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Investigation on supply chain losses in brewing industry

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Abstract

Beer is the alcoholic beverage which is most widely used in the globe nowadays. Brewing industry is expected to increase to $685,4 billion in 2025, yielding a compound annual growth rate of 1,8%. The growing interest of customer brings potential and also challenges to the industry. For instance, more demanding customers in terms of taste, flavor and freshness drives brewers to run a race of "premiumization", in which they offer new premium products to attain more market share and enhance competitive advantage. Another instance is the seasonality, in which specific products in specific format are produced to serve in certain occasions. These prevailing trends coupled together, resulting in the number of stock-keeping-units (SKUs). This consequently implies the supply chain losses.

The objectives of the study were to investigate where losses stem from and how to mitigate these losses. To achieve the objectives, the study used both qualitative and quantitative approach. First the relevant literature of sales and operations planning was reviewed, and then a case study about a beverage company was investigated. Within the case study, production planning and material requirement planning were carried out.

The analysis of the case showed that losses always remain in form of either stock holding or stock out costs. Losses can be ascribed to different contributing factors, i.e. the diversification of products, failure in capturing a bigger picture in production planning, supplier's order lot size and performance, and demand variation.

The study also recommended ways to mitigate losses, such as facilitating a more flexible production model, adopting a wider perspective in production planning, enabling smaller order lot size, keeping trace of supplier's performance and shift in demand pattern.

Keywords/tags (subjects)
Brewing industry, Sales and Operations planning, Material requirement planning, Supply chain losses

Miscellaneous (Confidential information)

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1 Introduction

1.1 Topic background

Brewing industry has been considerably contributing in the growth of the economy. Back to 1960s, beer production and sale were limitted locally, which resulted from issues of shelf life and transportation. Nevertheless, technological development since then opens the way to industrializing beer production. More precisely, production innovation helps prolong product shelf life, transport evolution remarkably contributes to product distribution, and packaging improvement facilitates mass production. Technological advancements in brewing industry are applied globally, making the product homogeneous. Apart from that, thanks to merges and acquisition, integration has taken place in a very large scale, which then leads to product homogeneity. In 2010, five big brewers are responsible for 50% of beer production.

Main players in the industry are well-established, creating relatively great entrant barrier. Actually, competition in beer market does not happen on price basis, but on marketing and its various components instead. Prevailing is the "premiumization", an effort of brewers to offer premium brands. Apart from that, market growth rate is ascribed to consumer's enthusiasm of experiencing new brands and products. This is proven in both trends of "premiumization" and the increasing number of microbreweries. 75% of brewers across Europe are microbreweries who offer craft beer, posing a tough challenge to the traditional products of the big players. The market picture undeniably well explains the augmenting amount of stock keeping units (SKUs) in this industry. For example, there were eight times more new beer products in 2012 compared to 2007 in Italy, five times in Czech Republic, four times in Spain, three time in France.

These trends on the one hand have promisingly encouraged the industry's continuous growth, yet implied risk of supply chain losses on the other hand. How production could keep up with such trends in the market demand, and how production planning could mitigate the supply chain loss caused from the possible mismatch really worth investigation.

1.2 Research objectives, questions and limitations

The study aimed at finding out where supply chain losses stem from and how to reduce those losses. The scope of the study was only limited to losses occurred due to the possible mismatch between supply and demand. Other kind of supply chain losses, for instance losses during transportation, losses caused during storage due to the product's perishability, etc. would not be addressed. Based on that objectives, the main research questions of the study are built as follows.

RQ1: What causes the supply chain losses in brewing industry?

RQ2: How to mitigate the supply chain losses in brewing industry?

1.3 Research methodology

Both quantitative and qualitative approach were adopted in the study. First, the literature review tried to build a foundation, on which a case study was then investigated and analyzed to give a better perspective of the problem. More precisely, the relevant literature of Sales and Operations Planning was addressed to give knowledge of how and from where losses might occur. Then based on that, the case study observation would help to give a real picture about the sources of loss.

Within the case study, relevant literature (Vollmann, T.E. et al, 1997) was the base on which the analysis and calculations of production planning and material requirement were done. Also, operation research method such as optimization and simulation were used for production plans.

It should be noted that case study investigation is a proper choice in conducting this study, as it stems from the nature of the study, which is explanatory. Case study with focused and specific settings allow to dive deeper and give understanding of underlying reasons, i.e. the causes of the supply chain losses in brewing industry. Qualitative approach helps gain understanding of a whole picture (Norman, K.D. et al, 2005).

1.4 Data and information gathering

Qualitative data was collected by interviews with the company's production planner. Numerical data was collected from company's information system. More precisely, data of demand forecast for June 2019 was built based on the historical sales data of June 2018, and also from a consultant company and retailers.

1.5 Research structure

The study is organized as follows. Chapter one presents an overview of topic background, the objectives, questions and limitations of the research. Also, in this chapter is included the research methodology, which addresses and justifies the selection of qualitative approach. Finally, research structure gives the general overview of how the study is organized.

Chapter two builds the foundation of the research, where the existing literature review on the topic of Sales and Operation Planning is presented. Here the issue of discrepancy between demand management and supply planning is addressed.

Next, chapter three gives a glance of brewing industry, its significance in economic perspective. Also, in this chapter is described the specific traits of brewing industry, which might potentially suggest possible source of losses. There is also a quick overview of challenges encountered in production planning, which stem from the nature of beer product and market.

Then comes chapter four with the illustration of a case study about a beverage firm. Within this case study, production planning and material requirement planning processes are observed and investigated to find out the possible source of losses. Based on this, ideas about how to mitigate these losses are suggested.

Key findings are presented in the fifth chapter. Apart from that, other remarks would be addressed, which might serve for further potential investigation. Finally, the thesis is concluded in the sixth chapter.

2 Literature review

2.1 Sales and Operations Planning (S&OP)

In the age of cross-functional management, a prevailing argument is that functional conflicts should be overcome. The ever-conflicting area of marketing and manufacturing, or sales and production has gained interest among researchers. One of the earliest literatures came from Shapiro, who first addressed this issue in his article "Can marketing and manufacturing coexist?" in 1977. He identified the causes of these conflicts, which consist of functional orientation, reward and evaluation system result from that orientation, culture difference and the inherent complexity (Shapiro, B. 1977).

Existing literature gives several definitions of S&OP. It is a tactical planning process which help balance demand with supply, ensuring that different functional units would be aligned, aiming at supporting the business strategic plan (Feng, Y. et al. 2008). It is also defined as a process that integrates, assesses, and revises, harmonizes all conflicts of different business functions' plans, with the aim of generating a set of plans to control performance (Ling, R.C. 2002).

The aim of S&OP is to continuously keep supply and demand in balance because the mismatch between supply and demand brings forth undesirable consequences. More precisely, when supply outweighs demand, increasing inventory level causes the rise of inventory holding cost, cash flow problem due to the capital tied to inventory, reduced production rate and worker layoffs, shrinking profit margin and more frequent discounts and promotions. On the other hand, when demand exceeds supply, a firm suffers from customer service and quality deterioration, longer lead time, longer order backlog, extra costs due to unplanned overtime, materials and freight, which make the business eventually lost. The demand supply balance through S&OP process results in customer service improvement, reduced inventory, shorter lead time, more stable production rate, better collaboration with suppliers, better internal integration across different functional units (Wallace, T. F., et al, 2008).

The goal of S&OP is the balance at aggregate level, which include overall sales and production, inventories and order backlogs. The next focus to be dealt with is mix which is individual products and orders (Wallace, T. F., et al, 2008).

S&OP process is a five-step process, which begins with data gathering for demand and supply planning. Next, demand planning step largely emphasizes on forecasting, which is based on sales history, competitors' moves, management directives and economic situations. This demand plan then becomes a critical input of next step, supply planning. In this step, production is planned with reference to available capacity, inventories, and demand plan. The last two steps are meant to attain balance of supply and demand plans. People from different functional units gather for discussion and decision making (Wallace, T. F., et al, 2008).

In planning an efficient S&OP process, some key parameters need to be decided. For instance, (i) planning horizon defines how far should the plan be projected into the future. Planning horizon might vary from one to more than three years. However, it should be reasonable to align available capacity to existing demand in a way that both market chance and company resources are fully utilized. Planning horizon is therefore uniquely determined by company's context (Jonsson, P. et al, 2009). (ii) Planning frequency defines how frequent should the plan be revised, and the meeting be scheduled. A good number of literatures recommend a monthly basis. Nevertheless, the planning horizon should also be decided in reference to company's and market's specific traits. (iii) Planning object is the aggregate level of product family, as S&OP aims at overall planning and neglects to focus on detail. Products of homogenous demand pattern and of the similar required resources should be categorized as the same product family (Jonsson, P. et al, 2009). (iv) Unit of capacity shows how capacity is specified, for example machine hours, man hours (Jonsson, P. et al, 2009). (v) Time fences for changes defines how far and how big changes are allowed. Time fences for changes are decided based on other elements, such as time for material sourcing, capacity adjusting, and system flexibility (Jonsson, P. et al, 2009).

2.2 Demand planning in S&OP

Demand management is the key to this second step of S&OP process. Demand management process includes four main steps, as follows. (i) Creating demand plan. Demand plan consists of the forecast, assumptions attached to the forecast and action plan to realize the demand plan. The assumptions need to be evaluated to give more insight into demand driving factors and create a well-grounded demand plan. In creating the demand plan, perspectives from sales, marketing, production management, customer, statistical, business plan and strategy need to be taken into consideration. (ii) Communicating demand plan. As the basis of S&OP process, details of demand plan need to be shared to all functional units. (iii) Creating consensus plan. This step is designed to avoid misalignment between sales and marketing, bringing them together, facilitating a demand plan which marketing supports and sales commits to sell. (iv) Managing exceptions. An example could be abnormal demand. Demand management should prepare solution to satisfy abnormal demand without affecting regular demand (Schorr, J.E. 2007).

Concerning the inputs of demand planning, apart from the product development plan of the first step, other data is needed such as business strategy, sales forecast, customer plan, market intelligence, statistical projection and product management plan. These inputs are reviewed and integrated. Assumptions are jointly developed and discussed as per how they would impact the demand plan. Past performance metrics, such as of demand plan accuracy, sales forecast accuracy, market share, and so on are reviewed in order to update the demand plan if needed. Output of this step is the unconstrained demand plan in aggregate by family and detail by sub-family. This demand plan is later constrained by senior management, based on whether the priority is given to capacity ensuring or demand restricting to achieve business objective (Schorr, J.E. 2007).

2.3 Supply planning in S&OP

This is the third step of S&OP process whose participants consist of four groups. First, manufacturing and production address the issue of capacity to produce the required supply plan. Next, purchasing figures out if the capacity of company’s suppliers goes in line with the supply plan. Then come the logistics and distribution who answer the questions of truck capacity to move product and warehouse capacity to keep inventory. Finally, the engineering and design who determine if their capacity is sufficient to realize the required changes of product, in case of an engineer-to-order context (Schorr, J.E. 2007). The aim is however, not only limited to having enough capacity to cover the supply plan, but also about avoiding redundant capacity which leads to low utilization of capacity and undesired costs (Karlsson, S. et al, 2011).

In supply planning, firms are challenged to manage and balance three elements simultaneously, i.e. customer service, inventory and operating costs. The difficult part is to determine the aggregate inventory level or aggregate backlog by product family (Schorr, J.E. 2007).

The crucial process in supply planning is Rough Cut Capacity Planning (RCCP), which translates and makes a connection between marketing and manufacturing. Sales or marketing prefers to use the term of customers, brands, markets whilst manufacturing prefers to speak of resources and suppliers. RCCP links these two in a common language (Schorr, J.E. 2007). Input of RCCP is the load profiles – the way to relate products to the crucial resources needed to produce them. Typical examples of crucial resource are plant capacity, labor hours, machine capacity, warehouse space needed, etc. (Christopher, D.G. 2007).

Concerning the inputs of supply planning, apart from the product development plan of the first step and the forecast of the second step, other data is needed such as business and manufacturing strategies, internal and external supply chains' performance, hedging strategies, improvement and seasonality plans, flex capacity potentials. These inputs are reviewed and integrated. Assumptions of materials, capacity, hedging strategies are analyzed on how they would impact the supply plan. Past performance metrics, changes in product development plan, and forecast are also reviewed in order to adjust the supply plan if needed (Schorr, J.E. 2007).

In S&OP, supply planning is presumed to always support the demand side. Hence, if demand outweighs the maximum available capacity, scenario of how to bridge the gap is needed to develop. Some alternatives for consideration might be building new facilities, purchasing new equipment, and using third party manufacturers. For all these alternatives, costs and issues attached to them must be identified and evaluated. To prioritize capacity expanding or sales restricting is a management decision. It is therefore decided in S&OP meeting based on the overall business strategy, plan and direction (Schorr, J.E. 2007).

2.4 Information sharing in S&OP

In order to better match supply with demand, one of initiatives that has been largely mentioned is "information sharing", or "knowledge sharing", or "information integration" between supply chain's members (Lee et al., 2000, Lotfi, Z. et al, 2013), as it is an efficient way to facilitate connection of partners and synchronization of activities across the whole supply chain (Baihaqi, I. et al, 2013). Thanks to the development of information technology, firms are offered a wide chance to low cost integration, realized by electronic data interchange and other communication devices between supply chain partners (Huang, G.Q. et al, 2003, Siau, K. et al, 2004).

Information that can be shared among supply chain's partners are diversified. Existing literature suggests various ways for categorization. Chopra, S. et al (2004) categorize information based on supply chain's phase perspective. More precisely, information flowing through a supply chain can be divided into six types, which are supplier, manufacturer, distributor, retailer and customer information. Another way of categorizing is based on operation perspective, which divides the shared information into product, process, resource, inventory, order and planning (Huang, G.Q. et al, 2003). Pandey, V. et al. (2010) present a framework in which the shared information is divided into Purchases and Sales, Inventory status, Product development, Sales and forecasting, Market development, Future plan, Production cost, Technology know-how and Order tracking.

There are three levels of information sharing based on time horizon. At operational level, information is shared to fulfill orders, reduce information distortion and stock level. At tactical level, information sharing aims at collaboration in monthly and quarterly forecasting and planning to ensure sufficient capacity. At strategic level, annual demand, promotion plans, and marketing strategies are shared to plan the future purchase and growth within the alliance.

In tackling the issue of information sharing, firms have to answer four key questions, i.e. what to share, with whom to share, how to share, and when to share. Clearly defined scope of the answers to these questions help avoid redundancy, decrease sharing cost and improve the responses (Sun, S. et al, 2005). The answers to these questions are decided by the supply chain structure (D'amours, S. et al., 1999), which refers to how firms are arranged, and activities linked (Lambert, D.M. et al., 1998); also, by integration level (Kumar, S.R. et al., 2012), which depends on firm capabilities, product complexity, and corporate culture (Lambert, D.M. et al, 1997); and by relationship between partners. For instance, production schedule is shared with part suppliers to avoid cost of stockpiling or stock-out, and shipping information is shared with logistics agents to ameliorate customer service level (Kumar, S.R. et al, 2012).

The topic about benefits resulted from information sharing have sparked the interest of many researchers. Several investigations of these benefits have been conducted. For instance, (i) shared information of inventory helps avoid the risk of overstock and stockout, bringing down inventory cost (Mourtzis, D. 2011). (ii) Revealing the picture of actual demand, sharing of sales data has been considered as the key strategy in tackling the problem of "bullwhip effect" (Lee, H.L. et al, 1997a, 1997b), a phenomenon in which a small fluctuation in demand results in greater fluctuations as the information is transmitted and penetrated upstream along the supply chain, from retailers, distributors, manufacturers, etc. Bullwhip effect, or demand distortion, can result in problems of forecast inaccuracy, low utilization of capacity, excessive inventory and poor customer service (Lee, H.L. et al, 2000). Shared sales data contributes to finding the resolution for these problems. (iii) Sharing of order information enables firms to early anticipate the supply chain's bottleneck, ensuring customer service quality (Zha, X. et al, 2005). Researches still extend the list of benefits of information sharing, for example the enhanced visibility and reduced uncertainties (Fiala, P. 2005), increased productivity (Mourtzis, D. 2011) and efficiency of the supply chain (Baihaqi, I. et al, 2013), earlier time to market (Lee, H.L. et al, 2004), and so on. Information sharing by downstream partner of a supply chain is the basis of Quick Response (QR) and Efficient Consumer Response (ECR) (Lee, H.L. et al, 2000).

The benefit of information sharing is influenced by several factors. For example, it is decided by the quality of information shared, which is defined as how well the information shared serve the need of firms (Petersen, K.J. 1999). Information quality is measured based on fours attributes, validity, timeliness, sufficiency, and reliability (Li, S. et al, 2006). In addition to that, the benefit of information sharing becomes apparent when the information is used across the whole supply chain (Mason-Jones, R. et al, 1997). Lee, H.L. et al. (2000) suggest that information sharing value can be realized only when the system is flexible enough to react.

The benefit of information sharing is also highly contextual-based. For example, Simchi-Levi, D. et al (2003) acknowledge that the sharing of demand information does not convey considerable value if the manufacturer is under tight capacity. Another example is from Lee, H.L. et al. (2000) who realize that sharing of demand information becomes more valuable when demands is highly correlated over time, highly variable, or the lead time is long. For product of high demand variation, shared information about forecast brings forth considerable value (Angulo, A. et al, 2004). In case of high predictability of demand, the value of information sharing is low.

2.5 Forecasting and S&OP

Sales planning and production planning are two key components in S&OP process. Demand forecast is the basis on which one of these two components, i.e. sales planning, is built. Accurate forecasting is therefore essential to facilitate S&OP integrated planning (Ivert, K.L. et al, 2011). Other researchers also share the same view that forecasting plays a crucial role in S&OP process because the process itself is market driven (Cecere, L., 2012). Demand planning should effectively function before any effort of production planning optimization would be made (Reyman, G., 2005). More accurate forecast therefore gives a well-grounded basis for S&OP process.

On the other hand, S&OP mutually reinforces the task of forecasting. More precisely, S&OP contributes to solve some of the classic forecasting problems, as follows (Wallace, T. 2006).

(i) The forecast accuracy is improved when S&OP is implemented. In some companies, it would be the case that too much emphasis has been put to demand forecast while supply side might be overlooked. As S&OP is highly cross-functional, efforts are also equally put in supply side, which helps mitigate problems caused by forecasting inaccuracy.

(ii) Conventionally, different functional units have their own forecast data. S&OP implementation requires that the same set of forecast data applies to the whole business. Different functional units therefore harmoniously and holistically work according to the agreed integrated plan. Moreover, this allows a quick response to any change of market demand.

(iii) With S&OP, forecast workload is lessened, because S&OP requires less detail level. The volume forecast is expanded in a horizon of three years, while the mix forecast at detail level is for the period of three weeks to three months, which provides enough visibility and validity.

(iv) Part of S&OP deals with abnormal demand, which is usually beyond the reach of forecasting.

2.6 Advanced planning and scheduling system (APS) in S&OP

S&OP seeks alignment between different business functions in order to balance supply with demand (Feng, Y. et al, 2008). Nowadays, together with the trend of globalization, these business functions are most likely going beyond national boundaries, which in turn makes S&OP a more challenging task (Stadtler, H. et al, 2005). Apart from individual and organizational factors (Grimson, J.A. et al, 2007), APS is also of crucial significance for a succesful implementation of S&OP (Ivert, K.L. et al, 2014).

Emerged in the late 90's, APS deals with finite capacity scheduling, a scheduling method which aims at creating a realistic production plan, considering the finite resources availability and capacity. APICS (2010) defines APS as an information system which facilitates planning decisions by using advanced mathematical algorithms or logic. APS functionalities include integral planning, constraint-based planning, optimization and simulation (Stadtler, H. et al., 2005), which give great support in S&OP process (Wallace, T. 2006).

There are four main modules in APS system: (i) strategic planning defines service areas and select partners; (ii) demand planning estimates future demand based on forecasting techniques; (iii) master planning satisfies demands while minimizing inventory, production and transportation costs; (iv) factory planning schedules each demand and assigns it to factory machines (Stadtler, H. et al., 2005). Of these modules, factory planning is the most significant one, as it is the basis for the fulfillment of master plan and aggregate plan (Kung et al., 2009).

2.7 When and how APS should be used in S&OP

(i) APS is suitable in complex planning environment (Kok, A.G. et al, 2003) or changing business environment (Setia, P. et al, 2008) which is characterized by "complex tasks with large number of products categories, frequent changing demand patterns, and uncertain supply conditions". Ivert, K.L. et al (2008) go further by defining the prerequisites of planning environment for APS implementation, which include complexity, uncertainty, and vulnerability.

The complexity is defined by the detail complexity, which is the number of entities influencing to S&OP process, and dynamic complexity, which is the restrictions and uncertainties of supply, demand, production system (Bozarth, C. et al, 2009). Another way to define complexity is as below, according to Ivert, K.L. et al (2008).

Product complexity, which is the number and variety of products, the dependencies and constraints. The dependencies, if any, lead to the need of integral planning. The constraints, if any, lead to the need of optimization tools.

Material flow complexity, reflected in the amount and variety of production sites, warehouses, suppliers, and customers, the dependencies and constraints. The dependencies or constraints, if existed, lead to the need of optimization, constraint-based planning, and integral planning.

Organizational complexity, which is the number and variety of business units, the dependencies and constraints. Optimization tools might be needed, as the common case is the instant struggle and conflict between individual business units and the whole organization.

Uncertainty is the happening of unpredicted events, due to the lack of information, time needed for feedback, and the relationship nature (Lysonski, S. 1985). In S&OP context, uncertainties of supply and demand lead to the need of scenarios testing and simulations (Ivert, K.L. et al, 2008).

Vulnerability is defined by how sensitive a system is in response to disturbance (Svensson, G., 2001). The more dependent business units are on each other, the more vulnerable they become. This ultimately leads to the need of scenarios testing and simulations (Ivert, K.L. et al, 2008).

(ii) Successful implementation of APS also needs other prerequisites, such as the people using the system (Zoryk-Schalla et al., 2004), knowledge and understanding (Ivert, L.K. et al, 2011), a central planning function (Rudberg, M. et al, 2008), integration into existing IT infrastructure (Wiers, V.C.S., 2002). These prerequisites are reflected in the individual, technological, and organizational (ITO) dimensions, as follows.

Individual dimension associates with system education, experience, and knowledge (Cox, J.F. et al, 1984). Those who implement and use APS system should know how to understand the model design, identify the significant data as well as interpret the outputs (Ivert, K.L. et al, 2011).

Technological dimension associates with system integration, data quality, and model design (Stadtler, H. et al, 2005). More precisely, APS system must integrate into IT infrastructure and any modification in one system should be incorporated into the other to avoid inconsistencies (Jonsson, P. et al., 2007). APS model design plays a significant role in the successful use of APS. However, there is no way to verify the modelling process and correct modelling is impossible (Lin, C.H. et al, 2007).

Organizational dimension associates with how activities are organized and structured (Berglund, M. et al, 2007). A critical factor is S&OP maturity, which is divided into S&OP structure, the holding of S&OP meeting, and collaboration (Ivert, K.L. et al, 2014).

2.8 Conclusion

The most important thing is to balance supply with demand. Failing to match these two consequently lead to the risk of losses, which might become more severe if the context is characterized with complexity, uncertainty, and vulnerability.

Concerning demand planning, crucial factor is the demand forecast, which is a decisive input for other consecutive steps of S&OP process. Demand forecast, as mentioned above, is essential to facilitate S&OP process, because S&OP process is strongly market driven. Accurate demand forecast hence gives the well-grounded basis for S&OP process. However, forecast and planning of demand have become more complex due to the trend of globalization, coupled with the market unpredictability, fragmentation, and dynamics. The risks of S&OP failing and supply chain loss even become more severe in industries characterized by shrinking product life cycle. In addition to that, demand planning becomes more challenging in a complex supply chain, as it scatters throughout the chain.

Concerning supply planning, a crucial factor is the RCCP, which is the translation of demand plan into the required resources and capacity, in term of manufacturing and production (plant capacity, labor hours, machine hours), purchasing (materials availability, depending on suppliers' capacity), logistics and distribution (truck capacity, warehouse space), engineering and design (capacity to realize product changes). RCCP is complicated due to complex production environment, for example shared resource and other variables. In supply planning, another difficult thing is to determine the aggregate inventory level or aggregate backlog by product family. This task is difficult due to several reasons. First, it requires the planner to avoid short-sighted effects, in which stock is demanded in small amount one day, and then in larger amount the other day. Longer-term view helps avoid both stockholding and stock-out costs. Aggregate inventory level should be decided in a way that minimizes costs. Second, it relates to the capacity, which is normally translated into how many products that can be produced in a time unit. This amount, however, depends on the product mix, as production time might vary for different products. Moreover, it is important to be noted that at this step, product variation, for instance in term of color, model, size, etc. is neglected, and only aggregate level is concerned. In addition to that, aggregate inventory level depends on the production plan, which later might depend on production cycles, and on basic production strategies, i.e. chase, level, or combination of these two.

2.9 Optimization and simulation

Within the domain of logistics and supply chain, there is a tremendous need of tools and techniques to achieve efficiency when tackling various problems, among which the most important one is how to optimize the resources and yield efficient operational costs (Silva, C.A. et al, 2008). Methods of optimization and simulation have captured the interest of many decision makers, as they have been considered powerful tools in dealing with logistics problem in recent years (Qin, X.S. et al, 2009).

Optimization is simply defined as a striving for perfection. Optimization problems could be very cost and time consuming. In a highly complex setting, however, optimization may fail to thoroughly represent all real life complexities of variable interactions, constraints, and appropriate objectives. Therefore, it should be seen as an approximation (Huang, G.H. et al, 2001, Belegundu, A.D. et al, 1999). Among different optimization techniques, linear and integer programing have been largely employed by researchers in tackling various logistics problems, such as production planning and distribution planning (Ryu, J.H. et al, 2004), resource planning in supply chain (Ozgur, K. et al, 2011), centralized and decentralized production and transport planning (Jung, H. et al, 2008), just to name a few.

On the other hand, simulation is defined as the process of building a model which reflects and represents the real situation. Based on the model built, experiments can be conducted and system behaviors observed. Also, different strategies within different scenarios set by system constraints are evaluated (Shannon, E.R., 1975). Simulation offers decision makers alternative solutions and gives insight into the system under various conditions, but it could not ensure an optimal solution. Simulation effectively answers what-if questions, but fails to answer which solution is the best (Huang, G.H. et al, 2001).

3 Brewing industry at a glance

3.1 Industry overview

Beer is the alcoholic beverage which is most widely used in the globe. With roughly 150 beer styles sold over the world, the global market is worth $593 billion in 2017 and expected to increase to $685,4 billion by 2025, yielding a compound annual growth rate of 1.8%. In recent years, beer consumption has increased due to the growth of consumer income and preference. Moreover, the rise of female drinker and young population also plays a considerable part in boosting the growth of beer market (Janice, F. 2017, Sinha, B. 2018).

The industry is of crucial significance in reference to how it contributes to the economy growth rate. For example, EU – the second largest beer producer of the world, has about 8,500 active breweries, producing approximately 415.5

million hectoliters in 2016 (Beer statistics 2017 edition). So far, EU's brewing industry has been creating 2.3 million jobs. Furthermore, every single job generates further 17 jobs in other sectors, i.e. supply and agriculture, retail, bars, pubs, cafes, and restaurants (Brewers of Europe, 2016).

3.2 Industry's specific traits

Technological advancement

Beer production and sale used to be locally constrained before 1960s due to the short shelf life and difficult transportation. However, after 1960s, technological advancement paved the way to the industrialization of beer production. For example, in nineteenth century, innovation which helps stabilize production process, i.e. thermometer, hydrometer, fermentation by yeast, etc. enable product to have a longer shelf- life. Trains and steamboats evolution makes transportation and distribution easier. Packaging improvement, i.e. bottling and canning, facilitates mass production. Many of large players appeared during this period, for instance, Carlsberg in 1847, Heineken in 1864, Anheuser-Busch in 1860, South-African Breweries in 1895 (Gammelgaard, J. et al, 2013).

Similar technologies globally

The industry has applied similar technologies globally because technological achievements in brewing industry are non-proprietary in nature (Gammelgaard, J. et al, 2013).

Homogeneous product globally

The fact that brewing industry has offered homogeneous product globally results from the enormous integration and consolidation of brewing industry. Furthermore, production process is standardized and remains the same for many years. Vertical and horizontal differentiations do exist, but the difference is so slight that consumers could not distinguish in a blind test (Gammelgaard, J. et al, 2013). Vertical differentiation is based on different quality of raw material and ways of handling the brewing process. Meanwhile, horizontal differentiation is the variants of flavor and bitterness, based on the difference in malting process of barley and the malt-hop mix in brewing process.

Dominated by a few large multinational firms

Since 1970s, the industry has witnessed integration which makes it more concentrated. Until 1990s, 80% of market share was held by only two or three main players. However, the consolidation was limited in national market only due to the high cost of trading across boundaries, consumer taste and drinking habits, taxation and regulation. At this phase, the level of concentration of the industry was still low. For example, five big players accounted for 25% of production in 1998. However, in recent years, the industry has become more globally consolidated and internationalized through the activities of merges and acquisitions. For example, five big players accounted for 50% of production in 2010 (Gammelgaard, J. et al, 2013).

Non-price competition

Oligopolistic is the nature of the industry, which stems from large scales integration. Main players of the industry are well-established, which further creates a great barrier to new entrants. In addition to that, integration also takes place vertically, which means that firms aim to acquire other players along the chain, i.e. supplier and retailer. Consequently, competition is unavoidably a matter of concern. In fact, brewing industry is investigated by regulators, in order to avoid anti-competitive practices. For instance, 50% of pubs in UK attached to main brewers. And in 2000, Interbrew was forced by UK's Competition Commission to sell some of theirs in order to be allowed to consolidate (The Brewing Industry).

Firms in brewing industry nowadays do not compete on price, but on marketing and its various components. This results from several reasons. First, it is because that "few technological achievements in brewing industry in the last century have been of a non-proprietary nature or did not have long-term effects on the competitiveness of the first-movers". Second, slight difference among products make consumers fail to distinguish. Brand value and marketing strategies are hence resorted to win the competition. Furthermore, the shift of beer consumption from on-premise, i.e. consumption at the selling site, to off-premise, i.e. consumption at home. More precisely, 75% of beer is consumed off-premise in The US and Europe. This consequently puts an emphasis on brand packaging, a significant factor in consumer's decision. Also, many researches proved that demand of beer is proof against price change (Spáčil, V. et al, 2016).

Among large-scale breweries, another way to gain competitive advantage and new market share is through product innovation, or the initiative so-called "premiumization", in which new brands or variants of existing brands are creating as premium offerings. This trend is demonstrated by a switch of sales volume from core products to premium ones across the globe. Consumer's enthusiasm of product diversity is proven not only in "premiumization" effort, but also in the rise of microbreweries in recent years. 75% of brewers across Europe are microbreweries and SMEs whose products are craft beers, which is a tough challenge for traditional, homogeneous product of hyper-consolidated breweries. According to statistical data, there were eight times more new beer products in 2012 compared to 2007 in Italy, five times in Czech Republic, four times in Spain, three time in France (Symington, S. 2014, Rutishauser, G.E. et al., 2015).

3.3 Challenges in production planning

More demanding customer

Customers generally have become more demanding concerning taste, flavor and freshness. This issue especially becomes severe in market areas where consumers have adopted a more sophisticated taste. For example, in certain markets, wholesalers might require product that reaches up to six months prior to expiry date.

In order to serve customers with high quality and fresh flavor product, brewing firms are taking various initiatives, from production point of view, i.e. high hydrostatic pressure, or sterile filtration for shelf-life extension, to logistics point of view, i.e. lower temperature in shipping and storage, fast turnaround times from brewery to glass, innovative packaging solution, coherent partnership across the supply chain (Beer freshness: not just a number).

The taste, flavor, and freshness of beer are significantly decided by shelf-life of the product, which therefore needs to be taken into consideration while planning the production. More demanding consumer is a challenge for production planning in a sense that it complicates and gives more restrictions to the planning process.

Product seasonality

The seasonality of beer product can be understood in two terms. In general, the consumption is normally higher in spring and summer time compared to fall and winter. Seasonality, on the other hand, is expressed in the fact that different beers are served in different occasions. Seasonal beer finds its origin in craft breweries, because traditionally certain ingredients are only available in specific season, not the whole year round. In today's competition, macro-breweries attempt to narrow their gap with craft beer by offering seasonal beer in some market areas where customer demand is shrinking.

Seasonality of product requires that stock needs to be built up before the season comes. This ultimately results in the challenge of production planning, in a sense that (i) stock building might expose product to the shelf-life risk due to the perishability of product, (ii) stock building might expose product to risk of obsolescence for those to be served in specific seasons.

Challenging in product-mix ratio decision

S&OP first focuses on the balance at aggregate level, then the product mix. However, product mix ratio in production planning could be of great challenge, in a sense that it is difficult to well capture on how consumer and demand pattern behave, and forecast accuracy therefore comes into question. The reasons are stated as below.

Consumer's taste preference is subject to change. They are enthusiastic to try new beer and taste new flavor. This trend makes demand become more volatile and transient. A survey conducted in the US among international students (Swinnen, J.F.M. 2011), shows that beer consumption habit changes due to several reasons, among which the change of taste accounts for 29%. Other reasons are peer influence (24%), availability (31%), price (10%), and other (6%).

Market dynamics, e.g. premiumization, craft breweries explosion, even encourages the consumer's enthusiasm, generating a reinforcing loop in which market dynamics and consumer's enthusiasm interact with each other, resulting in more implications and uncertainties for the planning of production.

4 Case study

In this chapter, a case study of a beverage firm is introduced, in which demand data for June 2019 is presented. Production then is planned with reference to the relevant literature (Volmann, T.E. et al, 1997). Production planning is done with different scenarios, i.e. with or without stock at the beginning of the planning horizon, with average and stochastic demand.

Optimal planning yields lowest total costs, as shown graphically. Also, simulation is built in excel spreadsheet to see how the system behaves, i.e. how total costs and cost structure behave in different production plans. The plan which most likely yields lowest cost is the optimal one. Based on that, the material requirement planning is done. In material requirement planning, travelling salesman problem (TSP) is referred in case that there is cost applied for changing product items in the line, in order to find out the optimal sequence. During the processes of production planning and material requirement planning, potential sources of loss are pinpointed accordingly.

4.1 Case study introduction

A beverage manufacturer has an aggregate demand of 6 million liters per month. In total, the company produces 11 products with 2 product categories, 4 products (B1 – B4) in the first category and 7 products (S5 – S11) in the second category respectively. There are two production lines and each serves one product category. The table below illustrates the demand of each product in the total monthly volume of 6 million liters.

TABLE 1 Monthly demand by product

Product	**%**	**Demand (1000 liter)**	**Product**	**%**	**Demand (1000 liter)**
B1	32	1.920	S5	17	1.020
B2	16	960	S6	10	600
B3	7	420	S7	6	360
B4	2	120	S8	4	240
Total	**57**	**3.420**	S9	3	180
			S10	2	120
			S11	1	60
			Total	**43**	**2.580**

4.2 Production planning

Preliminary demand plan

The demand is planned with a horizon of five periods which make up a month. Demand of each products is described below.

- B1 is quite stable with seasonal peaks. This month is within the season, and the demand reaches highest at 1.920.000 liters.
- B2 vary like sine curve almost. In this month, the demand is in the downtrend, expected to reach 880.000 liters.
- B3 has two swings in this month. Both are high swings, making demand reach 440.000 liters.
- B4 is stable. The demand is expected to be 120.000 liters.
- S5 has small growing tendency within the month. The demand is expected to be 1.050 liters.
- S6 varies, making zig zag lines in this month. The demand is 500.000 liters approximately.
- S7 is expecting to decrease in the next month. The demand is 320.000 liters.
- S8, S9, S10, S11 are quite stable, but small swings appear in the consumption. The demand is 240.000, 180.000, 120.000, 60.000 liters respectively.

Demand follows normal distribution. The table below shows the mean and standard deviation of demand value across five-period horizon.

TABLE 2 Mean and standard deviation of demand

Item	**Period 1**		**Period 2**		**Period 3**		**Period 4**		**Period 5**		**Total**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
B1	400	3	380	2	390	3	360	2	390	3	1920	
B2	180	2	170	1	176	1	174	1	180	2	880	
B3	82	1	90	1	87	1	92	1	89	1	440	
B4	25	1	23	1	22	1	25	1	25	1	120	**3360**
S5	214	3	209	2	213	3	208	2	206	2	1050	

S6	108	2	88	1	108	2	88	1	108	2	500	
S7	68	1	62	1	63	1	65	1	62	1	320	
S8	51	1	48	1	45	1	49	1	47	1	240	
S9	37	1	34	1	36	1	35	1	38	1	180	
S10	26	1	24	1	25	1	23	1	22	1	120	
S11	12	1	13	1	11	1	13	1	11	1	60	**2470**

Other assumptions

- Holding cost is € 20 per unit.
- Shortage costs include two parts, first, 20% of lost order costs € 200 per unit, second, 80% of the remaining costs € 50 per unit for late delivery.
- Cost of changing production level is € 15000 per time
- The number of product items which could be produced per week is 2 for production line 1 and 3 for production line 2.

Production planning with no stock at the beginning of the period

Average demand

Lot size is decided at the average level of aggregate demand of different product items across the time horizon. The lot size could be heuristically adjusted around the average level to yield as low total costs as possible. Below is the production plan of two lines.

TABLE 3 Production plan of line 1

Production line 1		**1**	**2**	**3**	**4**	**5**	**Total**
Aggregate demand		687	663	675	651	684	**3360**
Production		671	671	671	671	671	**3355**
Ending inventory	0	-16	5	1	21	8	
Holding costs	20	0	96	16	416	156	**684**
Shortage		-16	0	0	0	0	
Shortage costs		1280	0	0	0	0	**1280**
Production change cost	15000		0	0	0	0	**0**
Cost per pediod		**1280**	**96**	**16**	**416**	**156**	**1964**

TABLE 4 Production plan of line 2

Production line 2		**1**	**2**	**3**	**4**	**5**	**Total**
Aggregate demand		516	478	501	481	494	**2470**
Production		492	492	492	492	492	**2460**
Ending inventory	0	-24	9	0	11	9	
Holding costs	20	0	184	4	224	184	**596**
Shortage		-24	0	0	0	0	
Shortage costs		1920	0	0	0	0	**1920**
Production change cost	15000		0	0	0	0	**0**
Cost per pediod		**1920**	**184**	**4**	**224**	**184**	**2516**

Also, different production levels are tested to observe how inventory holding, shortage, and overall costs behave. The illustrating chart below gives some ideas, (i) as production level increases, inventory holding cost increases and shortage cost will decrease; (ii) at some point, when the company can satisfy all the customer demand, shortage cost will be equal to zero, yielded service level of 100%. Total cost is then equal to the inventory holding cost.

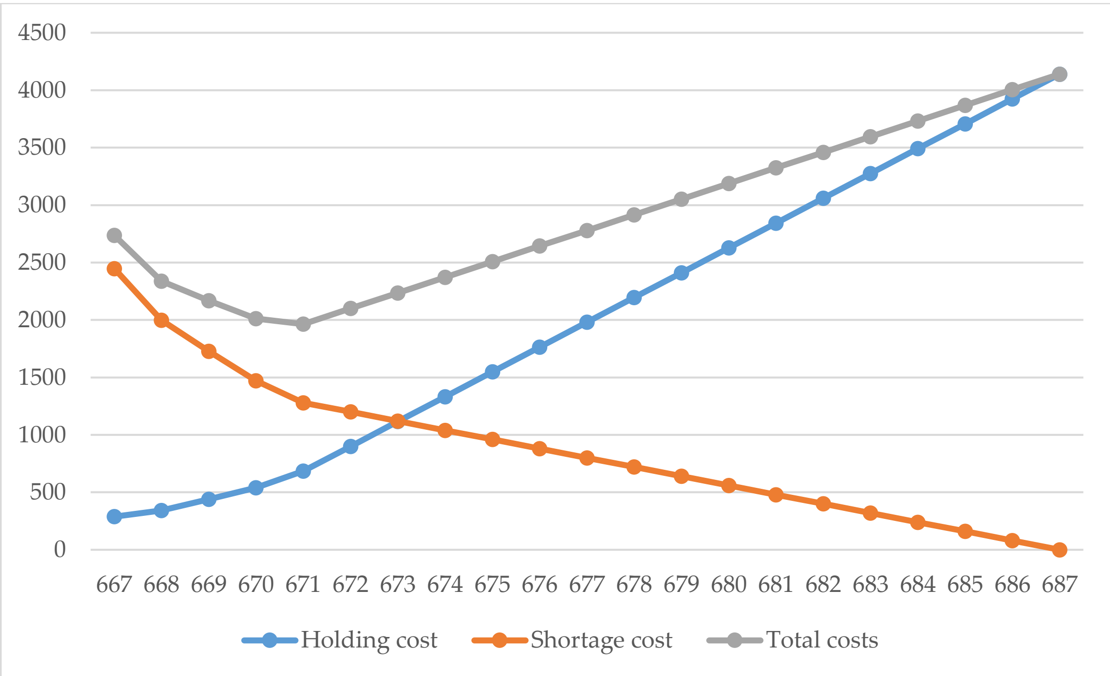

FIGURE 1 Line 1 costs with average demand

Remarks

- The approach to decide production lot size is plain and simple, as demand is fixed data.
- Adopting levelling strategy is less costly than chase or hybrid strategy, due to the cost of changing production output level is relatively high compared to stock holding and shortage costs.
- Shortage cost accounts for a higher proportion in total cost, in comparison with stock holding cost, which might be ascribed to different cost elements, i.e. lost orders, late delivery penalty.

Stochastic demand

Demand variation, if taken into account, makes it difficult to plan the production. This is because that the demand value keeps changing while production needs specific value on which its plan is based.

A simulation model therefore should be built, in which demand varies, following normal distribution. Based on the demand variation, production is planned with fixed average demand value across five periods, i.e. output level of 672 for line 1 and 494 for line 2 respectively. Then, the total costs, i.e. shortage cost, inventory holding cost, and output changing cost are investigated. These costs vary as demand varies, which are illustrated in the histogram below, based on the result of 100 simulation runs.

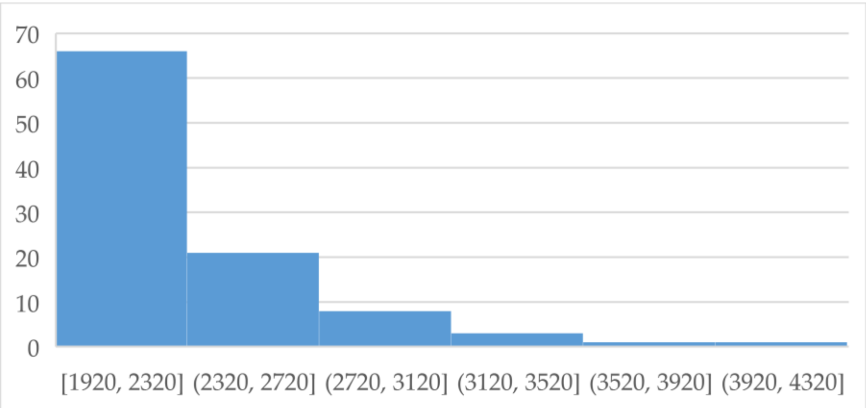

FIGURE 2 Line 1 cost distribution with stochastic demand

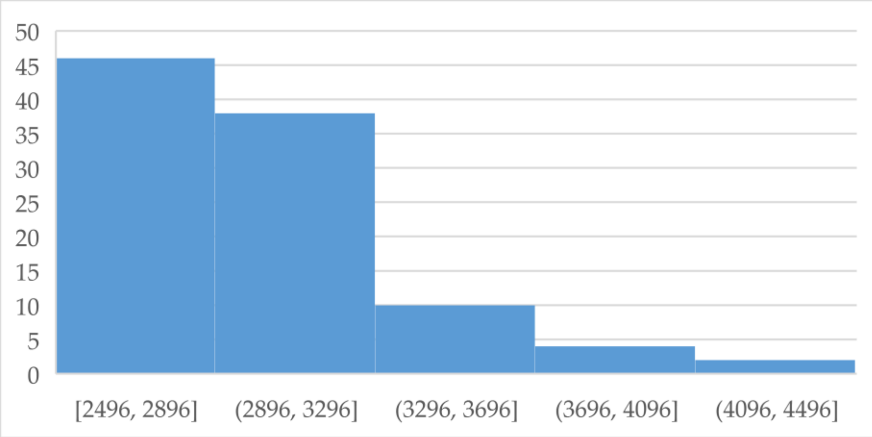

FIGURE 3 Line 2 cost distribution with stochastic demand

Again, the cost behavior is tested with different production levels. The chart below shows the similar behavior of average demand, i.e. (i) inventory holding cost increases and shortage cost decreases when increasing production level; (ii) total cost is equal to inventory holding cost when service level is yielded at 100%.

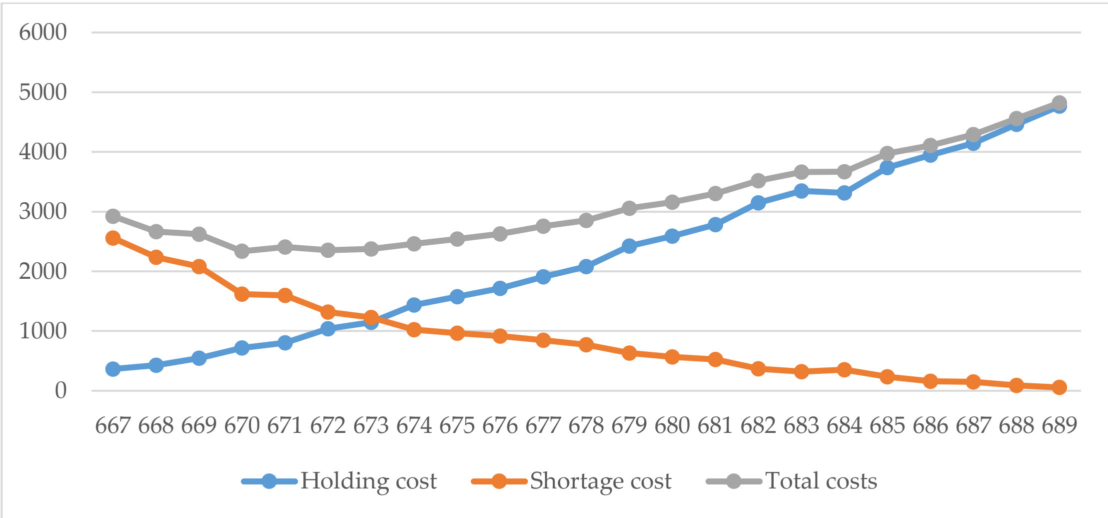

FIGURE 4 Line 1 costs with stochastic demand – no beginning stock

Remarks

- The discrepancies between production and demand always remain. There is no ideal level of production that should avoid the risk of stock or stock out, which means that costs will always occur, either stock holding cost or shortage cost. Deciding a reasonable production lot size is therefore challenging in reference to the reality of stochastic demand.

- Again, the same remarks are made. Adopting leveling strategy is less costly than chase or hybrid strategy. And shortage cost is higher than stock holding cost due to different cost elements.

Production planning with stock at the beginning of the period

The same preliminary plan of demand is used, but with 8 units of stock in the beginning of the period. New production plan has less products in the production line. Also, it yields a lower total cost. In conclusion, levelling strategy still works well in this case.

TABLE 5 Production plan of line 1

Production line 1		**1**	**2**	**3**	**4**	**5**	**Total**
Aggregate demand		687	663	675	651	684	**3360**
Production		670	670	670	670	670	**3350**
Ending inventory	8	-9	5	0	19	5	
Holding costs	20	0	104	4	384	104	**596**
Shortage		-9	0	0	0	0	
Shortage costs		720	0	0	0	0	**720**
Production change cost	15000		0	0	0	0	**0**
Cost per pediod		**720**	**104**	**4**	**384**	**104**	**1316**

TABLE 6 Production plan of line 2

Production line 2		**1**	**2**	**3**	**4**	**5**	**Total**
Aggregate demand		516	478	501	481	494	**2470**
Production		491	491	491	491	491	**2455**
Ending inventory	8	-17	10	0	10	7	
Holding costs	20	0	192	0	198	138	**529**
Shortage		-17	0	-0,4	0	0	
Shortage costs		1360	0	32	0	0	**1392**
Production change cost	15000		0	0	0	0	**0**
Cost per pediod		**1360**	**192**	**32**	**198,4**	**138,4**	**1921**

The cost structures behave the same as in the case of zero inventory. However, lesser total costs are needed to yield the same service level. For example, for average demand, it costs $2540 to yield 100% service level compared to $4140.

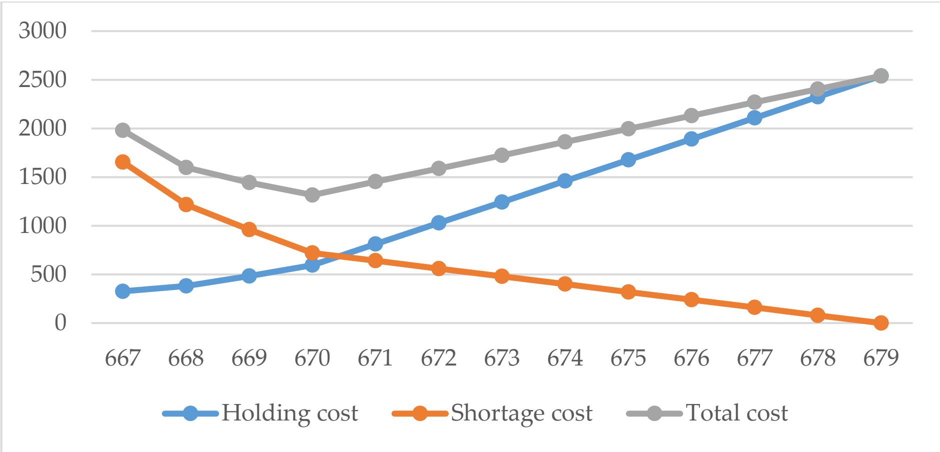

FIGURE 5 Line 1 costs with average demand – with beginning stock

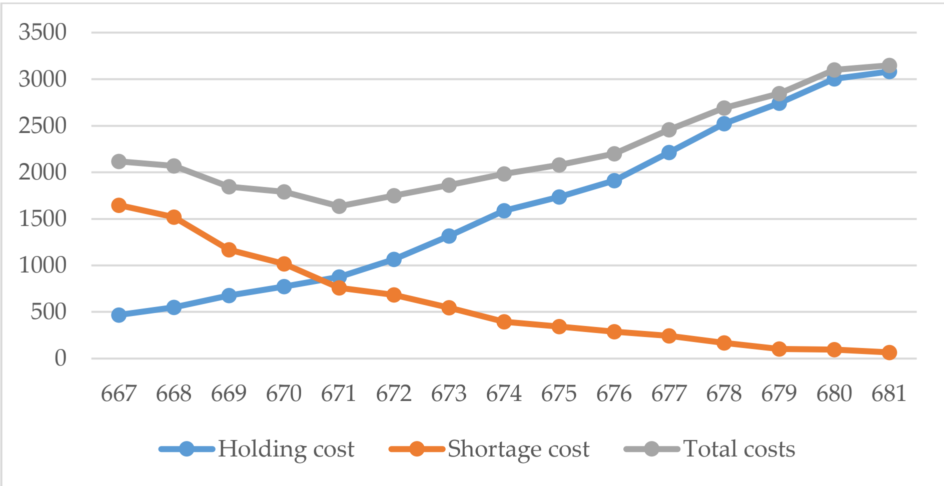

FIGURE 6 Line 1 costs with stochastic demand – with beginning stock

4.3 Material requirement planning (MRP)

Product structure diagram

<u>Production line 1</u>

The main material for production is water which the company can use from their own spring in their own real estate. Apart from that, production needs also malt (M1 – M2) and other ingredients (I1 – I3). B1 and B2 use M1 while B3 and B4 use M2. Product structure diagrams are shown below.

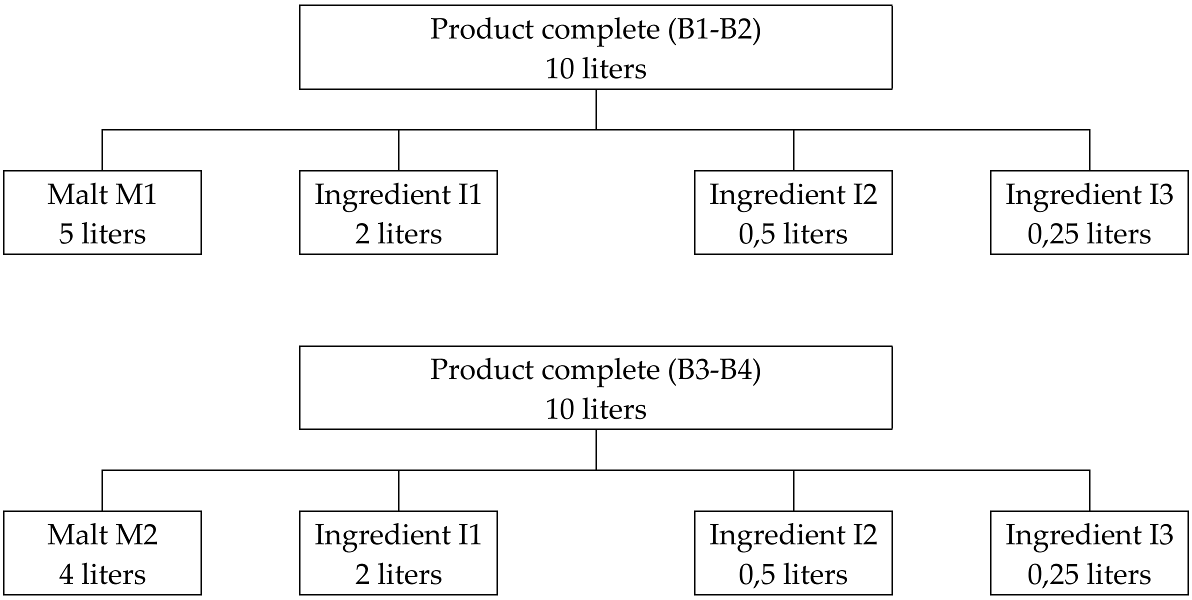

FIGURE 7 Line 1 product structure diagram

<u>Production line 2</u>

Apart from water, production needs also sugar (10%), carbon dioxide (1%), flavoring (3%), additive (1%). Product structure diagram is as below.

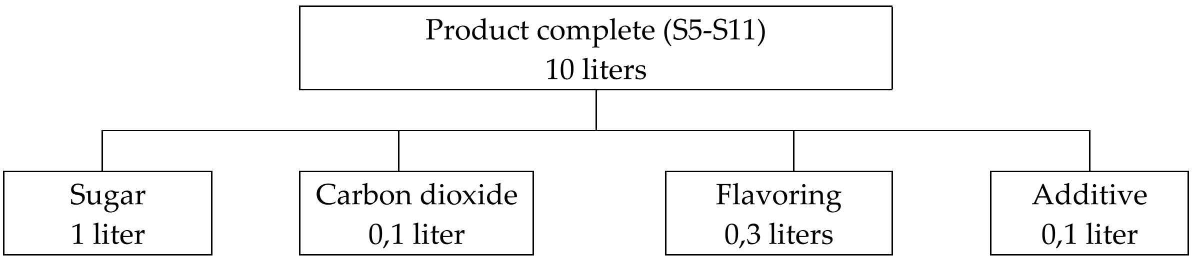

FIGURE 8 Line 2 product structure diagram

Travelling salesman problem (TSP) in detail production plan

The model is built with the assumption that a cost would occur when changing product items in the production line. When the cost is the same for all items, there is no need to concern about the sequence. When the cost varies depending on product items, the route or sequence of product items produced in the line is decided in referring to the TSP optimization, which helps yield the least cost. In reality, it is less expensive when switching from low volume to high volume item in the production line. For example, the best route or sequence of producing items in the line is B1 – B2 – B3 – B4, if the cost matrix below applies. TSP optimization is helpful even in the case of insufficient capacity, since it helps set the least costly combination of product item in the line in each period.

TABLE 7 Cost matrix for line 1

	B1	**B2**	**B3**	**B4**
B1		3000	4000	5000
B2	3000		1000	2000
B3	2000	5000		1000
B4	1000	4000	5000	

Detail production plan

Production line 1

The detail production plan is made with the assumption that the changing cost in the line is the same for all items. Material requirement is planned with stochastic demand, which means an output level of 672 for line 1. The number of product item types which could be produced is 2 per period at most. The detail production plan for each item is in the table below.

TABLE 8 Line 1 detail production plan

Product item	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**	**Total**
B1	552	232	386	360	390	**1920**
B2			286	312	282	**880**
B3		440				**440**
B4	120					**120**
Total	**672**	**672**	**672**	**672**	**672**	**3360**

Production line 2

The detail production plan is made with the assumption that the changing cost in the line is the same for all items. Material requirement is planned with stochastic demand, which means an output level of 494 for line 2. The number of product item types which could be produced is 3 per period at most. The detail production plan for each item is in the table below.

TABLE 9 Line 2 detail production plan

Product item	Period 1	Period 2	Period 3	Period 4	Period 5	Total
S5	210	210	202	234	194	**1050**
S6	224	164	112			**500**
S7	60		180	80		**320**
S8					240	**240**
S9				180		**180**
S10		120				**120**
S11					60	**60**
Total	**494**	**494**	**494**	**494**	**494**	

Remarks

- Maintaining the fixed production rate ensures the leveling strategy and therefore low possible cost, i.e. at 672 for production line 1 and 494 for production line 2.
- Products that are produced only once in five periods imply losses due to stock holding cost, i.e. B3, B4 of production line 1, and S8, S9, S10, S11 of production line 2.
- Products that are produced later in the planning horizon cause loss due to shortage cost, i.e. B2, B3 of production line 1, S8, S9, S11 of production line 2.

- These stockholding and shortage costs can be reduced if the production model is more flexible, or in other word, the constraint of items produced per period is loosened.
- The plan helps save stockholding and shortage costs by reaching the allowed number of items produced per period which is 2 and 3 for production line 1 and 2 respectively.

Material requirement planning

<u>Production line 1</u>

The aggregate material requirement is calculated based on the product structure diagram and detail production plan. Detail requirement of each material is then planned with the assumption accordingly.

TABLE 10 Aggregate material requirement for line 1

	Period 1	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Malt M1	276	116	336	336	336
Malt M2	48	176	0	0	0
Ingredient I1	134,4	134,4	134,4	134,4	134,4
Ingredient I2	33,6	33,6	33,6	33,6	33,6
Ingredient I3	16,8	16,8	16,8	16,8	16,8

TABLE 11 Material requirement planning for line 1

Malt M1, Lead time 1, Lot size 100ǀ200ǀ300 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		276	116	336	336	336	
Scheduled receipts		300					
Projected available balance	200	224	108	72	36	0	88
Planned order releases			300	300	300		
Malt M2, Lead time 1, Lot size 50ǀ100ǀ150ǀ200 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		48	176	0	0	0	
Scheduled receipts							
Projected available balance	100	52	26	26	26	26	31,2
Planned order releases		150					

Ingredient I1, Lead time 1, Lot-for-lot		**1**	**2**	**3**	**4**	**5**	
Gross requirement		134,4	134,4	134,4	134,4	134,4	
Scheduled receipts							
Projected available balance	150	15,6	0	0	0	0	3,12
Planned order releases		118,8	134,4	134,4	134,4		
Ingredient I2, Lead time 2, Lot size 30/40/50/60 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		33,6	33,6	33,6	33,6	33,6	
Scheduled receipts			30				
Projected available balance	40	6,4	2,8	9,2	5,6	2	5,2
Planned order releases		40	30	30			
Ingredient I3, Lead time 2, Lot size 10/20/30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		16,8	16,8	16,8	16,8	16,8	
Scheduled receipts			10				
Projected available balance	25	8,2	1,4	4,6	7,8	1	4,6
Planned order releases		20	20	10			

Production line 2

The aggregate material requirement is calculated based on the product structure diagram and detail production plan. (Please refer to excel file). Detail requirement of each material is then planned with the assumption accordingly.

TABLE 12 Aggregate material requirement for line 2

Material	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Sugar	49,4	49,4	49,4	49,4	49,4
Carbon dioxide	4,94	4,94	4,94	4,94	4,94
Additive	4,94	4,94	4,94	4,94	4,94
Flavoring S5	6,3	6,3	6,06	7,02	5,82
Flavoring S6	6,72	4,92	3,36	0	0
Flavoring S7	1,8	0	5,4	2,4	0
Flavoring S8	0	0	0	0	7,2
Flavoring S9	0	0	0	5,4	0
Flavoring S10	0	3,6	0	0	0
Flavoring S11	0	0	0	0	1,8

TABLE 13 Material requirement planning for line 2

Sugar, Lead time 1, Lot size 20ǀ40ǀ60 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		49,4	49,4	49,4	49,4	49,4	
Scheduled receipts		60					
Projected available balance	25	35,6	26,2	16,8	7,4	18	20,8
Planned order releases		40	40	40	60		
Carbon dioxide, Lead time 1, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		4,94	4,94	4,94	4,94	4,94	
Scheduled receipts							
Projected available balance	10	5,06	10,12	5,18	10,24	5,3	7,18
Planned order releases		10		10			
Additive, Lead time 1, Lot for lot		**1**	**2**	**3**	**4**	**5**	
Gross requirement		4,94	4,94	4,94	4,94	4,94	
Scheduled receipts							
Projected available balance	10	5,06	10,12	5,18	10,24	5,3	7,18
Planned order releases		10		10			
Flavoring S5, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		6,3	6,3	6,06	7,02	5,82	
Scheduled receipts							
Projected available balance	15	8,7	2,4	6,34	9,32	13,5	8,05
Planned order releases		10	10	10			
Flavoring S6, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		6,72	4,92	3,36	0	0	
Scheduled receipts			10				
Projected available balance	8	1,28	6,36	3	3	13	5,33
Planned order releases				10			
Flavoring S7, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		1,8	0	5,4	2,4	0	
Scheduled receipts							
Projected available balance	6	4,2	4,2	8,8	6,4	6,4	6
Planned order releases		10					
Flavoring S8, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		0	0	0	0	7,2	
Scheduled receipts							
Projected available balance	5	5	5	5	5	7,8	5,56

Planned order releases				10			
Flavoring S9, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		0	0	0	5,4	0	
Scheduled receipts							
Projected available balance	4	4	4	4	8,6	8,6	5,84
Planned order releases			10				
Flavoring S10, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		0	3,6	0	0	0	
Scheduled receipts			10				
Projected available balance	3	3	9,4	9,4	9,4	9,4	8,12
Planned order releases							
Flavoring S11, Lead time 2, Lot size = 10ǀ20ǀ30 m³		**1**	**2**	**3**	**4**	**5**	
Gross requirement		0	0	0	0	1,8	
Scheduled receipts							
Projected available balance	2	2	2	2	2	10,2	3,64
Planned order releases				10			

Remarks

- Changing order lead time does not affect average inventory.
- The smaller possible order lot size, the more reduced average inventory.
- The average inventory is reduced the most in case of lot-for-lot.
- Material planning should take into consideration the production of the coming horizon, as saving cost of stock holding in current horizon might lead to cost of stock-out in the next horizon. So, this is more of an art of balancing. For example, planning of material M1 leaves ending inventory at zero, which implies stock-out cost in the next horizon.
- Material should be planned also with reference to how well suppliers perform. For example, if the scheduled material I2 arrives in bad quality and therefore it is rejected, this affects the production of all line 1 products (B1-B4). The loss in such a case is extended to a much greater level.

- The same loss applies if the scheduled material I2 does not arrive as expected. How well suppliers perform is also shown in their lead time variation. The more lead time variates, the more loss it causes.
- How well suppliers have performed is hence a very important input of material planning. Historical record might be a good reference to investigate more, for example how often an event of rejection occurs, how often an event of delay occurs, in which time of the year these events happen, is there any seasonality of these events, how much the lead time deviates from the mean, etc. in order to have better material planning, i.e. holding stock or looking for alternative suppliers.
- Loss could also happen in other forms. For instance, when demand varies, gross requirement of materials varies also. Such case results in loss from both stockholding and stock-out cost.

5 Discussion

The research answers the research questions.

RQ1: What causes the supply chain losses in brewing industry?

- Levelling strategy helps yield the lower possible cost compared to chase or hybrid strategy, because normally the cost of changing production output is remarkably higher compared to stock holding and shortage costs. However, adopting levelling strategy means that losses will always occur in the form of either stock holding or stock out, because the discrepancies between production and demand always remain and there is no ideal production lot size that should completely avoid the risk of losses.
- Loss also happens due to the challenges in deciding a reasonable product mix ratio, in reference to the dynamics of brewing industry, which is shown in the trend of premiumization, the enthusiasm of customers to try

new things, etc. Product mix ratio is not stable across the time, and historical sales data is not a sufficient input. Instead product mix ratio should take into consideration market dynamics, reflecting all the uncertainties coming from both upstream and downstream of the supply chain.

- The more diversified the products are, the more likely losses occur, as there is a constraint in production capacity, and balancing which product item to be produced at which point across the time horizon within the constraint is a challenging task, and the most likely case is that stock holding cost applies to items produced early, and stockout cost applies to those produced later in the time horizon. It should be noted that diversification of product in brewing industry is unavoidably a prevailing trend, as mentioned above.
- Failing to see a whole bigger picture might lead to losses, as saving cost of stock holding in current horizon might lead to cost of stock-out in the next horizon.
- When concerning the supply chain upstream, losses in the form of stock holding happen also due to the order lot size. The smaller possible order lot size, the more reduced average inventory, or more reduced stock holding cost. Stock holding can be saved the most in case of lot for lot. Moreover, losses occur when suppliers do not perform well. The more lead time or production quality variates, the more likely losses occur.
- When concerning the supply chain downstream, losses occur when demand vary which is also prevailing in brewing industry, as beer consumers are very enthusiastic to try new things.

RQ2: How to mitigate the supply chain losses in brewing industry?

- Allowing a more flexible production model, in which constraints are loosened.
- Adopting a wider perspective in production planning and material requirement planning.

- Working with suppliers to enable a smaller possible order lot size. Keeping trace of supplier's performance to have better material planning.
- Working closely with supply chain participants downstream, for instance the retailers to quickly grasp any change of demand and reflect such change in demand forecasting model.

Other remarks

The case investigation does not reflect how demand variation might cause losses to a far great extent. For example, there is a case when a retailer simply decides to 'de-list' certain products from their shelves, or in other word, they decide not to purchase those products anymore. Between this retailer and the brewing company, there is no agreement about what products they commit to purchase in a term, let say in the next six months. When such a sudden move happens, there is a 'lag' in the whole chain to absorb the information, and meanwhile, the brewing company unknowingly keeps producing those products in anticipating future sales.

Previous research shows the same problem. According to Mamillo, D. (2015), main source of uncertainty of Albanian beer market stems from demand, which is caused by the lack of sharing information. Invisibility of data is ascribed to organizational culture. Cultures with external orientation promisingly facilitate collaboration. Yet, Albanian beer producers' culture is characterized by internal orientation, which in turn hinders supply chain collaboration.

Another study of Igwe, S.R. et al (2016) shows that information sharing between brewery manufacturers, distributors and retailers in South-South Nigeria is of crucial significance because it mitigates the bullwhip effect which is the most common case in brewing industry. Supply chain key participants, though skeptical about the fact that trade secret might be revealed, yet they adopt the approach of information sharing to a large extent. On the other hand, the study also investigates incentive alignment, another approach of supply chain collaboration. Within this approach, incentive programs are built and agreed between supply chain members, in which costs, risks, and benefits are shared. Some examples of incentive programs could be sharing of saved inventory cost, performance reward, and agreement about changing order.

6 Conclusion

The study shows how S&OP links functional important units to match supply and demand, i.e. forecast, production, purchasing. The case investigated exemplifies that losses always occur, especially in the context of brewing industry with its own specific traits, i.e. premiumization trend, consumer's enthusiasm in trying new products, the rise of micro-breweries, the seasonality of the product, etc.

Although the study partially explains how losses happen, the assumptions are simplified, and in such a way, it could not reflect the whole picture of complexities.

For example, demand uncertainty in brewing industry is one of specific traits and bullwhip effect which leads to forecasting inaccuracy is a very common. In such a case, information sharing is of crucial importance to reduce losses. It should be noted that within this case study, however, information sharing is not the main issue, because manufacturer and supplier are in the same country and information sharing is therefore not a big problem with regard to source of losses. Demand data which is collected from a consultant company and from retailers relatively well reflects the real market demand. However, with the emergence of prolonged supply chain which crosses national borders, the case would be much more complex.

Simplified assumption is also reflected in the only constraint of the case study, which is the number of items produced within a time period. However, such perspective is myopic and production itself is not a stand-alone entity. Instead, reality suggests considering other constraints as well, for example supply constraints, storage constraints, etc.

Forecasting is a very important input, as S&OP process is very market driven. Every shift in demand pattern should be promptly reflected in the forecast. This case study does not count how a remarkable change of demand might happen and affect the loss to a greater extent, as reflected in the remarks of section 5, i.e. the de-list of retailers.

The study might potentially suggest further researches on different relevant topics, for example how information sharing contributes to loss reduction, how far loss occurs if more constraints are added to the case investigation, i.e. supply constraint, storage constraint, etc., how to build feasible process of updating demand data across the chain, how complex the S&OP planning environment is with reference to the potential and suitability of APS deployment.

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Appendix

Stochastic demand simulation model for production line 1 with production level 672

Simulation #	**Demand**	**Random #**	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**
1	B1	0,775	402	382	392	362	392
	B2	0,106	178	169	175	173	178
	B3	0,271	81	89	86	91	88
	B4	0,588	25	23	22	25	25
	Total		**686**	**663**	**675**	**651**	**683**

Simulation #	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**
1	686	663	675	651	683
2	687	664	675	652	684
3	686	662	674	650	683
4	692	666	680	654	689
5	682	660	671	648	679
...					
...					
...					
98	691	665	677	653	688
99	684	661	672	649	681
100	690	665	677	653	687

Simulation #	**Holding cost**						**Shortage cost**						**Total costs**
	1	2	3	4	5	Total	1	2	3	4	5	Total	
1	0	124	64	484	264	936	1120	0	0	0	0	1120	2056
2	0	100	40	440	200	780	1200	0	0	0	0	1200	1980
3	0	144	104	544	324	1116	1120	0	0	0	0	1120	2236
4	0	40	0	336	0	376	1600	0	480	0	16	2096	2472
5	0	200	220	700	560	1680	800	0	0	0	0	800	2480
…													
…													
…													
98	0	64	0	373	53	490	1520	0	144	0	0	1664	2154
99	0	172	172	632	452	1428	960	0	0	0	0	960	2388
100	0	68	0	374	74	515	1440	0	128	0	0	1568	2083