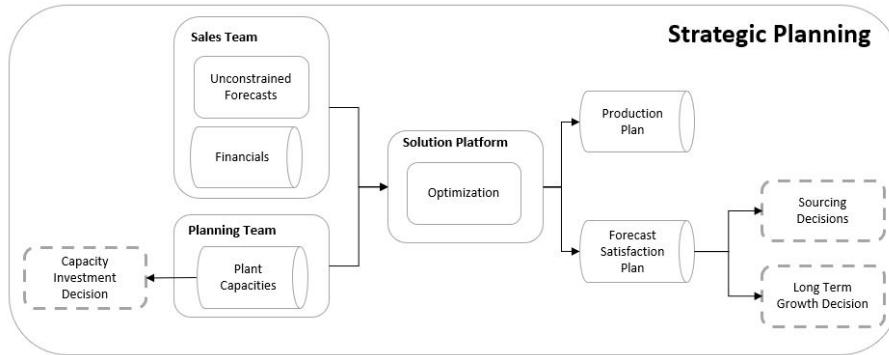


Figure 5.1. StrategicPlatform.

supply two levels of forecast which are minimum and unconstrained forecast. Minimum forecast represents quantity which has to be satisfied. Unconstrained forecast corresponds maximum quantity that can be sold by given price.

On the other hand, production planners have capacity interfaces. Likewise forecast screens, users can observe past capacity usages in product family detail and they are expected to supply yearly future capacities with the support of past data. Platform also enables defining special constraints. If users are willing to assign some of production quantities to specific value, they can force optimization to produce fixed quantities for assigned periods.

Platform gathers forecast and capacity data from users and extract remaining information from ERP system automatically. Subsequently, SP optimization whose details will be illustrated in the next section is run. Optimization calculates satisfied forecast and production plan by obeying constraints and maximizing profit. Optimization also decides sourcing units of demand (Decision 3).

Platform creates volume & financial figures based on optimization result. User can immediately analyze expected growths, status of forecasts and capacity usages (Decision 1). In the next step, users can simulate system by changing forecasts and capacities. This is an iterative process. The process lasts until reaching the final solution. Meantime, increase of capacity in different plants can be simulated and long term capacity investments can be set (Decision 2).

5.1.2. Budget Planning Platform

Budget platform is designed for first level tactical decisions whose horizons and frequencies one year. These are short term growth and inventory policy decisions. Figure 5.2 represents flow diagram of budget platform. In the first step, yearly satisfied quantities which are decided in strategic platform are disaggregated into SKU and customer level. Yearly data is split into months, then budget forecast is created. Supply chain team defines monthly capacities and safety stock levels. In the second step, optimization model determines a production plan and monthly ending stocks of finished goods. If there are backlogs or unsatisfied requirements, either the sales team updates requirement plan or the planning team adjusts capacities. Similarly, if safety stock levels are not reached, same cycle could repeat or gap from safety stock could be confirmed by leadership team.

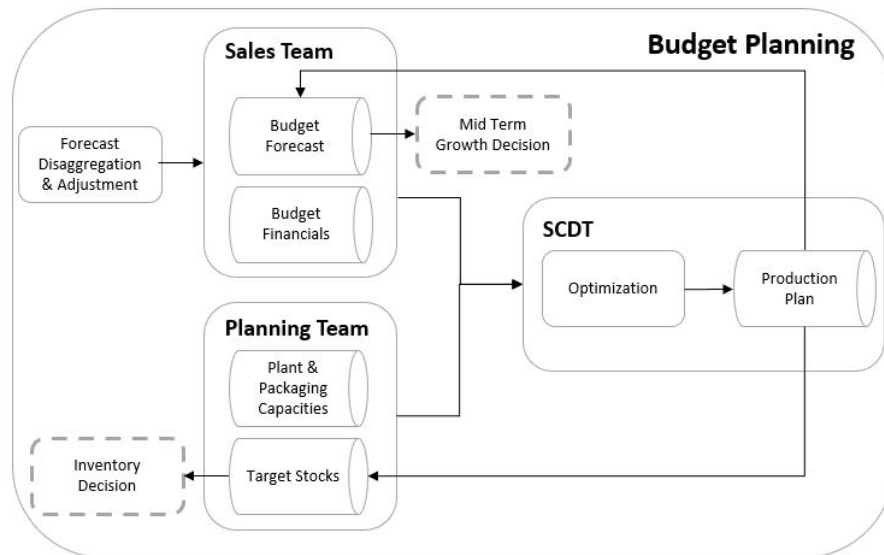


Figure 5.2. Budget Planning.

Platform provides a feature disaggregating sales volume based on past data. In strategic platform, sales volume is illustrated in terms of product family and country. Budget platform matches different hierarchies automatically. Furthermore, budget planning platform enables users some functionality to fine-tune volume and timings. When the process is over, revenue, gross margin and other financial measurements can

be represented in monthly, SKU and customer based (Decision 4). However, finalization of this process requires supply check. Only if, production plan is sufficient to satisfy the disaggregated demand, sales plan and growth decisions can be confirmed.

Budget platform has interfaces where planning team can enter capacity and target stocks. Past productions in ERP system are aggregated to level of given capacities. This enables user to compare capacity usages and projected capacities instantly. Planners could run multiple scenarios for different capacity and target stocks. Planners can define inventory policy based on feedback coming from SCDT (Decision 5).

Optimization process calculates production plan and ending stocks based on the inputs above. SCDT either confirms the budget or demands adjustments from sales or planning teams. When process is over, budget plan of next year is frozen. S&OP and operational plan in the next year base this frozen plan.

5.1.3. S&OP Platform

S&OP platform is designed to manage second level tactical decisions which are short term growth targets, maintenance & shutdown plans. Figure 5.3 represents flow diagram of S&OP platform. In the first step, YTG monthly sales plan is revised to be aligned with budgeted plan. YTG projected capacities are set in order to satisfy revised sales plan. In the second step, optimization calculates production plan and backlogged quantities. Revised plan is either confirmed or sales team is informed to update sales plan and then cycle repeats.

S&OP platform provides an interface where sales team manage their forecast, orders and past sales. The interface automatically connects ERP and retrieve past sales and open orders data. Afterwards, it enables users to enter contract and forecast values. In the end, monthly figures are created and monitored automatically by the platform. Users can compare sales plan of S&OP and budget platforms in terms of different metrics such as volume, revenue, profit, location and product family. If the

plan is confirmed after optimization part, it is published as short term growth targets (Decision 6).

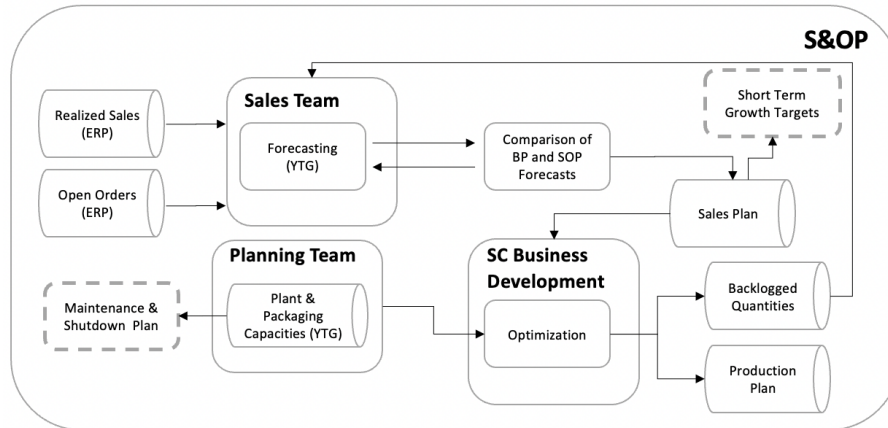


Figure 5.3. S&OP Planning.

S&OP platform has a similar design with budget platform for planners. Planners can enter YTG capacities considering maintenance and shutdown plans. If management team demands increasing or decreasing capacity, planning team might adjust capacity usage projections (Decision 7).

S&OP platform has an optimization model calculating production plan and backlogged quantities. Mathematical model of S&OP, which will be explained in detailed in Section 5, is similar to budget planning. While budget model solves full next year, S&OP model solves only remaining months of current year. In the end, total demand need to be satisfied and target stock levels should be reached. If there are some backlogged quantities, the sales team could update forecast or the planning team adjust YTG capacities. The cycle repeats until management team confirms sales targets and supply plan and closing stocks.

5.1.4. Operational Planning Platform

Operational planning platform is designed to manage operational decisions which are sales adjustments, customer prioritizing and inventory policy (material) decisions.

Figure 5.4 represents flow diagram of operational planning platform. In the first step, sales team nets forecast and net requirement is calculated. Planning team defines projection plan for capacity usages. In the second step planning team runs optimization and publishes production plan. The platform automatically matches productions and net requirements so released plan also calculates due dates of customer order.

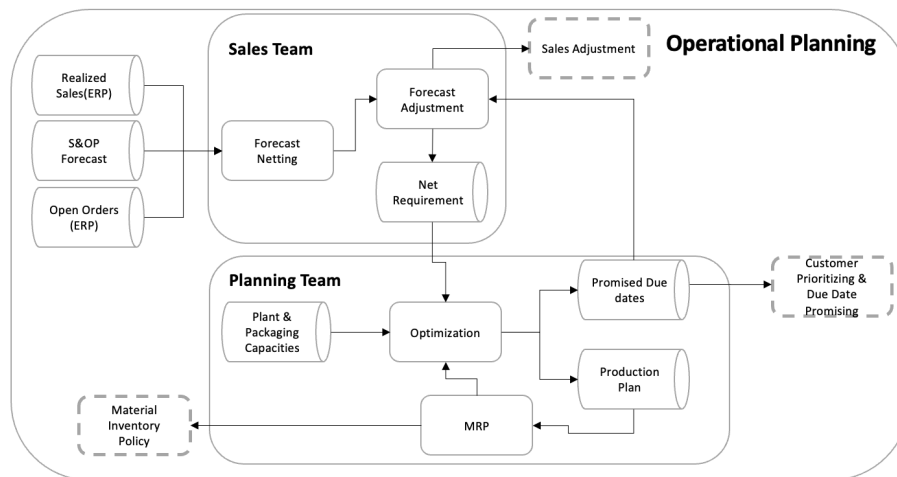


Figure 5.4. OP Planning.

OP platform has a daily cycle. Platform connects to external data sources including ERP and retrieve updated data every morning. Platform schedules production orders in ERP, match stocks and productions with demand and highlight order satisfaction times by the end of frozen time. This enables user to monitor general framework, detect urgent issues and check compliance to production plan. Platform provides features adjusting productions, editing demands and synchronizing updates with ERP.

At the first step, planning team manages actions within frozen time. In the second step, the planning team runs the optimization model and prepares a production plan from end of frozen time to end of the next month. Optimization needs two main inputs which are net demand and production capacities. OP platform automatically nets weekly forecasts in S&OP section with customer orders and realized sales. Thereafter, open orders in ERP and net forecasts are merged and net requirement is calculated. Also, OP platform provides an interface to manage capacities. At the beginning, platform connects ERP, creates resources and their default capacities

accordingly. Users could adjust capacities, assign maintenance to resources, update calendars by using manual functions. In the end, optimization creates a production plan based on requirements and capacities.

When production plan is projected, platform matches productions and requirements, then, calculate satisfaction date of each requirement (Decision 9). Users could confirm plan and extend frozen time or could adjust plan with manual functions. If there are major delays, planners contact sales team and may request them to update orders or forecast plan. This communication is repeated in daily basis (Decision 8). When plan is confirmed, OP platform synchronize productions with ERP. Afterwards, MRP is handled in ERP based on new production plan released from the platform. Procurement decisions are managed according to result of MRP (Decision 10).

5.2. Integrated Data Flow

In Section 5.1, we basically defined design of each platform and their functionalities but we discussed each platform independently. In this section, we will discuss how data flow will be realized among different platforms. Figure 5.5 represents timeline of data flow and Figure 5.6 shows type of data transferring among platform.

As it can be seen from Figure 5.6. data flows from higher-level to lower-level decisions. Thus, it is critical to complete higher-level decisions sufficiently earlier than their related lower-level decisions and horizon of higher-level decisions must involve lower-level ones. Timeline in Figure 5.5. was designed accordingly.

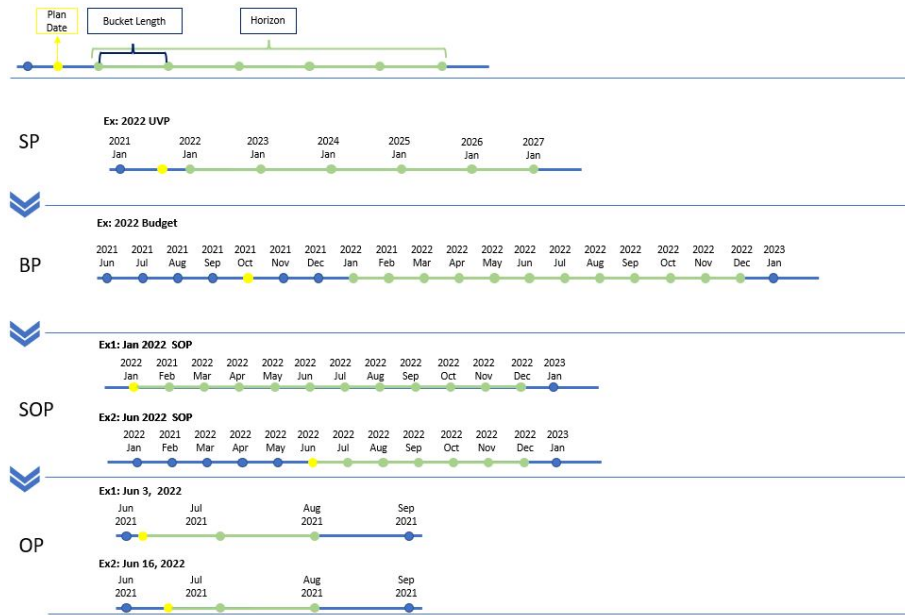


Figure 5.5. Yearly Planning Cycle.

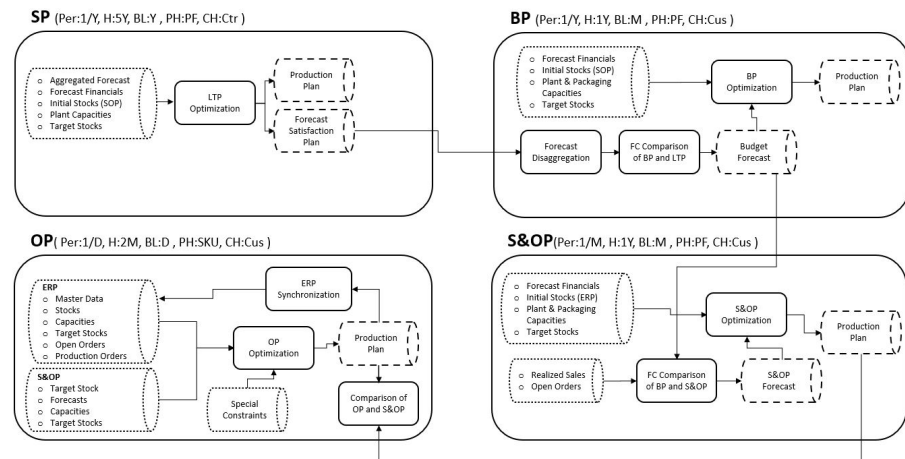


Figure 5.6. Data Flow.

5.2.1. Data Flow from Strategic Planning to Budget Planning:

Strategic planning is done once a year and is completed in the third quarter of the year while budget decisions are finalized in the fourth quarter. When strategic plan for the next year is confirmed, only first year of production plan and forecast plan is shared with budget plan. Since SP has aggregated decisions, an auto-disaggregation process is run and decisions are converted into budget formats. In this process, yearly

data turn to monthly, product families and customer groups turn SKU and customers respectively. Afterwards, budget planning adjustments are handled in more detail. However, integrated platform aggregates budget decisions and compare them with strategic decisions continuously. This enables users to ensure that tactical decisions follow strategic ones.

5.2.2. Data Flow from Budget Planning to Sales and Operational Planning

S&OP cycle is repeated at the beginning of each month. S&OP bases budget plan which is released at the end of previous year. Both SOP and BP has same horizon which is one year. Purpose of S&OP is to be aligned with BP in year total after each cycle. To reach this goal, BP shares forecast plan with S&OP. This plan includes volume and financial data. Since SOP and BP has same aggregation levels, information supplied by BP can be directly used. S&OP platform creates yearly comparison figures automatically based on adjustments in S&OP. Thanks to these reports, users can follow budget decisions throughout the year and escalate possible conflicts to leadership team on time.

5.2.3. Data Flow from S&OP to Operational Planning

OP has a daily cycle. At the beginning of each day, production plan of previous day is revised to adapt to changing environment. Revised plans are expected to be parallel to monthly S&OP decisions so that tactical decisions can be applied to operational levels. To provide the alignment, S&OP shares first two months of production and forecast plan at the beginning of the month. Throughout the month, sales team manages forecasts and orders in S&OP platform. S&OP platform shares also new forecast plan once or twice a week. OP platform calculates production plan based on updated forecast values. As other platforms, OP has auto-comparison figures with SOP for sales and production plans, enabling alignment between the platforms.

To sum up, although different set of decisions have various timings and complexity level, each high-level decision is disaggregated and transfer lower levels as input. In lower level, possible decisions are aggregated and compared with the higher level. When alignment is accomplished, lower-level decisions are confirmed thereby decision from various levels could be synchronized. In conclusion, while each platforms optimizes decision making processes independently, integrated platform aligns decisions and ensures system is optimized totally.

6. MATHEMATICAL MODEL

6.1. Strategic Planning Optimization Model

We discussed functionalities of strategic platform in Section 5.1. Mathematical model of strategic platform is supposed to determine production plan and forecast satisfaction plan of product families in country detail. Normally, strategic platform monitors figures for five-year horizon. However, unconstrained forecast can be estimated for only one-year horizon with pricing detail. Following four years, can be roughly estimated by sales team. For this reason, model we developed focuses only one year horizon. In the next step, a simple algorithm calculating future figures is run and projection of five-year horizon can be monitored in the platform.

Property 1: Sales team provides demand quantity d_{ij} for item i and order j . Item i represents one of three product family and customer j is cumulative forecast of customers in a specific country. Sales team also provides a required quantity r_{ij} which is a lower bound for satisfaction. Required quantities should be satisfied first regardless profitability of orders.

Property 2: The planning team provides yearly production capacity c_i for product families. Production in next year cannot exceed this level. In SP, SKU or packaging capacity specific constraints are ignored since forecasts do not includes this detail.

Property 3: Target stocks t_{ij} for product families has to be reached at the end of the next year. This is even more significant than satisfying an order. Therefore, first target stocks are built and then orders are satisfied.

Property 4: If required (minimum) quantities r_{ij} are satisfied then profit should be maximized based on gross profits g_{ijk} . Item i customer j pairs are satisfied with different margins according to their sourcing plant k .

Property 5: Some demands d_{ij} can only be satisfied from specific facilities or they can be satisfied from maximum amount of h_{ijk} units from inventory k .

Table 6.1. Symbols in SP Optimization Model.

SETS	
C	set of customer orders
I	set of items
K	set of inventories
PARAMETERS	
b_{ik}	initial stock of item i , inventory k
c_{ik}	total capacity of item i , inventory k
d_{ij}	demand quantity of item i , order j
g_{ijk}	gross profit of item i , order j from inventory k
h_{ijk}	maximum satisfaction quantity of d_{ij} from inventory k
r_{ij}	required quantity of item i , order j
t_{ik}	target stock of item i , inventory k
DECISION VARIABLES	
O_{ik}	overstock of item i , inventory k
P_{ik}	production quantity of item i , inventory k
S_{ijk}	satisfied quantity of item i , order j from inventory k
U_{ik}	underage stock from target stock for item i , inventory k
X_{ij}	unsatisfied quantity of required amount for item i , order j
Y_{ij}	additional satisfied quantity of item i , order j
Z_{ik}	ending stock of item i , inventory k

The model has a multi-phase optimization objectives. Objectives are sorted based on their priorities and they are accomplished one by one. Each successive objective becomes a constraint for the next objective. For example, first objective Equation (6.1) has the highest priority and is optimized in first phase. In subsequent phases, value of first objective becomes a constraint and cannot be increased.

6.1.1. Objective Function

$$\min \sum_{i \in I} \sum_{k \in K} (U_{ik}) \quad (6.1)$$

minimizes underage stocks of inventories. In order to keep service level on a desired level, targeted stocks must be reached at the end of the year.

$$\min \sum_{i \in I} \sum_{j \in C} (X_{i,j}) \quad (6.2)$$

minimizes unsatisfied quantity calculated based on required (minimum) quantity of orders. As mentioned before, required quantities correspond to strategic priorities.

$$\max \sum_{i \in I} \sum_{j \in C} \sum_{k \in K} (S_{ijk} * g_{ijk}) \quad (6.3)$$

maximizes gross profit. In the previous phase strategic priorities are satisfied. Remaining capacities will be evaluated to maximize profit.

$$\min \sum_{i \in I} \sum_{k \in K} (O_{ik}) \quad (6.4)$$

minimizes overstock.

6.1.2. Constraints

$$X_{ij} + \sum_{k \in K} (S_{ijk}) = r_{ij} + Y_{ij} \quad \forall i \in I, \forall j \in C \quad (6.5)$$

is a balance equation of an order. Since minimization of unsatisfaction is a prior objective, optimization try to satisfy at least as much as r_{ij} . As a second objective,

the model maximizes S_{ijk} .

$$r_{ij} + Y_{ij} \leq d_{ij} \quad \forall i \in I, \forall j \in C \quad (6.6)$$

limits excess satisfaction S_{ij} so that total satisfaction of an order cannot exceed order quantity d_{ij} .

$$Z_{ik} + U_{ik} - O_{ik} = t_{ik} \quad \forall i \in I, \forall k \in K(\text{target stock}) \quad (6.7)$$

refers target stock balance. If ending stock Z_{ij} is less than target stock t_{ij} , difference is assigned to understock quantity U_{ij} . If it is more, difference is assigned to over stock O_{ij} .

$$Z_{ik} = b_{ik} + P_{ik} - \sum_{j \in C} (S_{ijk}) \quad \forall i \in I, \forall k \in K \quad (6.8)$$

refers to inventory balance constraint. Since it is single period optimization problem, initial stock b_{ij} plus production P_{ij} minus satisfied quantities S_{ijk} is equal to ending stock of the inventory.

$$P_{ik} \leq c_{ik} \quad \forall i \in I, \forall k \in K(\text{production capacity}) \quad (6.9)$$

refers production capacities. Since inventories correspond product families, each inventory in model has a specific capacity c_{ik} .

$$S_{ijk} \leq h_{ijk} \quad \forall i \in I, \forall j \in C, \forall k \in K(\text{production capacity}) \quad (6.10)$$

refers maximum satisfaction limitations from specific inventories.

Note that, SP optimization model includes all strategic decisions as either input or output. Capacity and sourcing decisions correspond parameter c_{ik} and decision variable S_{ijk} respectively. Objective function $\sum_{i,j,k}(S_{ijk} * g_{ijk})$ is revenue of next year which implies growth.

Table 6.2. SP Optimization Model Result.

Decision Variables	Constraints	Time(sec)
3282	2677	0.02

As it can be seen from Table 6.2, optimization model includes 3282 decision variables and 2677 constraints. The model has been solved in 0.02 seconds. All optimization model in this study was run by the system whose features are illustrated in Table 6.3.

Table 6.3. System Properties.

Processor	RAM	System Type	Solver
Intel(R) Platinum 8272CL @ CPU 2.60GHz	128GB	64-bit	Gurobi

6.2. Budget Planning Optimization Model

Property 1: Budget plan of all facilities are done separately. It starts from beginning of next year and covers 12 months $j \in 1,2 \dots 12$

Property 2: In SP, satisfied FC quantities are published in product family and country detail. Also, this quantity represent total next year. In BP, disaggregation process is conducted and monthly sales numbers d_{ij} are calculated in SKU i and customer j detail.

Property 3: Budget plan calculates monthly productions P_{it} in SKU detail.

Property 4: All d_{ij} must be satisfied on time. If backlog quantity X_{ij} occurs, forecasts or capacities should be adjusted until obtaining a plan without backlog.

Property 5: Production family capacity constraints c_{at} represent maximum amount of production from product family k in period t . Additionally productions of all items in period t cannot exceed work-center capacity w_t . Productions of all items in packaging group k in period t cannot exceed packaging constraints g_{at} .

Property 6: If there is available capacity after satisfying demand, remaining capacity is used to build target stock t_{it} for item i in period t .

Table 6.4. Symbols in BP Optimization Model.

SETS	
C	set of customer orders
F	set of product families
I	set of items
PT	set of packaging types
T	set of periods
PARAMETERS	
b_i	initial stock of item i in first period
c_{at}	total capacity of product family a , in period t
d_{ij}	demand quantity of item i from customer order j
F_a	1 if type of product family is a , 0 otherwise
g_{at}	total capacity of packaging group a in period t
l_{ijt}	lateness punishment of item i from customer order j in period t
PT_a	1 if packaging type is a , 0 otherwise
t_{it}	target stock level of item i in period t
w_t	workcenter capacity in period t

Table 6.4. Symbols in BP Optimization Model (cont.).

DECISION VARIABLES	
O_{it}	overstock of item i in period t
P_{it}	production quantity of item i in period t
S_{it}	satisfied quantity of d_{ij}
U_{it}	underage stock from target stock for item i in period t
X_{ij}	unsatisfied quantity of d_{ij}
Z_{it}	ending stock of item i in period t

6.2.1. Objective Function

$$\min \sum_{i \in I} \sum_{j \in C} (X_{ij}) \quad (6.11)$$

minimizes unsatisfied quantities.

$$\min \sum_{i \in I} \sum_{j \in C} \sum_{t \in T} (S_{ijt} * l_{ijt}) \quad (6.12)$$

minimizes late satisfactions. Lateness punishment l_{ijk} increases depending on elapsing time after due date.

$$\min \sum_{i \in I} \sum_{t \in T} (U_{it}) \quad (6.13)$$

refers minimization of safety stocks.

$$\min \sum_{i \in I} \sum_{t \in T} (O_{it}) \quad (6.14)$$

refers minimization of over stocks.

6.2.2. Constraints

$$\sum_{i \in I} (P_{it}) \leq w_t \quad \forall t \in T \quad (6.15)$$

restricts total production P_{it} of items in each period according to workcenter capacity w_t .

$$\sum_{i \in F_a} (P_{it}) \leq c_{at} \quad , \quad \forall t \in T, \forall a \in F \quad (6.16)$$

limits production of items based on product family capacity c_{at} .

$$\sum_{i \in PT_a} (P_{it})^* \leq g_{at} \quad \forall t \in T, \forall a \in PT \quad (6.17)$$

limits production of items based on capacity of packaging types g_{at} .

$$Z_{it} = Z_{i,t-1} + P_{it} - \sum_{j \in C} (S_{ijt}) \quad \forall i \in I, t \neq 1 \quad (6.18)$$

refer inventory balance.

$$Z_{i1} = b_i + P_{i1} - \sum_{j \in C} (S_{ij1}) \quad \forall i \in I, \quad (6.19)$$

and

$$Z_{it} + U_{it} - O_{it} = t_{it} \quad \forall i \in I, \forall t \in T \quad (6.20)$$

refer target balance.

$$d_{ij} = \sum_{t \in T} (S_{ijt}) + X_{ij} \quad \forall i \in I, \forall j \in C \quad (6.21)$$

refers order balance.

Note that decision variable S_{ijt} defines mid term growth values, parameter t_{it} corresponds to inventory policy decision. Users might get multiple run by applying several inventory policy scenarios and check growth values based on optimization output.

Table 6.5. BP Optimization Model Result.

Decision Variables	Constraints	Time
18300	1284	0.74

As it can be seen from Table 6.5, optimization model includes 18300 decision variables and 1284 constraints. The model has been solved in 0.74 seconds.

6.3. S&OP Optimization Model

S&OP has same problem definition and mathematical model with BP. Only difference of S&OP is active period numbers. S&OP starts from the current month and ends at the of end the year. Therefore active period t is defined as $t \in (t = \text{current month index}, t+1 \dots 12)$

Note that decision variable S_{ijt} defines short term growth values, capacities c_{kt} and g_{kt} implies shutdown and maintenance decisions. Users are able to optimize and adjust level two tactical decisions with S&OP platform.

Table 6.6. S&OP Optimization Model Result.

Decision Variables	Constraints	Time
27264	1884	0.92

As it can be seen from Table 6.6, optimization model includes 27264 decision variables and 1884 constraints. The model has been solved in 0.92 seconds.

6.4. OP Optimization Model

Property 1: Production plan is done in daily bucket and SKU detail. Each facility is responsible for its own plan.

Property 2: Frozen area is managed by production orders. It starts from the day after frozen period and ends at the end of the next month.

Property 3: Workcenter, product family, subfamily, packaging group capacities restrict the production volume.

Property 4: SKUs can be shipped directly from production facility or they can be sent to port. Port plan is also managed by the planning team in facility. Daily transfer volume from facility to port cannot exceed port-shipment capacity r_t .

Property 5: Stock in port cannot exceed silo capacity pm_{it} .

Property 6: Material constraint is ignored during production planning process. MRP is run by ERP based on finished good production plan. If there occurs infeasible material supply in MRP, finished good plan is revised manually over optimization output.

Property 7: S&OP defines closing stocks of first and second months. These levels are targeted in operational plan t_{ijt} .

Property 8: Product Family Three has 7 different subfamilies. These subfamilies are classified as additives and non-additives. When a subfamily starts a production run, it cannot be stopped during at least three days.

Property 9: There are some special customer orders and forecasts requiring order specific labeling. Productions and stocks of these orders have to be managed. In mathematical model, we used notation $SampleParameter_{ij}$ for parameters and decision variables where i and j denotes item and label type respectively.

Property 10: Some SKUs have to be produced over a certain limit in specified days

Property 11: SKUs in pouch form cannot be produced in different runs. If a specific order is started to be produced, it has to be produced until it is completely satisfied.

Table 6.7. Symbols in OP Optimization Model.

SETS	
A	additive items
C	set of customer orders
F	set of product families
H	set of pouch items
I	set of items
L	set of labels
NA	non-additive items
PT	set of packaging types
SF	set of subfamilies

Table 6.7. Symbols in OP Optimization Model (cont.).

T	set of periods
PARAMETERS	
b_{ij}	initial stock of item i , label type j in first period
c_{at}	total capacity of product family a in period t
d_{ijk}	demand quantity of item i label type j customer order k
F_a	1 if type of product family is a , 0 otherwise
g_{at}	total capacity of packaging group a in period t
k_{at}	total capacity of subfamily group a in period t
l_{ijkt}	lateness punishment of item i label j from customer order k in period t
L_a	1 if type of label is a , 0 otherwise
m_{at}	silo capacity of product family a in period t
n_t	1 if additive products can be produced in period t
nr_{it}	net requirement of inventory i and period t
r_t	daily port transfer capacity in period t
pb_{ij}	initial port stock of item i , label type j in first period
pd_{ijk}	port demand quantity of item i label type j customer order k at period t
pt_{ijt}	port target stock level of item i label type j period t
pl_{ijkt}	port lateness punishment of item i label j from customer order k in period t
pm_{at}	port silo capacity of product family a in period t
PH_{ijkt}	pouch heuristic quantity of item i label type j customer order k at period t
PT_a	1 if packaging type is a , 0 otherwise
q_{ijkt}	minimum daily production quantity of item i , label j in period t
t_{ijt}	target stock level of item i label type j period t
V	daily production capacity of PF3
w_t	workcenter capacity in period t
W_t	remaining capacity of package lines in period t
DECISION VARIABLES	
O_{ijt}	overstock of item i label type j period t

Table 6.7. Symbols in OP Optimization Model (cont.).

\mathbf{P}_{ijt}	production quantity of item i label type j period t
\mathbf{PO}_{ijt}	port overstock of item i label type j period t
\mathbf{PS}_{ijkt}	port satisfied quantity of pd_{ijkt}
\mathbf{PU}_{ijt}	port underage stock from target stock for item i label type j period t
\mathbf{PX}_{ijk}	port unsatisfied quantity of item i label type j customer k
\mathbf{PZ}_{ijt}	port ending stock of item i label type j period t
\mathbf{S}_{ijkt}	satisfied quantity of d_{ijkt}
\mathbf{TR}_{ijt}	port transfer quantity of item i label type j period t
\mathbf{U}_{ijt}	underage stock from target stock for item i label type j period t
\mathbf{X}_{ijk}	unsatisfied quantity of item i label type j period t
\mathbf{Z}_{ijt}	ending stock of item i label type j period t

6.4.1. OP Previous Processing:

Since operational planning covers SKU and day detail, model size is significantly larger than mathematical models of other platforms. Some of the properties require binary decision variables causing increment in model complexity. Throughout the implementation, different solutions are tried. Eventuality, we decided to use following heuristic algorithms for property 8 and property 11.

Property 8 states that Product Family Three has seven different subfamilies and four of them are additive, remaining ones are non-additive. Production runs must be at least three day long. Both additives and non-additive mix have capacity of V unit daily. Our additive heuristic is shown in Figure 6.1.

STEP 1 Calculate net requirement of each SKU in *PF3*. \mathbf{nr}_{it} stands for net requirement of item i in period t . Let us select \mathbf{p} as a iterator where $\mathbf{p} \in T$.

STEP 2 Assign $p = 0$ which is the first period after frozen.

if $\sum_{i \in A} \sum_{t=0}^{t=p+9}(\mathbf{nr}_{i,t}) > \sum_{i \in NA} \sum_{t=0}^{t=p+9}(\mathbf{nr}_{i,t})$ then

$\mathbf{n}_0 \doteq 1, \mathbf{n}_1 \doteq 1, \mathbf{n}_2 \doteq 1, , \quad \mathbf{p} \doteq 3$

else

$\mathbf{n}_0 \doteq 0, \mathbf{n}_1 \doteq 0, \mathbf{n}_2 \doteq 0, \quad \mathbf{p} \doteq 3$

end if

STEP 3

if ($(\sum_{i \in A} \sum_{t=0}^{t=p+9}(\mathbf{nr}_{i,j}) - \sum_{t=0}^{t=p-1}(\mathbf{n}_t * \mathbf{V})) >$
 $(\sum_{i \in NA} \sum_{t=0}^{t=p+9}(\mathbf{nr}_{i,t}) - \sum_{t=0}^{t=p-1}((1 - \mathbf{n}_t) * \mathbf{V}))$) then

if $\mathbf{n}_{t-1} \doteq 1$ then

$\mathbf{n}_t \doteq 1, \quad \mathbf{p} \doteq \mathbf{p}+1$

else

$\mathbf{n}_t \doteq 1, \mathbf{n}_{t+1} \doteq 1, \mathbf{n}_{t+2} \doteq 1, \quad \mathbf{p} \doteq \max(T_{max}, \mathbf{p}+3)$

end if

else

if $\mathbf{n}_{t-1} \doteq 0$ then

$\mathbf{n}_t \doteq 0, \quad \mathbf{p} \doteq \mathbf{p}+1$

else

$\mathbf{n}_t \doteq 0, \mathbf{n}_{t+1} \doteq 0, \mathbf{n}_{t+2} \doteq 0, \quad \mathbf{p} \doteq \max(T_{max}, \mathbf{p}+3)$

end if

end if

STEP 4

if $\mathbf{p} \doteq T_{max}$ then

DONE

else

GO TO STEP3

end if

Figure 6.1. Additive Heuristic

Property 11 states that pouch requirements has to be satisfied in single run. Pouches are produced in a specific packaging machine group. The company has a rule of thumb, pouch machines never stops and have higher priority than other packaging types. For this reason, our heuristic in Figure 6.2 fills the pouch capacity iteratively. Setup times are ignored by assumption. The algorithm also consider additive constraints.

6.4.2. Objective Function

$$\min \sum_{i \in I} \sum_{j \in L} \sum_{k \in C} (X_{i,j,k} + PX_{i,j,k}) \quad (6.22)$$

minimizes unsatisfaction.

$$\min \sum_{i \in I} \sum_{j \in L} \sum_{t \in T} ((S_{ijkt} * l_{ijkt}) + (PS_{ijkt} * pl_{ijkt})) \quad (6.23)$$

minimizes lateness.

$$\min \sum_{i \in I} \sum_{j \in L} \sum_{t \in T} (U_{ijt}) \quad (6.24)$$

minimizes gap from safety stock.

$$\min \sum_{i \in I} \sum_{j \in L} \sum_{t \in T} (O_{ijt}) \quad (6.25)$$

minimizes over stock.

STEP 1 Calculate net requirement of each order. \mathbf{or}_{ijk} stands for net requirement of order \mathbf{d}_{ijk} . Let us denote \mathbf{PH}_{ijkt} as satisfaction quantity, $t = 0$

while $t < T$ **do**

if $\mathbf{n}_t = 1$ **then**

 Pick earliest order \mathbf{or}_{ijk} whose item is i ($i \in (PF3 \wedge A) \vee i \notin PF3$) \wedge
 $\mathbf{or}_{ijk} > 0$

if $\mathbf{W}_t \geq \mathbf{or}_{ijk}$ **then**

$\mathbf{PH}_{ijkt} = \mathbf{PH}_{ijkt} + \mathbf{or}_{ijk}$

$\mathbf{W}_t = \mathbf{W}_t - \mathbf{or}_{ijk}$

$\mathbf{or}_{ijk} = 0$

else

$\mathbf{PH}_{ijkt} = \mathbf{PH}_{ijkt} + \mathbf{W}_t$

$\mathbf{or}_{ijk} = \mathbf{or}_{ijk} - \mathbf{W}_t$

$\mathbf{W}_t = 0, t = t + 1$

end if

else

 Pick earliest order \mathbf{or}_{ijk} whose item is t ($t \in (PF3 \wedge NA) \vee t \notin PF3$) \wedge
 $\mathbf{or}_{ijk} > 0$

if $\mathbf{W}_t \geq \mathbf{or}_{ijk}$ **then**

$\mathbf{PH}_{ijkt} = \mathbf{PH}_{ijkt} + \mathbf{or}_{ijk}$

$\mathbf{W}_t = \mathbf{W}_t - \mathbf{or}_{ijk}, \mathbf{or}_{ijk} = 0$

else

$\mathbf{PH}_{ijkt} = \mathbf{PH}_{ijkt} + \mathbf{W}_t$

$\mathbf{or}_{ijk} = \mathbf{or}_{ijk} - \mathbf{W}_t, \mathbf{W}_t = 0, t = t + 1$

end if

end if

end while

Figure 6.2. Pouch Heuristic

6.4.3. Constraints

$$\sum_{i \in I} \sum_{j \in L} (P_{ijt}) \leq w_t \quad \forall t \in Q \quad (6.26)$$

restricts total production P_{ijt} of items in each period according to workcenter capacity w_t .

$$\sum_{i \in F_a} \sum_{j \in L} (P_{ijt}) \leq c_{at} \quad \forall a \in F, \forall t \in T \quad (6.27)$$

limits production of items based on product family capacity c_{at}

$$\sum_{i \in SF_a} \sum_{j \in L} (P_{i,j,t}) \leq k_{at} \quad \forall a \in SF, \forall t \in T \quad (6.28)$$

limits production of items based on capacity of subfamilies k_{at}

$$\sum_{i \in PT_a} \sum_{j \in L} (P_{i,j,t}) \leq g_{at} \quad \forall a \in PT, \forall t \in T \quad (6.29)$$

limits production of items based on capacity of packaging types g_{at} .

$$P_{i,j,t} \geq q_{ijt} \quad \forall i \in I, \forall j \in L, \forall t \in T, \quad (6.30)$$

refers minimum production level q_{ijt} for each item periodically.

$$\sum_{i \in I} \sum_{j \in L} (TR_{ijt}) \leq r_t \quad \forall t \in T \quad (6.31)$$

implies that transfer to port TR_{ijt} cannot exceed daily capacity r_t

$$\sum_{i \in F_a} \sum_{j \in L} (Z_{i,j,t}) \leq m_{at} \quad \forall a \in F, \forall t \in T, \quad (6.32)$$

and

$$\sum_{i \in F_a} \sum_{j \in L} (PZ_{i,j,t}) \leq pm_{at} \quad \forall a \in F, \forall t \in T, \quad (6.33)$$

indicate that total ending stock of product families cannot exceed silo capacities m_{at} and pm_{at} .

$$Z_{ijt} = Z_{i,j,t-1} + P_{ijt} - \sum_{k \in C} (S_{ijk t}) - TR_{ijt} \quad \forall i \in I, \forall j \in L \quad t \neq 1 \quad (6.34)$$

and

$$PZ_{ijt} = PZ_{i,j,t-1} + TR_{ijt} - \sum_{k \in C} (PS_{ijk t}) \quad \forall i \in I, \forall j \in L \quad t \neq 1 \quad (6.35)$$

and

$$Z_{ij1} = b_{ij} + P_{ij1} - \sum_{k \in C} (S_{ijk1}) - T_{ij1} \quad \forall i \in I, \forall j \in L \quad (6.36)$$

and

$$PZ_{ij1} = pb_{ij} + T_{ij1} - \sum_{k \in C} (PS_{ijk1}) \quad \forall i \in I, \forall j \in L \quad (6.37)$$

refer inventory balance equations of items in facility and port.

$$Z_{ijt} + U_{ijt} - O_{ijt} = t_{ijt} \quad \forall i \in I, \forall j \in L \quad (6.38)$$

and

$$PZ_{ijt} + PU_{ijt} - PO_{ijt} = pt_{ijt} \quad \forall i \in I, \forall j \in L \quad (6.39)$$

refer underage over stock of items in facility and port.

$$\sum_{i \in A} \sum_{j \in L} (P_{i,j,t}) \leq M * n_k \quad \forall t \in T \quad (6.40)$$

and

$$\sum_{i \in NA} \sum_{j \in L} (P_{i,j,t}) \leq M * (1 - n_k) \quad \forall t \in T \quad (6.41)$$

refer additive and non-additive limitations of PF3.

$$d_{ijk} = X_{ijk} + \sum_{t \in Q} (S_{ijkt}) \quad \forall i \in I, \forall j \in L, \forall k \in C \quad (6.42)$$

and

$$pd_{ijk} = PX_{ijk} + \sum_{t \in Q} (PS_{ijkt}) \quad \forall i \in I, \forall j \in L, \forall k \in C \quad (6.43)$$

refer balance equations of orders in facility and port.

$$P_{ijt} = \sum_{k \in C} (PH_{ijkt}) \quad \forall i \in H, \forall j \in L, \forall t \in T \quad (6.44)$$

refers pouch heuristic algorithm. Optimization is forced to produce quantity calculated by heuristic algorithm in Figure 6.2.

Note that parameter d_{ijk} corresponds Decision 8, decision variable S_{ijkt} implies Decision 9. Confirmed P_{ijt} defines material requirements and indirectly Decision 10.

Table 6.8. OP Optimization Model Result.

Decision Variables	Constraints	Time
148970	62172	843.4

As it can be seen from Table 6.8, optimization model includes 148970 decision variables and 62172 constraints. The model has been solved in 843.4 seconds.

7. RESULTS

Integrated solution platform has been deployed in September 2020. As of deployment, the management team decided to replace Excel spreadsheets with the solution platform. The system has been used by over 70 active users in the last one year. We compared current and earlier states for this period and got valuable feedback from company team. Based on our investigation, we will summarize a report for each platform and integrated system, which discusses result of the implementation.

7.1. Strategic Planning Results

7.1.1. Detailed bottom-up approach instead of top-down way of working

Solution platform allows users to create dynamic customer groups. Platform connects to related external systems and matches related data with user-generated customer groups automatically. When sales team defines a new group (based on country or region), average figures regarding sales volume, average price, incoterm, tax are monitored by the platform automatically and new estimates could be calculated by platform functions over past figures. This enables the sales team to work in detail. Similarly, components of logistics and manufacturing costs such as port, truck, silo bus, ship loading, shipping, container, machining, labor costs are all linked to the groups automatically by the platform. Before our implementation, these details were considered for top customers only and were ignored by the rest of them due to the massive effort needed.

With visualization of past figures and usage of manual functions, teams could prepare detailed data correctly and promptly. Furthermore, supply check over demand numbers can be instantly done via optimization. Now, teams can compare their input with past figures and targets while ensuring a possible supply plan. This simplified approach reduced preparation time significantly and teams have gained an ability to

cover minor details as well.

7.1.2. Optimization based scenarios

Optimization based scenarios lead users to maximize gross profit by highlighting the impact of capacity and sales decisions on business. With SP platform, sales team enters a min-max range for customer forecasts. Minimum value of range defines the minimum value that must be satisfied. Maximum range represents the unconstrained forecast, namely how much product can be sold over the defined price. Optimization satisfies minimum quantities as a priority, then it finds out most profitable scenarios based on given ranges and supply constraints. When optimization results are monitored, the sales team could adjust min-max ranges, switch volumes between customers and run multiple scenarios. They could also calculate impact of each constraint on the profit and manage sales activities accordingly. This process leads the sales team to maximize gross profit. Before the implementation, the sales team was proposing single forecast numbers for customer groups, and they did not have a possibility to compare results of solutions.

On the other side, the planning team could instantly check supply feasibility. They can also estimate the contribution of possible capacity investments and calculate their payback periods over the results. They can detect the best investment options promptly. Furthermore, they are able to adjust the investment plan depending on changing long term sales projections.

7.2. Budget Planning Results

7.2.1. Auto Forecast Generation Over Strategic Planning Results

We mentioned that strategic platform enables users to handle customer data entry processes in more detailed. In the second step, the budget platform retrieves data from the strategic platform, then disaggregates it. System automatically converts product

families into SKUs, countries or regions into customers and yearly values into months. The platform bases past data and past seasonality for repetitive sales and it uses an intelligence to manage new customers and items.

The disaggregation process handles the most time-consuming process of budgeting instantly. Even a single forecast consists of one item and one customer might have hundreds of past shipments. They could be realized with different sales price, shipment cost, manufacturing cost etc. The platform evaluates more than millions of past sales, defines characteristics of forecast and calculates 16 different cost & volume parameters on the forecast automatically.

For instance, a customer was supplied with CIF and FOB options in the previous year. If there is a sales plan in the strategic platform corresponding to a group including the customer, budget platform first finds the month volume of the customer in the group based on past shares. Afterwards, it splits the volume into two with respect to FOB and CIF sales. The platform assigns logistics cost depending on shipment types. If the user increases unit cost of shipping for the next year, all CIF forecasts in the system are affected accordingly so users can manage the system by controlling major parameters. They do not need to work on each forecast item specifically.

If users do not adjust the numbers, the platform equalizes volume and financial data of SP and BP for each group. In case of adjustments, the platform proposes a variance report highlighting differences for each group. Thus, users can explain the gaps with the strategic plan and their reasoning at once.

7.2.2. Instant supply check

Optimization model calculates optimal supply plan with given capacity constraints in order to minimize backlog and lateness of forecasts within seconds. Mathematical model also considers inventory policies to reach target stock levels. When the sales team prepares a draft forecast plan, they can instantly check whether there

exists a feasible supply plan to satisfy the requirements or not. They can also detect possible actions to make the sales plan implementable. For example, if there are tardy orders in May and June; nevertheless, all orders are satisfied on time after June, there is a supply problem in the first half of the year but there is no problem in year total. Users could shift some percentages of orders from the first half to second half with manual functions and could get a feasible plan with optimization immediately. Before the implementation, the sales and planning teams used to work independently, and this cycle was very time consuming. That was limiting scenario generation process.

7.2.3. SKU based planning rather than product family based planning

SKU based plan provides higher accuracy for estimating revenue and gross profit since gross margins or costs vary depending on items. As mentioned in Result 3, SKU based demand can be estimated anymore. On the other side, optimization can calculate SKU-based production plan promptly. Before the implementation, both demand management and supply checks were taking much more time although they were done in product family detail.

In addition to high-accuracy estimation in growth plans, SKU based planning has significant positive advantages in terms of material management. SKU production plan is used to calculate material requirement plan and indirectly procurement budget. In the past, teams used to estimate yearly SKU productions by roughly splitting product families to some major SKUs. Transitions among SKUs were misleading planning team during material budgeting process. Currently, the platform could calculate material budget precisely as well thanks to detailed plan.

7.2.4. ERP synchronization

Sales and planning teams used to feed all budget numbers to ERP system manually at the end of the budget process so that finance team could prepare relevant reports. The process was taking weeks and was open to mistakes. Since all informa-

tion was present in only Excel and different teams worked with different templates, manual operations were inevitable. With the implementation, the budget platform has been integrated with external data sources. Now, when the budget plan is over, outputs in SKU detail can be transferred to ERP within seconds with 100% accuracy.

7.3. S&OP Results

As mentioned above, budget and S&OP sections have common functionalities, and they have similar mathematical model. Instant supply check (Section 7.2.2) and SKU based planning (Section 7.2.3) results are also common for these platforms. In this section, we will mention only S&OP specific results and not repeat common ones.

7.3.1. Integrated forecast management tool

Forecast management is a major task of sales executives. They used to combine actual sales, open orders and forecasts in the same sheet to see total year figures and compare year total with budgeted numbers. When an order was turned an actual sales, they used to delete the order and add a new realized sale accordingly. Similarly, converting a forecast to an order was requiring an effort. When size of orders is considered, this process was too demanding and open to mismanagement. With S&OP platform, the process is connected to ERP and live data is always present in the platform. Additionally, the platform nets forecasts and orders smartly so that total year figures can be kept updated continuously. In the past, if and only if all sales executives updated their part simultaneously, the correct figure could be present.

7.4. Operational Planning Results

7.4.1. SKU based production plan

First, the production planning process requires basically capacity constraints, production orders, stocks and net demand that consists of sales orders and forecasts.

Capacity constraints are static data. When they are defined once, they could be used with minor adjustments. The OP platform enables users to define and manage production capacities. Stocks, production orders and sales orders are imported from ERP in daily basis. As mentioned above, forecast is kept updated in S&OP platform. OP platform retrieves net forecast from S&OP therefore all required data for production plan can be prepared by the platform without any effort of users.

Second, preparing a production plan in SKU detail for two months is not possible in practice without an intelligent and automated system. Optimization tool in OP platform could evaluate all inputs above and minimize backlog and lateness of demands in less than five minutes. This enables users to make a new production plan every day from the end of the frozen period to the end of next month.

Before the implementation, the production plan was done in product family detail and that caused extra management effort for the production team. Also sometimes, plans looking feasible in family detail were limited by constraints at the lower level. Although the plan was done in family detail, planners used to spend even more time supplying all inputs from external sources manually.

7.4.2. Evaluating port and label constraints

As shown in mathematical model section, the optimization model considers port related constraints which are port silo, port transfer and port loading capacities. Before the implementation, these details were estimated roughly. Since the production plan was not updated in daily basis, it was not possible to detect problems on time.

Management of labeled orders doubles the effort spent on production plan. In the past, special orders were managed manually outside the production plan for limited horizon. That caused conflicts and mismanagements despite a massive effort. Currently, special orders are managed systematically without additional work as mentioned in mathematical model section.

7.4.3. Due date promising

We mentioned that the production plan by the end of the next month could be kept as updated above. OP platform could match stocks and productions with requirements automatically and calculate the due date of each order in the system without any effort. In the past, there would be many calls and mail traffic among planning and sales teams to agree on due dates. Anymore, an updated and agreed satisfaction plan for orders is visible for all stakeholders continuously.

In the past, a rough due date process was in use. Since the plan had product family detail, SKU mix used to mislead teams about the plan. Furthermore, there was no mechanism separating standard and special (labeled) orders. That used to cause conflicts in order promising process as well.

7.4.4. Publishing supply report automatically

OP platform combines past realizations and production plan and monitors a supply report highlighting the total month figures. This report is essential to detect a possible variance between S&OP and OP plans in terms of sales and production. In the past, the planning team used to spend more than two hours daily to publish the supply report.

7.4.5. Synchronization of planned and production orders with ERP automatically

OP platform manages frozen period with production orders. Productions after frozen period are planned by optimization. If the user wants to adjust any productions, s/he could use the functionality of the platform. When the plan is ready, the user can send productions to ERP automatically. Productions within frozen period are updated as production orders, ones after frozen period are created in ERP as planned orders.

Before the implementation, creating production orders was so time-consuming therefore they were not updated on a regular basis. Also, planned orders were not in use due to the heavy workload. Currently, since the production plan is continuously updated and synchronization does not require any effort, planned and production orders can be kept correct consistently in ERP. That is particularly useful in terms of leading the manufacturing department and managing MRP process.

7.5. Integrated Platform

7.5.1. KPIs below to quantify the positive impacts

As shown above, the integrated solution platform has provided certain advantages throughout the various levels of planning. The platform calculates the KPIs below to quantify the positive impacts. All KPIs are calculated without a user effort, and accessible by leadership team. Therefore, efficiency of the system could be observed continuously.

The platform also generates analysis in terms of product families for each KPI. These details can lead users where to prioritize first while defining an action plan.

7.5.1.1. Stock Reports. Days on hand (DOH) metric is calculated as (closing stock value / daily cost of goods sold). Closing DOH and moving average DOH metrics monitors inventory levels. While month closing DOH points information about a specific month, 12 month moving average figures eliminate seasonality impact so that progressive stock trends can be highlighted clearly.

7.5.1.2. Forecast Accuracy. At the beginning of each month forecast snapshots are saved by the platform. These forecasts are compared with the realizations at the end of the month. Analyses are done in terms of SKU, product family and region. These figures help the sales team with focusing on correct markets and items. This KPI was

not present before the implementation.

7.5.1.3. Output Reliability. At the end of each week, the production plan for next week is saved by the platform. Planned and realized productions are compared in weekly buckets. The KPI expresses frequency of adjustments in the production plan. This KPI was not present before the implementation.

7.5.1.4. Service Level. The platform compares promised dates and shipment dates of orders. Based on the comparison, service levels are calculated for product families and customers. If there are problems regarding a specific item group or customer group, an action plan could be set accordingly.

8. CONCLUSION

The chemical company has an overly complex sales and operations structure. The company must optimize decision making processes and provide an alignment among decisions from various levels to be competitive in the global market. Finding optimal supply networks, managing capacity investments efficiently and growing in profitable markets contributes a lot to the company in terms of having sustainable growth. The solution platform we developed proposes optimized strategic decisions and speeds up decision making process significantly. That enables the company to evaluate many scenarios before making the final decision.

Aligning tactical and operational planning processes to strategic decisions is at least as important as optimizing strategic decisions. If the alignment is not achieved, optimal decisions can never be executed. For this reason, the company needs to set up a data flow mechanism ensuring that decisions having different frequency, bucket length, horizon, hierarchy can communicate among each other. The integrated solution platform provides this data flow without any user effort.

The system we implemented has been in use since September 2020 and has an integral role for planning and sales teams. Major responsibilities of these teams are mostly managed by the platform. Management team of company asserts that the platform has increased efficiency and reduced human dependent errors throughout the planning process. We expect to observe continuously improving KPIs over the following years with the increasing contribution of the platform.

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