Forecasting Demand of Beer at Rapscallion Brewery

Major Qualifying Project completed in partial fulfillment
Of the Bachelor of Science degree at
Worcester Polytechnic Institute, Worcester, MA

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March 2, 2018
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Abstract

Rapscallion Brewery faced a challenge with over and under producing certain types of seasonal beer. This was a problem due to their limited storage space for excess kegs. Rapscallion Brewery also planned on increasing their brewing capacity. The purpose of our project was to provide Rapscallion Brewery with accurate forecasts of their demand as well as simulate their new production capabilities with the planned increase in capacity. Using three different methods of forecasting, we were able to predict the demand that Rapscallion Brewery has for their many types of beer. We then modeled Rapscallion's brewing process with a discrete event simulator. We then applied their demand over multiple possible scenarios for production capacity and analyzed the results. We used our findings to give recommendations for Rapscallion Brewery that would allow them to optimize fermenting and brite tank utilization.

Acknowledgements

We would like to acknowledge and thank our advisor Professor Joe Zhu for providing great feedback and assistance throughout our Major Qualifying Project. We would also like to thank our sponsors from Rapscallion Brewery, Cedric Daniel and Jonas Noble, for taking time out of their schedules to accommodate meetings with us and for providing us the information we needed to complete our project.

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Background

Rapscallion Brewery opened in 2007 and moved to their current location in Sturbridge, MA in 2013. In addition to their Sturbridge location, where their beer is brewed and sold on tap, they have a restaurant and tap room in Acton, MA where their beers are also sold. Rapscallion's customer base and operations have only been growing since they opened.

Project Goals

The goal of this project was to support the implementation of Rapscallion's new fermenting tanks and brite tanks by providing them with recommendations that would reduce costs associated with overproduction of beers that are always on tap, those brewed a few times as year, as well as seasonal beers that are brewed once a year.

Deliverables

Our three deliverables are:

1. Forecasts - Past and current sales data for Rapscallion's beers was utilized to forecast the demand for all of Rapscallion's beers using Microsoft Excel. Three different forecasting methods were used: simple moving average, exponential smoothing and seasonal index.

2. Arena Simulation Model - A simulation model was developed using the Arena simulation software. Raspcallion's brewing process was modeled from start to finish using the average demand from the sales data as an input. After running the model, the results showed the number of batches of beer produced each quarter based on the demand.

3. Process Analyzer (PAN) Analysis - The Arena model was further analyzed using an Arena application called Process Analyzer (PAN). Using PAN, three different scenarios were analyzed without having to change the original model. These three scenarios were Rapscallion's current capacity, their anticipated capacity with the new fermenting and brite tanks, and a hypothetical scenario with even more capacity to see how it would affect the output.

Methods

We utilized online research, sales data provided by Rapscallion, Microsoft Excel, Arena Simulation Software, and the PAN Arena application to arrive at the aforementioned deliverables.

Results

The results of the forecasts were then averaged out in order to obtain an average demand that was used as an input for the Arena Simulation Model. The results from the PAN analysis showed that Rapscallion currently brews an average of 118 batches per quarter with their current capacity. With the addition of their two new fermenting tanks and one new brite tank, this output rose to 137 batches of beer. The third scenario tested, a hypothetical scenario with even more fermenting tanks and brite tanks also yielded an output of 137 batches of beer because the original model has an input that is based on the demand meaning that given the current average demand for Rapscallion's beer, they should not further increase their capacity.

Recommendations

Based on the results, we recommend that Rapscallion implement their new fermenting and brite tanks as soon as possible in order to increase their production to meet demand. We also recommend that Rapscallion focus more on their production of Honey Ale, their most popular beer, and make Rye IPA, a beer that is currently always on tap a seasonal beer or one that is only brewed a few times per year. Additionally, we recommend that Rapscallion host more events for their customers such as trivia nights, live music, and seasonal beer festivals such as Oktoberfest to continue growing their customer base and therefore increase sales.

Project Objective

The objective of our project is to forecast the demand for Rapscallion Brewery's beer sales and give them recommendations of how much to make of certain beer. We analyzed their quarterly sales data from the past three years using different forecasting, process analysis, improvement, and simulation techniques. We will also be supporting the implementation of two new fermenting tanks and one new brite tank and modeling this increase in capacity using Arena Simulation Software. Using information provided by the in-depth analysis of the forecasts and simulation model, a set of recommendations will be given to Rapscallion. These recommendations will help Rapscallion decide what beers should be brewed in each quarter for an entire year. This deliverable will increase the revenue of Rapscallion by reducing inventory costs and increasing sales.

Chapter 1: Introduction

1.1 Rapscallion Brewery

Rapscallion Brewery was founded in 2007 by twin brothers Peter and Cedric Daniel when they purchased Concord Brewery in Lowell, MA and changed the name to Rapscallion. Shortly after this, they moved to Paper City Brewing in Holyoke, MA. It was there that they began production of their Rapscallion Honey Ale, their most popular and most widely distributed ale.

In 2013, Rapscallion Brewery moved once again to their current location in Sturbridge, MA. The brewery and tap room is located on a 150 acre orchard. The location includes the brewery, tap room, and an outdoor pavilion for special events. They currently operate with one head brewer who is also in charge of operations. In 2017, the location began offering food by utilizing a mobile food truck right outside of the brewery. Rapscallion also hosts special events throughout the week and offers live music every Thursday through Sunday. They have a series of regular customers, or "mug members" that have their own mugs at the brewery, about 4 ounces larger than a normal pint.

Currently, the brewery bases what they will brew on three factors. These factors are how many taps are available, how long that beer takes to brew, and the season. The brewery currently has five fermenting tanks installed that they utilize to brew their beers. Two of the tanks have a capacity of 80 kegs, one can produce 30 kegs and the two have a capacity of 20 kegs. It takes around 42 days for lagers to ferment in the tanks and ales take around 21 days. After the beer has fermented they then transfer the batch to a brite tank. They currently have two brite tanks that hold 80 and 20 kegs, respectfully. Rapscallion plans on adding two fermenting tanks that hold 20 kegs each as well as one brite tank that can hold 20 kegs this winter. The situation of fermenting tanks and brite tanks at Rapscallion at the moment and in the future is summarized in Table 1.

	Brite Tanks (kegs)	**Fermenting Tanks (kegs)**
Current	2 total: capacities are (80 and 20)	5 total: capacities of (80, 80, 30, 20, 20)
Adding in the future	1 brite tank: capacity of (20)	2 fermenting tanks: capacities of (20 and 20)

Table 1: Brite Tanks and Fermenting Tanks (in Kegs)

Some beers are brewed year round while others are seasonally brewed. Some beers are only brewed once while others are constantly being brewed because they are in high demand all year round. The busiest times of the year for Rapscallion are the summer and fall and demand dies down towards January. When demand decreases, the two owners Cedric and Peter focus on making general improvements to the brewery. This ranges from purchasing new equipment to increase capacity, performing maintenance on their already existing machines, or focus on planning for the next busy season.

Currently, Rapscallion brewery does not have their exact demand for beer sales, and they use a just-in-time production method with the materials at hand. This need stems from past experiences of either brewing too much or too little of a certain beer. Our goal is to forecast Rapscallion’s demand based on their previous sales data. These forecasts were obtained using quarterly sales data from past years and a list of all the beers they want to brew this upcoming year. Three time series forecasting methods were utilized: simple moving average, exponential smoothing, and seasonal index.

Brewing an excess or insufficient amount of a certain beer has many negative implications for Rapscallion brewery. Brewing too much of a certain beer results in it taking up space in inventory and eventually being thrown away, therefore decreasing their revenue. Brewing too little of a certain beer results in not taking advantage of possible sales to customers and increasing their revenue. Both brewing too much or too little have negative implications on the revenue of Rapscallion, and we aim to mitigate this by providing them with forecasts that will accurately predict the amount of sales of certain beer. A repercussion that comes with the lack of forecasting the demand is wasted storage space and either an excess or shortage of raw materials. In forecasting Rapscallion's demand using sales data and discrete event simulation, the end goal was to reduce operating costs and increase sales. These forecasts and simulation model will help Rapscallion optimize their beer production and will result in an increase in their sales, therefore increasing their revenue.

Chapter 2: Background

2.1 Brewing Process

The process of brewing beer is a complicated process that involves many different materials, variables, and exact timing. From the start to finish of the process, it takes approximately four weeks for ales and six seeks for lagers. The figure "The Brewery Process", shows a basic flowchart of the brewing process.

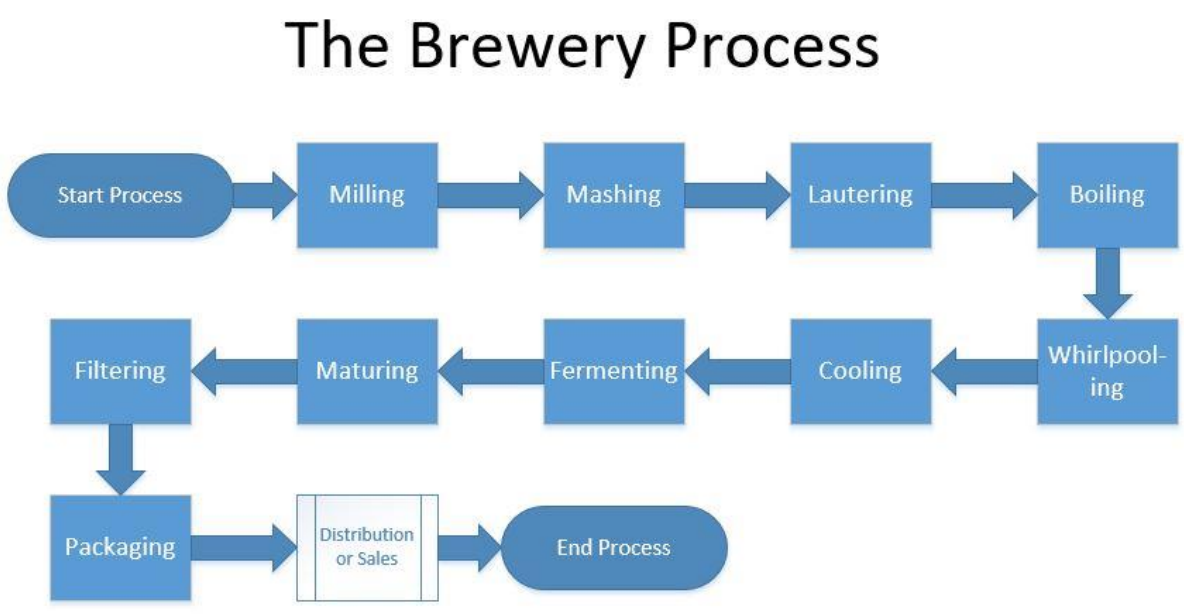


Figure 1: Flowchart for general brewing process

The first step in the process is milling. In the brew house, different malts are crushed together in order to break up the grain kernels. This extracts fermentable sugars and produces grist, a milled product. This process determines the darkness of the malt, which influences the flavor and color of the beer.

The next step in the brewing process is mashing. The grist is then put into a "mash tun" or "mash mier", which is a large round tank with specific temperature control. It is mixed with heated, purified water and undergoes what is called "mash conversion". Mash conversion involves a carefully controlled temperature and time process in which the malt's enzymes break down the malt's starch to sugar (C., 2018). Depending on the type of beer being made, a starch from other cereals such as wheat, rice, or corn is added.

The mash is then transferred to the "lauter tun" or "lautering vessel", which is known as the lautering phase. The vessel is a cylinder-shaped mechanism that drains the liquid from the mash and leads to the brew kettle. Water is sprayed through the lauter to maximize the amount of liquid extract that is washed out from the grain in the mash. This liquid extract is known as "wort", a sugar solution. The remaining grains are taken from the lauter and sold for cattle feed.

The wort then enters the boiling stage and is led to a brew kettle which holds up to 100,000 liters of liquid (C., 2018). Under very carefully controlled conditions, the wort is brought to a boil and hops are then added. The desired extract from adding the hops takes about 2 hours. After the hops have flavored the brew, they are removed. Also, the wort becomes clear of any protein substances that still remain in the extract through coagulation.

The wort then enters the whirlpool stage and is led to a whirlpool for the wort separation stage. This process removes any malt or hop particles that may remain. The liquid that remains is ready to be cooled and fermented.

After whirlpooling, the wort immediately goes to the cooling stage and is chilled in a plate cooler. Cooling the beer right away is essential so the beer will begin to oxidize and produce flavors. As the coolant and wort flow by each other on the opposite sides of stainless steel plates, the temperature of the wort drops dramatically from boiling to between 40-45 degrees Fahrenheit for lagers and 55-60 degrees Fahrenheit (C., 2018). This is a drop of more than 150 degrees Fahrenheit in a few seconds (Thebeerstore.ca., 2018).

Now that the wort has been cooled, it enters the fermentation stage and is added to the fermenting tank. Yeast is added to the wort, which starts the process of producing beer by converting the sugar in the wort into carbon dioxide and alcohol. Fermentation is where the brewer decides if they are brewing an ale or a lager by using an ale yeast or lager yeast. Fermentation lasts 7-10 days while the yeast grows to a frothy head at the top of the brew (C., 2018). The yeast is then removed, finally yielding beer.

After fermentation, the beer is known as "green beer" and needs to go through the maturing stage to allow the remaining yeast to settle so there is full development of flavor.

After reaching its full potential, the beer then needs to go through a filtering stage, be carbonated, and be transferred to the bright beer tank. It is stored cold in a cellaring process that takes about 3-4 weeks to complete (C., 2018). After this, the beer is ready to be packaged by being put into kegs, bottles, or cans. The product is then ready to be shipped out on delivery trucks to distributors, restaurants, or liquor stores for distribution and sales. A process map of a general brewing process can be seen in Appendix A.

2.2 Forecasting

Forecasting is a critical component to the success of any business. Forecasting allows companies to plan for changes in the demand of their market and adjust their supplies accordingly. While forecasts are a great tool to help companies, they are dependent on many different variables and it can be a complex process to find relevant trends in the data. "When you have obtained a promising data set and begun to analyze it, you may at first see complex relationships whose pattern is not obvious, or (what is often worse), you may see patterns that aren't really there" (Nau, R., 2017). One of the biggest issues with not having an accurate forecast of demand is that a company can run out of stock of a certain product or overproduce the product, “Out of stocks equal lost sales, which will never be recovered. Not having inventory can create delivery and service disruptions as customers expect placed orders to be filled” (B., 2009). Being able to match customer demand is especially important in the beer industry as demand changes drastically from season to season.

There are two types of methods used to employ forecasting techniques: qualitative and quantitative. Qualitative methods rely on “judgements, opinions, intuition, emotions, or personal experiences and are subjective in nature and do not rely on any rigorous mathematical computations” (Nau, R., 2017). Quantitative methods “are based on mathematical (quantitative) models, and are objective in nature” (Nau, R., 2017).

Some qualitative methods include executive opinion, market surveys, sales force composites, and the delphi method. An executive opinion is formed when a management or leadership personnel meet and develop a forecast together. A market survey is a technique that uses interviews and surveys in order to assess customer wants and therefore assess the demand for any given product. A sales force composite is an approach predominantly used in larger companies with sales representatives in different regions in which each representative assesses demand in their region. Lastly, the delphi method, or expert opinion, is an approach in which an agreement on a particular forecast is agreed upon by experts in the field.

While there are two main quantitative methods - time-series models and associative models - there are many subgroups of time-series models that can apply to different situations. Associative models, which can also be referred to as causal models, assume that the variable being forecasted is related to all the other variables in the environment and bases predictions off of the relationships between the variables. Time-series models look at past data and search for patterns within the past data. After finding patterns, they try and predict the future based upon these patterns. Some common time-series models are: naive, simple mean, simple moving average, weighted moving average, exponential smoothing, trend projection, and seasonal indexes.

Model	Description
Naive	Uses last period's actual value as a forecast
Simple Mean (Average)	Uses an average of all past data as a forecast
Simple Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight)
Weighted Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving a different emphasis (weight)
Exponential Smoothing	A weighted average procedure with weights declining exponentially as data become older
Trend Projection	Technique that uses the least squares method to fit a straight line to the data
Seasonal Indexes	A mechanism for adjusting the forecast to accommodate any seasonal patterns inherent in the data

Table 2: *Most common type of Time-Series Forecasting models with descriptions*

(Taken from: University of Arizona, Forecasting Fundamentals)

With seasonality being a major influence in the demand for different types of beer, it is important that breweries prepare accordingly. Preparation not only involves research and demand forecasting, but also informing customers of your schedule. Release schedules and calendars have become a prevalent aspect in many breweries outreach to their customers. A release schedule allows customers to become informed of the release date of their favorite beers, and serves as an interactive way for the company to incorporate customers in their operations planning.

2.3 Error Analysis

Error analysis was also done using the results of the exponential smoothing forecast in order to evaluate the accuracy of the forecasts. Mean absolute percentage error (MAPE) expresses the accuracy of the forecasts in percent form. Mean absolute deviation (MAD) expresses the accuracy of the forecasts in the same unit as the data, which in this case is kegs. Both of these methods were used to evaluate the accuracy of the exponential smoothing forecasts and justify the use of .9 as the alpha value, or smoothing constant, of the forecast.

A Microsoft Excel workbook was created with a different worksheet per each type of beer. Each worksheet contains the sales data in ounces and the three forecasts for each beer - simple moving average, exponential smoothing, and seasonal index - as well as graphs of each of the forecasts. Respective formulas for both MAPE and MAD can be seen below.

MAPE formula: $$\frac{\sum_{t=1}^{n} \left| y_t - \hat{y}_t \right|}{n}$$

MAD formula: $$\frac{\sum_{t=1}^{n} \left| y_t - \hat{y}_t \right|}{n}$$

Figure 2: Formulas for MAPE and MAD

2.4 Forecasting Specific to the Beverage Industry

In order to remain competitive in today's rapidly-changing market, many businesses, especially those in the beverage industry, have participated in supply chain collaboration (Ramanathan, Muyldermans, 2010). For example, Walmart, Nabisco, and Proctor and Gamble "have been practicing Collaborative Planning, Forecasting, and Replenishment" (Ireland, R. K., & Crum, C., 2005). As companies have seen the success of Walmart and their supply chain collaboration with other large companies, more and more have tried to implement similar strategies. Partnering supply chains has become an effective strategy that has helped increase demand for certain products, especially in the beverage industry.

According to a study conducted with a leading soft drink manufacturer (SDM) in the UK, the four prominent factors that affect sales performance in the beverage industry are promotions, holidays, seasons, customer preference. In this study, it was determined that 60% of their sales volume was achieved during promotional events. This is because of the collaboration between SDM's supply chain and that of their suppliers and distributors. SDM has also developed a promotional calendar that they share with customers. This calendar contains information such as "products (or product families on promotion, timing and duration of the promotions, the types of promotions, the price discounts, the promotional displays and possibly other promotional features" (Ramanathan, Muyldermans, 2010). SDM will typically also offer promotions at the same time to the same family of products. In most cases, "the timing of a promotional deal is specified by fixing the starting week and the number of weeks the deal runs in stores", which in most cases promotions run "2-5 times a year, while each deal lasts for 1-5 weeks" (Ramanathan, Muyldermans, 2010).

The way the beverages are displayed also plays a major role in sales because it the potential to "capture maximum attention from potential buyers" (Ramanathan, Muyldermans, 2010). Other forms of advertising include sign boards, sports features with a product logo, and media advertisements outside of the stores such as radio, television, and magazines (Ramanathan, Muyldermans, 2010).

Apart from promotions and advertisements, other important factors that the beverage industry must consider are weather and temperature throughout the seasons and holidays. The demand for beverages is seasonal, especially in regions the variation in temperature is larger. Because weather and temperature are unpredictable and “external to the supply chain” they are “difficult or impossible to control by the supply chain members” (Ramanathan, Muyldermans, 2010).

The four aforementioned factors - promotions, holidays, seasons, customer preference - “may or may not be required to explain the demand of all soft drinks” (Ramanathan, Muyldermans, 2010). The effects of all of these factors can either be analyzed individually or collectively. From the data collected during this study, it can be concluded that promotions have a positive impact on sales while the sales of some products saw increases and others saw decreases depending on the season. During promotions, especially Buy One Get One (BOGO), “actual sales and inventory levels are monitored closely to make sure that right amount of products are deployed in the distribution network in order to prevent stock-outs”. (Ramanathan, Muyldermans, 2010).

2.5 Accuracy in Beer Sales Forecasting

In the beer industry, there is vast potential for distributors and suppliers to capitalize on efficiency gains and cost savings with beer sales forecasting. An increased collaboration between distributor and supplier will result in both sides benefiting. Suppliers need to track Stock Keeping Units (SKUs): a specific brand and package combination of beer for sale. SKUs have been rapidly increasing in recent years across breweries around the world. Product demand for beer is constantly influenced by a spectrum of variables: weather, economy, seasonal changes, holidays, marketing, and others. Optimizing inventory and accurately forecasting increases cash flow, sales volume, and profit. The benefits of highly efficient forecasting are: Minimizes out of stocks/lost sales, improve product freshness and warehouse efficiency, maximizes warehouse space utilization, provides cash flow efficiencies, optimum inventory levels, capitalize on peak sales weeks and provide a premium on gross margin, and suppliers rely on distributors to be accurate in beer sales forecasting to streamline their production costs. Rapscallion distributes to themselves, so we need to analyze the demand in their market and while also efficiently manufacturing and transporting beer.

Forecasting and streamlining of beer has improved over the years as technology has increased. In 1995, the average beer distributor carried 190 Stock Keeping Units (SKUs) (NBWA, 2009). An SKU is "a product and service identification code for a store or product, often portrayed as a machine-readable barcode that helps track the item for inventory" (SKU, 2018). This number increased almost twofold to an average of 351 SKUs by 2006, and continues to rise today (NBWA, 2009). Although forecasts are no longer handwritten, using the knowledge of employees in the system is important to retrieve the information that is not available in historical data. The frequency in which historical sales and inventory data is given to the supplier is important to how efficient the forecast is (NBWA, 2009). The goal is for the supplier to receive real time sales and inventory data so that forecast and order updates can be made more frequently (NBWA, 2009). If a forecasting software is in place but historical sales can only update weekly or monthly, the forecasting models and algorithms can only recalculate forecast data for the time period given (NBWA, 2009). Regardless of the size of the brewery and how many SKUs they carry, every brewery has the common goal to streamline forecasting and ordering processes to optimize inventory and improve service levels. This achieves giving the right people the right beer, at the right time, at the right price (NBWA, 2009). Reaching these goals will improve cash flow, sales volume, and company profitability.

2.6 Historical Data on Beer Sales

According to the United States Department of Treasury, the production of kegs per month for 2015 and 2016 had trends that stayed relatively the same. Production increased in March, June, and September. The data showed that production falls in the autumn months and then experiences peaks and drops as time goes on.

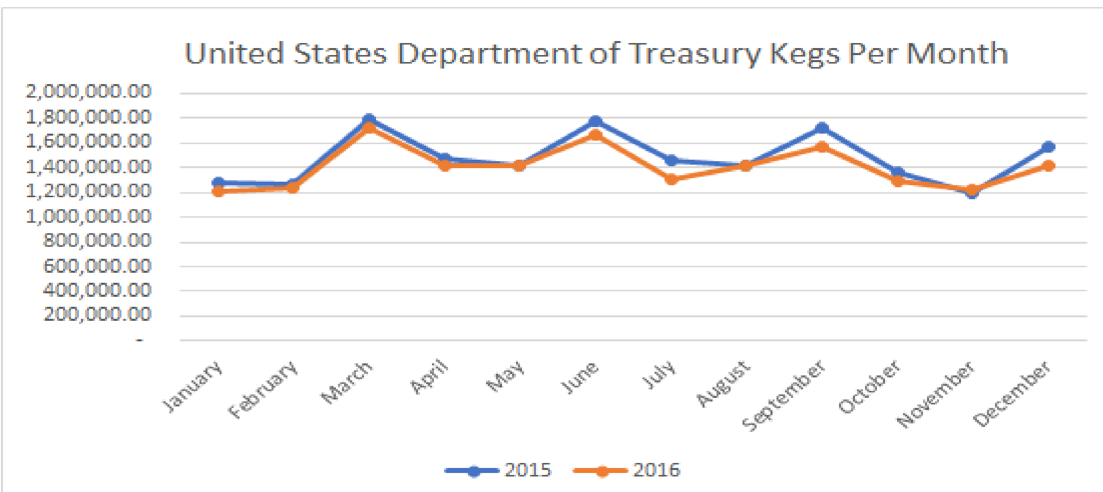


Figure 3: United States Department of Treasury Kegs per Month

In order to verify the seasonal influence of beer production, historical data was acquired on beer production per head of population in New Zealand. The data showed that each year the trends were rather consistent. Production was much lower during the autumn, winter, and spring. The rate then increased each year during the summer. This can be seen in Figure 3.

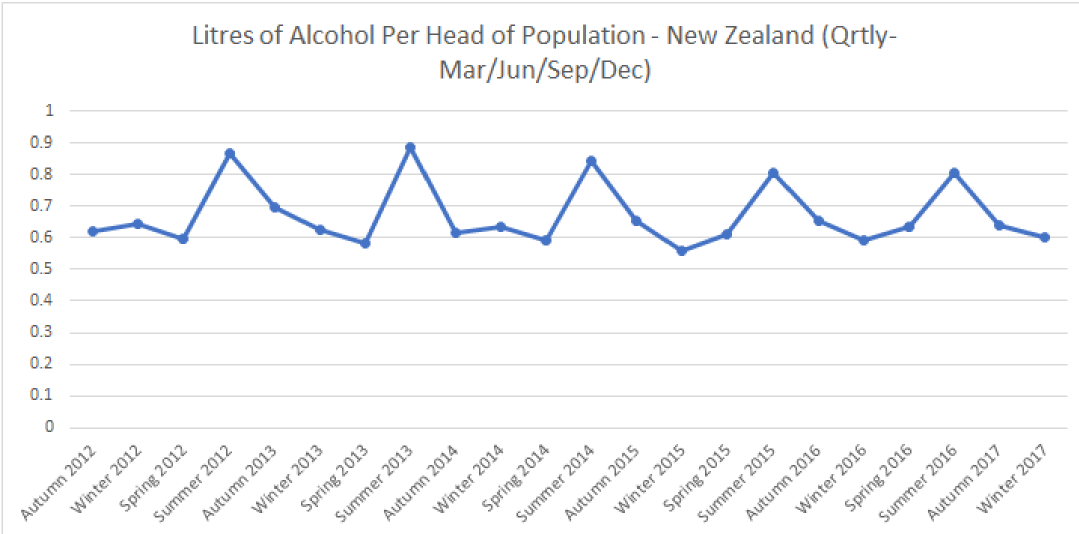


Figure 4: Litres of Alcohol Per Head of Population - New Zealand

2.7 The Rise of Craft Beer

In the past few years, since about 2012, there has been a prominent rise in the craft beer industry. What began decades ago as a few "microbreweries" has "swiftly grown into over 3,000 craft breweries today" (Pendleton, 2015). A craft brewery is defined as a brewery that brews less than 6 million barrels of beer annually, but many of these brands have become very well known in today's world, and research shows that "US craft beer sales nearly doubled between 2007 and 2012, increasing from $5.7 billion to $12 billion" (Pendleton, 2015).

2.8 Trends in the Craft Beer Industry

There are numerous factors that affect the sales of different beers. Many breweries, especially smaller craft breweries, such as Rapscallion, have to stay ahead of the industry in order to survive and make a profit. Dave Hoops, head brewer at Fitger's Brewhouse in Duluth, a slightly larger craft brewery than Rapscallion, says that "at the start of each New Year, [he] thinks about what's coming next in the beer world. [He] does this to stay ahead of trends, mull over ideas [he] likes and plan what [he] wants to focus on" (Hoops, 2016). Hoops, a veteran brewer and beer judge, describes seven beer trends that have been on the rise recently that he thinks will continue to grow throughout 2017. These seven trends are: re-inventing class beer styles, diversification by the big beer giants, craft lager beers, seasonal new brands and rotating hop beers, not-hoppy beer, barrel aging and blended beers, and keg and cask infusions.

With the growth of the craft beer industry and micro-breweries that brew specialty beers, older styles of beer have become less popular. Some of these older styles include "extra special bitter, porter, Scotch ale, brown and mild ale, and pale ale and stout" (Hoops, 2016). Although in the past few years these more classic styles of beer have been overshadowed by specialty beers as brewers continue to experiment, Hoops expects these classic beers to make a comeback.

While microbreweries are growing, big beer companies such as Anheuser-Busch have been both purchasing small craft breweries and brewing and distributing craft beer in order to capitalize on the demand for craft and specialty beers. This trend will continue as micro-breweries continue to distribute their beers out in the market and need to increase capacity in order to meet their demand. This benefits both the smaller microbreweries and the big beer companies because it makes craft beers more widely available to customers and provides financial incentives to the larger beer companies.

Craft lager beers have become much more popular in the past few years. However, these specialty beers take much longer to brew than traditional ales, which increases the cost of production. Hoops points out that "breweries are finding it worth the extra effort and cost, and consumers are really starting to seek great Pilsners and Helles' as opposed to the better-known Oktoberfest beers folks drink down in the fall" (Hoops, 2016).

Since 2015, seasonal beers have been a big hit with customers, and brewers have continued brewing more and more. Rapscallion has adopted this trend and brews a variety of seasonal beers. Based on each seasonal beer's popularity with customers, and the demand of other beers that they need to use their equipment to brew, they decide whether or not they will brew that beer again. Rapscallion also markets their seasonal beers by announcing when they will be ready ahead of time so regular customers who have drank and enjoyed the beer in past years, can come in and drink some before they run out. Hoops also points out that brewers oftentimes "make the same beer, changing the hops each time and using it as a way to show beer drinkers new hop flavors" (Hoops, 2016).

A very large variety of beer exists to satisfy the different tastes of beer drinkers around the world. One recent trend in the beer industry is non-hoppy beer. Hoops predicts that "malty and Belgian style of beer will continue to climb in sales, as not all beer drinkers are in love with the latest hop grenade beer to hit the market" (Hoops, 2016).

A law in Kentucky, where 95% of all American bourbon is distilled, states that oak barrels used for distilling can only be used once. American craft breweries are capitalizing on this and buying these used barrels and using them to brew. The barrels gives the beer "deep vanilla notes and complex flavors from the bourbon-soaked wood" (Hoops, 2016). Hoops - who has brewed using tequila barrels, sherry casks, port casks, red and white wine barrels, chambord liqueur barrels, and brandy and cognac barrels - predicts that many more breweries will begin using second hand barrels from other distilleries, not just bourbon. These barrels will give the beer very interesting and different flavors.

The last trend that Hoops expects to take off throughout the remainder of 2017 is keg and cask infusions. As mentioned earlier, brewers have begun and continued experimenting with new flavors and specialty beers. Many brewers have even started "adding fruit or spices at the time of the keg filling" (Hoops, 2016). Many experienced brewers agree that "many fun beers can be created by adding tea, coffee, fruits, and vegetables to a base beer for a fun one-off keg" (Hoops, 2017).

2.9 Discrete Event Simulation

Many processes, especially manufacturing processes such as brewing, are constantly changing. These changes can be in regard to capacity, number of resources, types of products, etc. Simulation "involves the modeling of processes using computer software in order to evaluate process improvement strategies" (Elam, Anderson, Lamphere, Wilkins, 2011). Simulation "is capable of realistically representing highly complex processes with numerous variables [and] has applications in business, engineering, education, and research" (Elam, Anderson, Lamphere, Wilkins, 2011). Discrete event simulation modeling "is the process of depicting the behavior of a complex system as a series of well-defined and ordered events and works well in virtually any process where there is variability, constrained or limited resources, or complex system interactions" (Arena Simulation, 2018). Additionally, "in discrete event simulation, changes occur at points in time separated by the occurences of events, such as parts arriving and departing a manufacturing process" (Elam, Anderson, Lamphere, Wilkins, 2011).

The Arena simulation software "was developed and introduced in 1992 [and is] a high-level simulator, which means that it operates by intuitive graphical user interfaces, menus, and dialogs" (Elam, Anderson, Lamphere, Wilkins, 2011). Arena also has extremely powerful and useful animation capabilities in that "a dynamic graphical animation of system components is shown as the move around and change" (Kelton et al., 2010). This animation can be especially useful if a model is being presented to an audience who is not familiar with Arena.

One of the most prominent advantages of using a discrete event simulation simulation software, such as Arena by Rockwell Automation are that you can easily see the effects that a certain change will have on the entire system as a whole. Arena also has very powerful statistical modeling capabilities. After building a model, you can run the model and different reports are given that provide the user with statistical outputs that are crucial to process improvement. Arena also gives outputs such as time in system, number in system, time in queue, number in queue, and utilization of resources among many others. These measures all allow process owners to see the problem areas in their processes and tackle them appropriately. For example, if a coffee shop is modeled using a discrete event simulation software such as Arena, and after this model is run, it shows that a cashier is being utilized 99% of the time, that would be an indicator to the shop owner to hire another cashier. This is just one example of how discrete event simulation software, such as Arena, can be a very powerful process improvement tool. Other advantages of modeling using the Arena software are finding and “reducing bottlenecks, reducing operational costs, improve financial forecasting and better managing inventory levels” (Arena Simulation, 2018).

Arena has many applications that can be used to further analyze any given system. One of these applications is Process Analyzer (PAN). PAN can be used to analyze and compare different scenarios without having to build a whole new model. Using PAN users can easily add resources or remove them and see how this manipulation of resources affects the system. These results can be used by business owners and managers to make decisions on whether one should add or remove resources.

Chapter 3: Methodology

This section of the report describes the methods utilized to complete all elements of the project from start to finish. These methods include those used to develop a process map of Rapscallion's brewing operations, organize and manipulate the raw sales data, and forecast the demand in sales for each type of beer brewed by Rapscallion brewery. Additionally, a discrete event simulation model using Arena simulation software was developed to account for Rapscallion's current capacity, added capacity, and to predict the outcome if even more brewing capacity was added. To assess the accuracy of the forecasts and the validity of the simulation model, error analysis, including mean absolute deviation (MAD) and mean absolute percent error (MAPE), was utilized and the simulation model was validated using the flowchart of Rapscallion's brewing process and the expert opinion of Jonas Noble, head brewer. A gantt chart was used to layout the project schedule.

3.1 Developing Rapscallion's Process Map

Before forecasting techniques could be applied and an Arena simulation model could be built, we wanted to familiarize ourselves with Rapscallion's process specifically. Although Rapscallion follows a beer making process similar to most other microbreweries, a process map for Rapscallion's specific brewing process was made. To construct an accurate process map, an interview with head brewer, Jonas Noble, was conducted. Noble gave a very detailed overview on Rapscallion's process from start to finish, specifically from right after the raw materials are received to when the tanks are cleaned after use. This process was then documented and laid out in a flowchart using Microsoft Visio. The process map of Rapscallion's brewing operations can be seen in Figure 5.

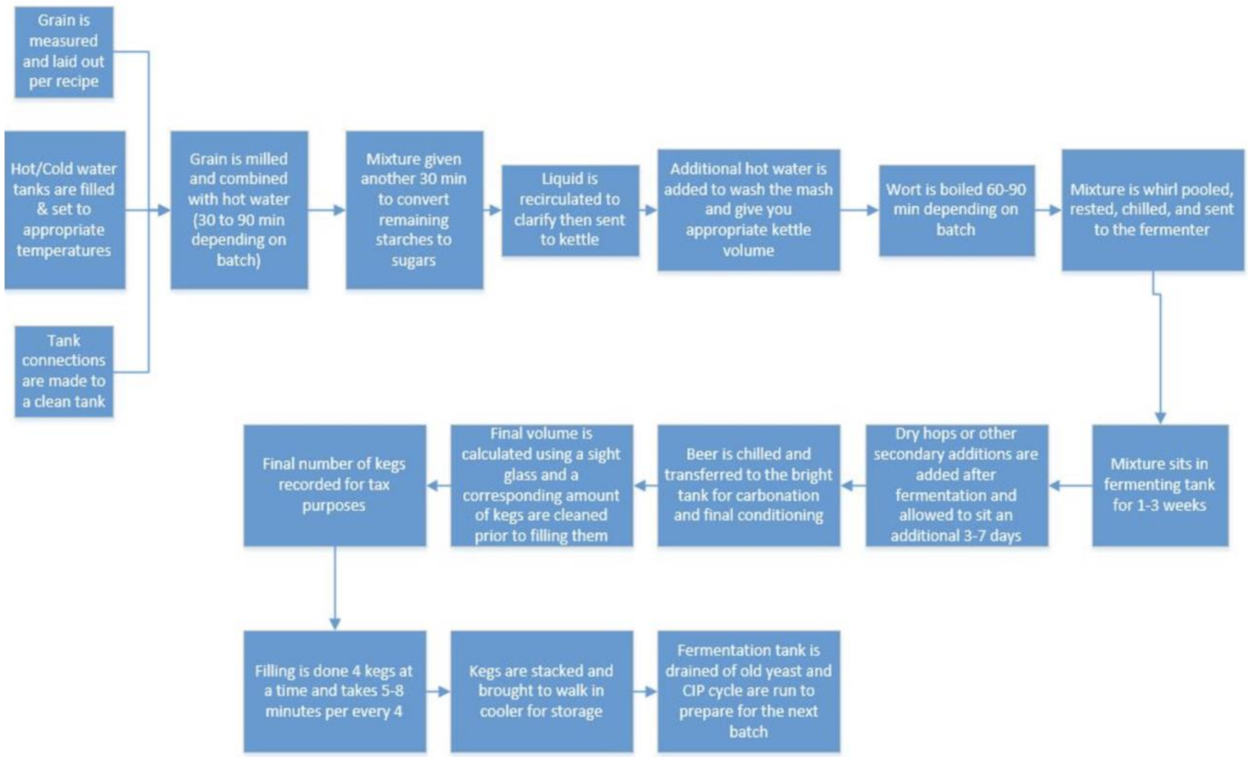


Figure 5: Process map of Rapscallion's brewing operations

3.2 Forecasting

Rapscallion brewery currently utilizes a POS system to register their transactions at both their Fiskdale and Acton locations. Quarterly sales data was extracted from this POS software. This raw data was then filtered and the quantity of each type of beer sold was extracted and different types of beers were distinguished by the amount (pint, pitcher, goblet, half-pint, flight, etc.). Eleven quarters of sales data were obtained and utilized for the forecasts. The exact years and quarters are not being disclosed in order to protect Rapscallion's data.

The necessary raw data was extracted from the original spreadsheet and organized into a single Microsoft Excel workbook with different worksheets for each beer type. The sales from both locations were combined in order to get a more holistic view of Rapscallion’s sales and overall demand. All of the data was then converted into a base unit of ounces in order to obtain accurate forecasts and make it easier to convert it once the forecasts were done. Three different time series forecasting techniques were used to forecast the data: simple moving average, exponential smoothing, and seasonal index. These three time-series forecasting methods were chosen in order to get a varied range of results. In Figure 5, one can see the forecasts with graphs and error analysis for Honey Ale. This method was repeated for Rapscallion’s 32 different beers.

Quarter	Actual Sales (Demand) in Kegs	3 quarter moving average	Forecast (Exponential Smoothing)	Seasonal Index	MAPE	MAD
Q1	63.6622619			0.844843424		
Q2	94.14380952			1.249355207		
Q3	73.37047619	77.05884921	77.05884921	0.973678322	5.03%	3.688373016
Q4	65.12166667	77.54531746	66.31538492	0.864210762	1.83%	1.193718254
Q1	67.36202381	68.61805556	67.25735992	0.893941892	0.16%	0.104663889
Q2	72.27714286	68.25361111	71.77516456	0.959169012	0.69%	0.501978294
Q3	72.10142857	70.58019841	72.06880217	0.956837159	0.05%	0.032626401
Q4	63.1497619	69.17611111	64.04166593	0.838042185	1.41%	0.891904027
Q1	72.58464286	69.27861111	71.73034516	0.963249756	1.18%	0.854297693
Q2	99.52261905	78.41900794	96.74339166	1.320735829	2.79%	2.779227388
Q3	85.5972619	85.90150794	86.71187488	1.135936451	1.30%	1.114612975
Average	75.35391775					

Figure 6: Forecasts and Error Analysis for Honey Ale on Microsoft Excel

Note: Numbers changed to protect sensitive information.

Simple moving average was chosen as a forecasting method because it will take all of Rapscallion’s data and give all the data equal weight, regardless of how long ago the data was collected meaning that the data from the first quarter in the first year of data will bear the same weight as the data from the third quarter from the last year of data. This will provide a good starting point. Some limitations of this forecasting technique, however, are that Rapscallion has made significant changes since the first quarter of data that was provided, such as adding different beers, adding a food truck, and hosting more public events. Therefore, the earlier sales data they provided should be weighted less than the more recent data. For this reason, the exponential smoothing model was applied because it puts less weight on the older data and more weight on the recent data, better reflecting the current state of Rapscallion. A comparison was made between the simple moving average forecast and the exponential smoothing forecast to see how the changes Rapscallion has made have affected their sales within the past few years. These results are further analyzed in the Analysis section of the report. The third and final forecasting technique that was applied was Seasonal Index. This technique was applied to account for the seasonality in the data, meaning how high or below the average sales were each quarter. Formulas and descriptions of each technique can be found in Table 2.

Error analysis was also done using the results of the exponential smoothing forecast in order to evaluate the accuracy of the forecasts. Both MAD and MAPE were used to evaluate the accuracy of the exponential smoothing forecasts and justify the use of .9 as the alpha value, or smoothing constant, of the forecast.

3.3 Arena Simulation Model

Currently, Rapscallion has two 80 keg, one 30 keg, and two 20 keg fermenting tanks. In early 2017, Rapscallion announced their decision to purchase two more 20 keg fermenting tanks and one more 20 keg brite tank. In order to estimate this increase in capacity, a discrete event simulation using the Arena Simulation Software was created to simulate Rapscallion's brewing process from start to finish. Please refer to Table 3 for definitions of terms used in describing the Arena model.

Term	Definition
Entity	"Entities are the dynamic objects in the simulation—they usually are created, move around for a while, and then are disposed of as they leave" (Kelton, Sadowski, Zupick, 2015).
Variable	"A variable (or a global variable) is a piece of information that reflects some characteristic of your system, regardless of how many or what kinds of entities might be around" (Kelton, Sadowski, Zupick, 2015).
Resource	"Represent things like personnel, equipment, or space in a storage area of limited size. An entity seizes (units of) a resource when available and releases it (or them) when finished" (Kelton, Sadowski, Zupick, 2015).
Attribute	"An attribute is a common characteristic of all entities, but with a specific value that can differ from one entity to another" (Kelton, Sadowski, Zupick, 2015).
Queue	"When an entity can't move on, perhaps because it needs to seize a unit of a resource that's tied up by another entity, it needs a place to wait, which is the purpose of a queue" (Kelton, Sadowski, Zupick, 2015).
Modules	"The basic building blocks for Arena models are called modules. These are the flowchart and data objects that define the process to be simulated and are chosen from panels in the Project Bar. Modules come in two basic flavors: flowchart and data"(Kelton, Sadowski, Zupick, 2015).
Flowchart Module	"Flowchart modules describe the dynamic processes in the model. You can think of flowchart modules as being nodes or places through which entities flow, or where entities originate or leave the model" (Kelton, Sadowski, Zupick, 2015).
Data Modules	"Data modules define the characteristics of various process elements, like entities, resources, and queues. They can also set up variables and other types of numerical values and expressions that pertain to the whole model" (Kelton, Sadowski, Zupick, 2015).

Table 3: Arena Terminology

The Arena model begins with one entity in the "start process" create module named "Batch of Beer". This entity represents the incoming demand of beer into the system. The arrival rate for this entity was found by taking the total sales for each quarter, converting the sales into ounces, summing it and then dividing it by 1,680 ounces. We chose 1,680 ounces because this is the capacity of one of Rapscallion's kegs. This number gave us the quarterly total demand for kegs. We then divided the number by 20 to represent a demand for 20 kegs. We chose 20 kegs as the amount for our demand as this is the capacity of Rapscallion's smallest Fermenting tank and Brite tank. We then fit a distribution to this data by putting it into a text file and uploading it to Arena input analyzer. The distribution that we found for the arrival rate of the batches of beers was a Beta distribution. The expression was: 12 +24 * Beta (0.62, 0.657) with a square error of: 0.0365.The user interface for the create module for the entity that represents demand can be seen below. The time between arrivals is set to 90 days to represent 3 months between arrivals. The entities per arrival is a distribution to match quarterly demand.

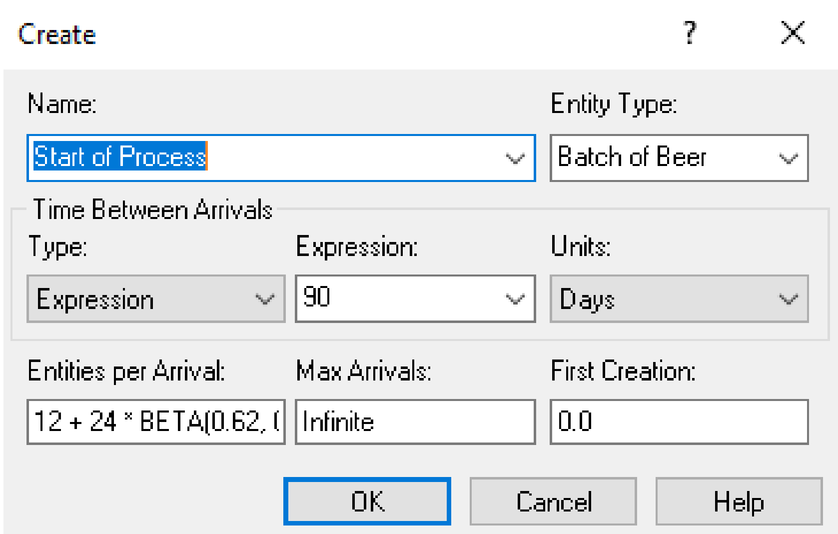


Figure 7: User interface for the create module

After entering the system the entity goes through an assign module titled, "Assign Beer Type". The assign module assigns an attribute, "Beer Type". The type of beer follows a discrete probability where there is a 79% chance that the beer will be an Ale and a 21% chance that the beer will be a lager. These percentages were chosen because based on the sales data, 79% of the beers that Rapscallion brews are categorized as ales and the other 21% are lagers. The Assign module then changes the entity type to the beer type. This generalization was used in order to simplify the model because all the ales they brew and all the lagers they brew have the same brewing times, respectively. The user interface for the beer type assign module can be seen in Figure 5. The beer type is assigned by a discrete probability and then sets the entity type to the new beer type of either Ale or Lager.

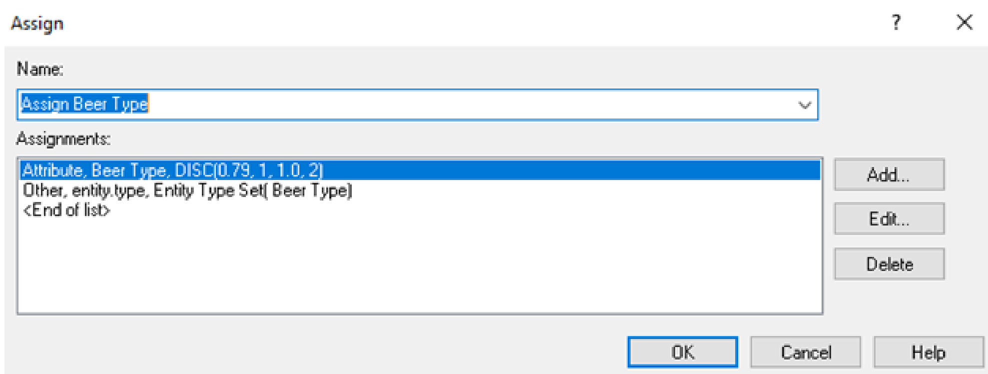


Figure 8: User interface for beer type assign module

After exiting the assign module the entity then enters a decide module titled, "Ale or Lager" that separates the entity by whether it is an ale or lager. The two separate entities are then assigned a processing time that assigns the variable for fermenting time in days to each entity type. Lagers are assigned 42 days for this variable and Ales are assigned 21 days.

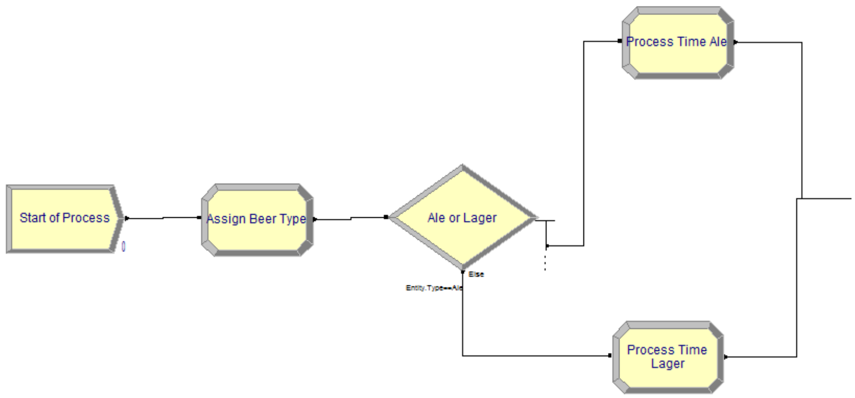


Figure 9: A close up view of the beginning of the simulation model flowchart

After the entities are assigned a fermenting time they then enter another decide module which transfers the entities to the fermenting tanks. The transfer is made by probability. We decided that the probability of an entity going to the 80 keg fermenting tank should be four times that of the probability for entering a 20 keg tank and that the probability for an entity to enter the 30 keg tank should be 1.5 times the probability to enter a 20 keg tank. We made this decision since the capacity for the 80 keg fermenting tanks is 4 times that of the 20 keg tank and the capacity for the 30 keg fermenting tank is 1.5 times that of the 20 keg fermenting tank. These probabilities can be found in Table 4.

Fermenting Tank Size	Probability of Transfer
80 Kegs	26.629
80 Kegs	26.629
30 Kegs	11.111
20 Kegs	7.407
20 Kegs	7.407
20 Kegs	7.407
20 Kegs	7.407

Table 4: Probability of an entity being transferred to each fermenting tank

When the entity arrives at one of the seven fermenting tank process modules the entity then seizes the resource and delays it for the fermenting time variable that was previously assigned to it. After the entity releases the resource it then enters another assign module. This assign module assigns a variable for the capacity tank that the entity had seized during the fermenting process.

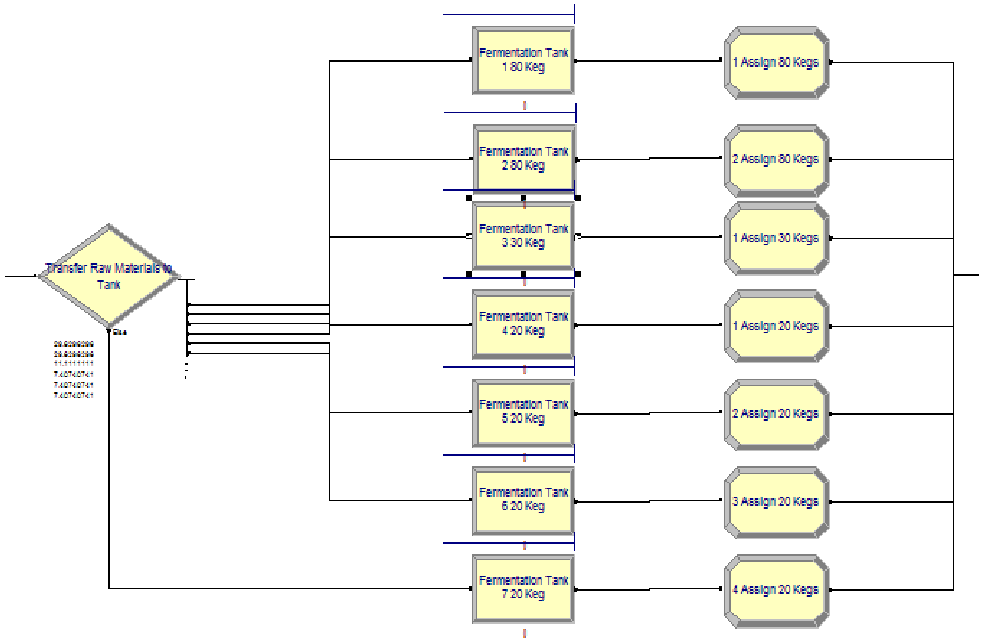


Figure 10: A close up view of the middle of the simulation flowchart

The entity then enters a decide module. The decide module then transfers the entity based on the amount of kegs that were assigned to one of the three brite tanks. The first brite tank will accept entities with 80 and 30 kegs assigned and the last one will accept entities with 20 kegs assigned. This decision module was modeled in conjunction with how Rapscallion Brewery currently decides which brite tanks to transfer to. After the entity seizes the brite tank resource for a uniform distribution of 1-2 days it then releases the resource and then exits the system.

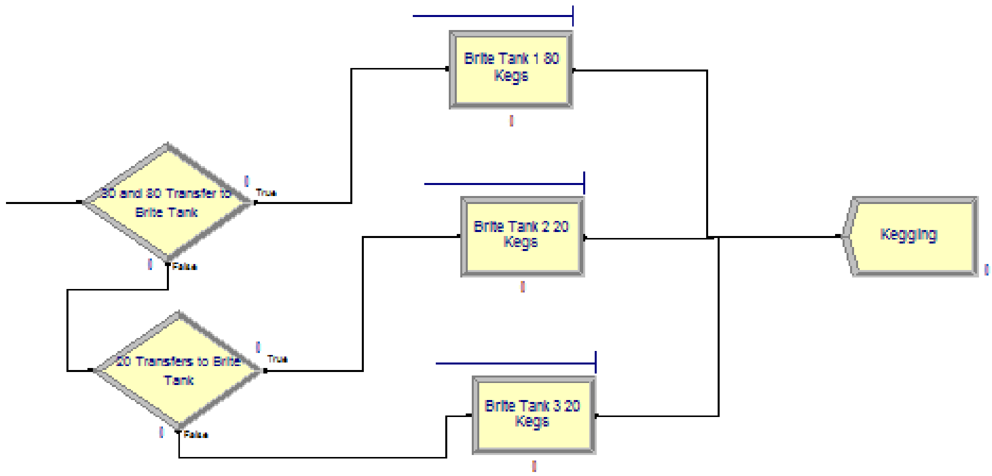


Figure 11: A close up view of the end of the simulation flowchart

After completing the Arena model, our group decided to utilize Arena's Process Analyzer (PAN) application in order to simulate different capacity scenarios. In order to utilize this application we had to make adjustments to our model. Our model was initially made to visualize the transfer to the different fermenting tanks as well as brite tanks. This choice was made as it is the easiest way to comprehend the different flows throughout the process as you can see each entity move from one module to the other. This type of modeling did not allow us to edit the amount of resources available in PAN accurately. In order to address this problem we created new model in which all of the resources that have the same capacity are in the same module.

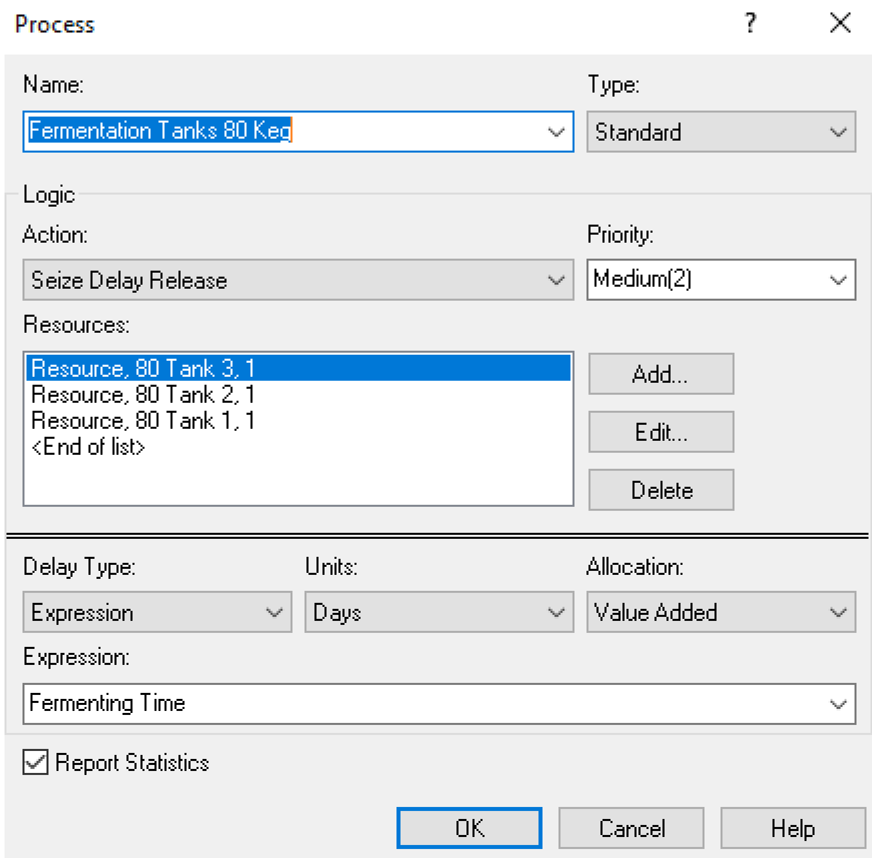


Figure 12: New Model's Fermenting Tank Process Module

The first scenario simulated was the current state of Rapscallion without the addition of their new fermenting tank and their new brite tank. The second scenario was included the addition of the new fermenting tank and their new brite tank, and the final scenario included the addition of another 80 keg fermenting tank and another 80 keg brite tank. The current state was simulated in order to compare those results with those with the addition of the new tanks and make recommendations accordingly. An overview of the completed model can be seen in Figure 10.

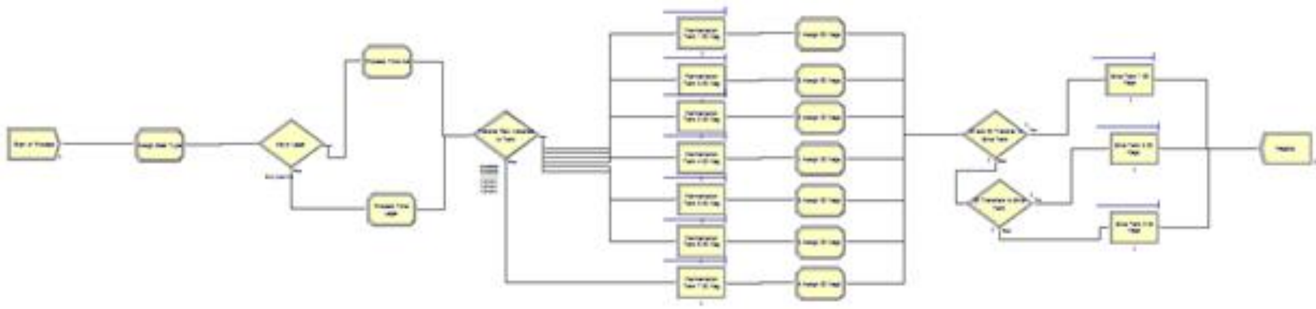


Figure 13: Overview of Arena simulation model for Rapscallion's brewing process

Note: This is to show the flow of the entire model. Module names and zoomed in screenshots of the model can be found in the Methodology section of the report.

3.4 Process Analyzer (PAN)

The Process Analyzer (PAN) Arena application was utilized to observe the increase in output of beer that the addition of the new fermenting and brite tanks. In order to utilize PAN, one must first run the Arena model and save it. One must then open PAN, a separate application that uses Arena .p files as its program file. In Figure 10, we can see that the program file for all the scenarios is the Arena file with Rapscallion's old capacity. The controls used for this PAN analysis were the resources, which in this case are the fermenting tanks and brite tanks.

	Scenario Properties				Controls							Response
	S	Name	Program File	Reps	80 Tank 1	80 Tank 2	30 Tank 1	20 Tank 1	20 Tank 2	80 Brite Tank 1	20 Brite Tank 2	Batch of Beer.Number
1		Current Capacity	9 : MQP_Rapscallion Updated.p	1	4.0000	4.0000	1.5000	1.0000	1.0000	4.0000	1.0000	118.000
2		New Capacity	9 : MQP_Rapscallion Updated.p	1	4.0000	4.0000	1.5000	2.0000	2.0000	4.0000	2.0000	137.000
3		Potential Tank Additions	9 : MQP_Rapscallion Updated.p	1	8.0000	4.0000	1.5000	2.0000	2.0000	8.0000	2.0000	137.000

Figure 14: Process Analyzer (PAN) scenarios, controls, and responses

Figure 10 shows three different scenarios: Rapscallion's current capacity without the addition of the new tanks, Rapscallion's planned capacity with the new tanks, and a scenario with a new 80 keg fermenting tank and 80 keg brite tank added in addition to the aforementioned new tanks to see if adding even more tanks would possibly increase sales. Tanks were added under the "Controls" section and the "Response" is the total batches of beer brewed. Therefore, the number Batches were defined as being 20 kegs, which is why the 80 keg tanks have a capacity of 4 batches, the 30 keg tank has a capacity of 1.5 batches and the 20 keg tanks have a capacity of 1 batch.

In the first row, in the "Current Capacity" scenario, none of the controls were changed because these capacities reflect those present in the original model. In the second row, for the "New Capacity" scenario, the capacities were changed to reflect those with the additional two fermenting tanks and the additional brite tank. We can see that "20 Tank 1" and "20 Tank 2" and "20 Brite Tank 2" were doubled from having a capacity of one batch in the "Current Capacity" scenario to a capacity of two batches in the "New Capacity" scenario. A third scenario was then created called "Potential Tank Additions" to see how the output "Batches of Beer" would be affected by an even greater increase in capacity. For this hypothetical scenario, another 80 keg fermenting tank was added and another 80 keg brite tank was added in addition to the new tanks added in the "New Capacity" scenario.

3.5 Project Schedule

A Gantt chart shows the project calendar. This chart provides the project timetable and activities. The timetable is roughly 6 months, from August 24th to March 2nd. The activities include regular meetings and interviews with Cedric Daniel and Jonas Noble, the co-proprietor and head brewer at Rapscallion. Additional activities include acquisition of Rapscallion's quarterly sales data, forecasting of the demand using time series methods, and the development of a simulation model using Arena simulation software. The Gantt chart also includes other milestones such as turning in the project proposal, completing the final project report and the final project presentation. The final Gantt chart can be seen in Appendix A.

3.6 Connecting the Forecasts and Simulation Model

Simulation models, such as ones developed in Arena, "have also been called financial planning models" (Erdman). The simulation model was used to validate and supplement the results obtained by the forecasts of the demand for Rapscallion's. Since Rapscallion's past sales data does not account for their increase in capacity due to their new fermenting and brite tanks, the simulation model was used to see how this increase in capacity would affect their resource utilization. As previously mentioned, three different scenarios were simulated using the model: one model without the new fermenting tanks (this model would be representative of the forecasts done), a model with the addition of the new tanks, and a model with an even greater addition of tanks to see how a greater increase in their capacity would affect demand.

Chapter 4: Analysis

This section will describe the analysis done on the two project deliverables: the forecasts and the Arena Simulation Model. Each project deliverable is analyzed individually and then they are analyzed together. Recommendations are made to Rapscallion based off of this analysis. Although forecasts were done for all 32 beers that Rapscallion brews, some of the beers had insufficient data to accurately predict demand utilizing any of the aforementioned forecasting methods. For this reason, only the seven beers that Rapscallion constantly has on tap were analyzed in depth, although elements from the forecasts of the other seasonal beers were also taken into account to make recommendations.

The Arena application Process Analyzer (PAN) was also used in order to compare different capacity scenarios for Rapscallion's brewing process.

4.1 Forecast Analysis

As previously stated, three different forecasting methods were used in order to accurately forecast Rapscallion's beer demand. These three methods are simple moving average, exponential smoothing, and seasonal index. Error analysis was then done comparing the forecasts to the original sales data in order to evaluate the accuracy of the forecasts. For the exponential smoothing forecast, a smoothing constant (alpha value) of 0.9 was used. After the forecasts were done and the error analysis was done, the three forecasts were graphed. Honey was chosen as this first example because it is Rapscallion's most sold beer. It is important to note that the y-axis values were removed to protect the confidentiality of the sales data, and the years were taken out of the x-axis as well.

The graphs for Rapscallion's seven beers that are always on tap can be seen below. These beers are Honey Ale, Blonde Ale, Harvard Lager, Session IPA, Rye IPA, Red Ale, and IPA (Pale Ale).

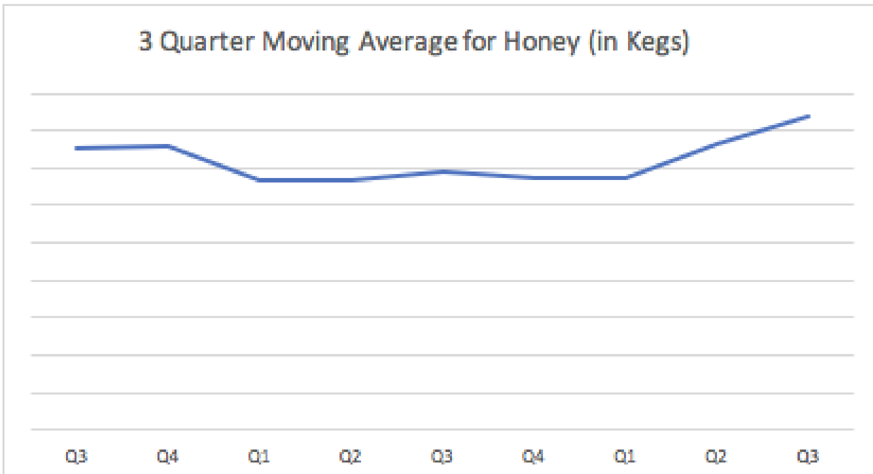


Figure 15: Three Quarter Moving Average Forecasts for Honey Ale

This graph of the Three Quarter moving average for Honey Ale shows in increase in sales from the last Q1 to Q3. Although there was a dip in sales in the first Q1, this is often expected as winter is the slower season with regards to craft beer demand and autumn is the more busy season.

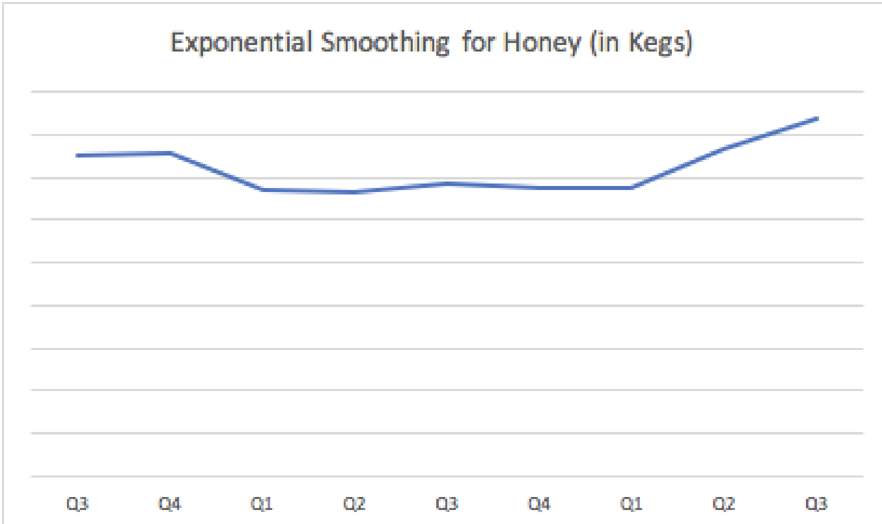


Figure 16: Exponential Smoothing for Honey Ale

This graph of the Exponential Smoothing forecast for Honey Ale shows an increase in sales from Q1 to Q3. It looks almost identical to the three quarter moving average graph for Honey, which is oftentimes the case because the only difference between the two forecasting methods is that the exponential smoothing puts more emphasis on the more recent data while moving average places equal weight on all the data.

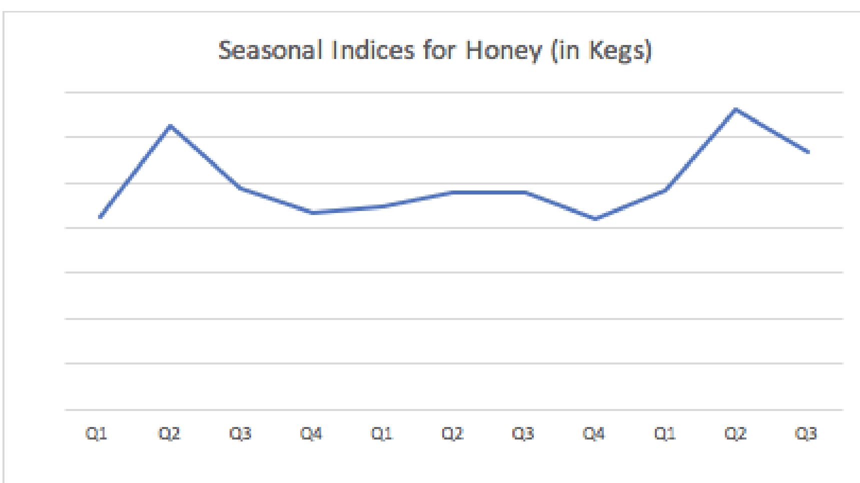


Figure 17: Seasonal Indices for Honey Ale

The seasonal indices for Honey Ale show a pattern that differs slightly from the usual trend in beer sales. This graph shows a rise in Q2 which is to be expected, but then a decline in sales in Q3 and Q4, where sales are usually higher according to seasonal trends in the craft beer industry.

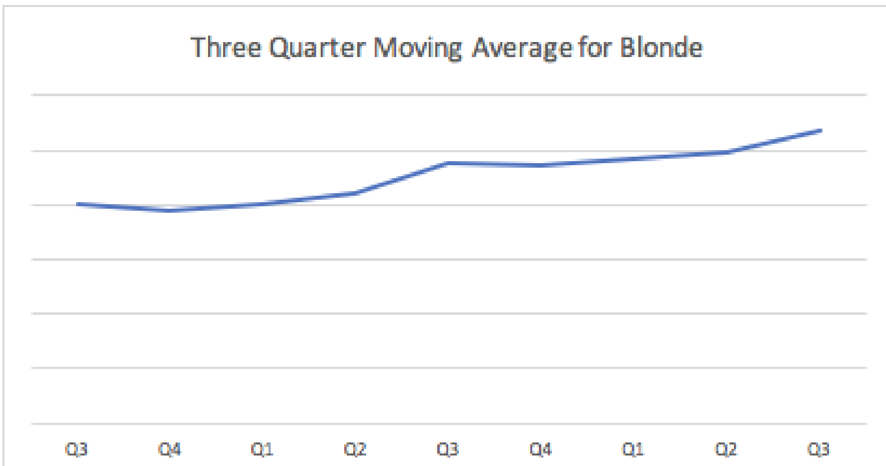


Figure 18: Three quarter moving average for Blonde

The three quarter moving average for Blonde Ale shows a steady linear trend in the data with a small peak in the second Q3. Overall it shows in increase in production as Rapscallion’s operations have continued, an indication that the demand for Blonde Ale will continue rising steadily in the future.

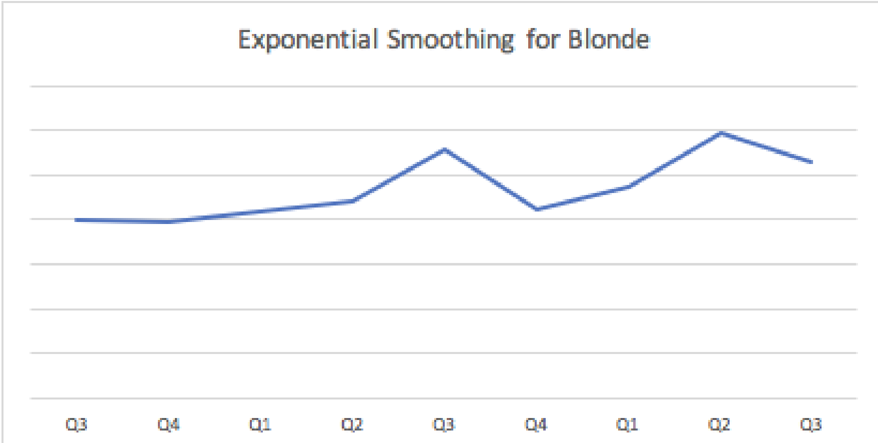


Figure 19: Exponential smoothing for blonde

The Exponential Smoothing forecast for Blonde shows the same peak in the second Q3 as does the simple moving average, but it is steeper which makes sense because more weight is placed on this data because it is more recent.

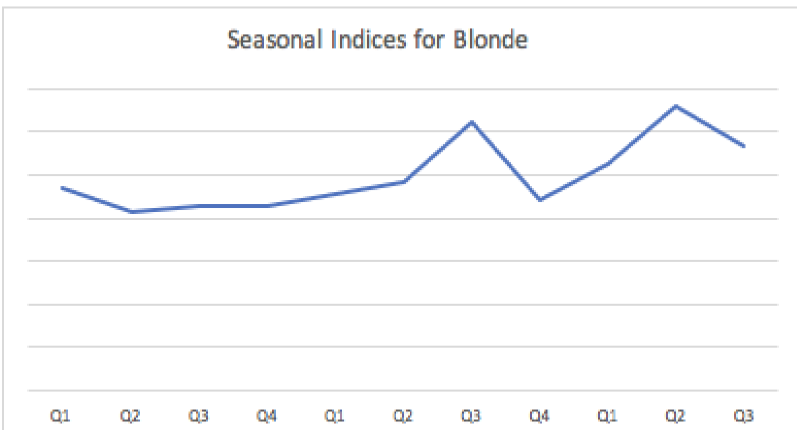


Figure 20: Seasonal Indices for Blonde

The seasonal indices for Blonde Ale look very similar to the exponential smoothing forecast. The seasonal indices represents how much the data is either above or below the average demand, so the dramatic spikes and dips in this graph show how affected the demand is by seasonality.

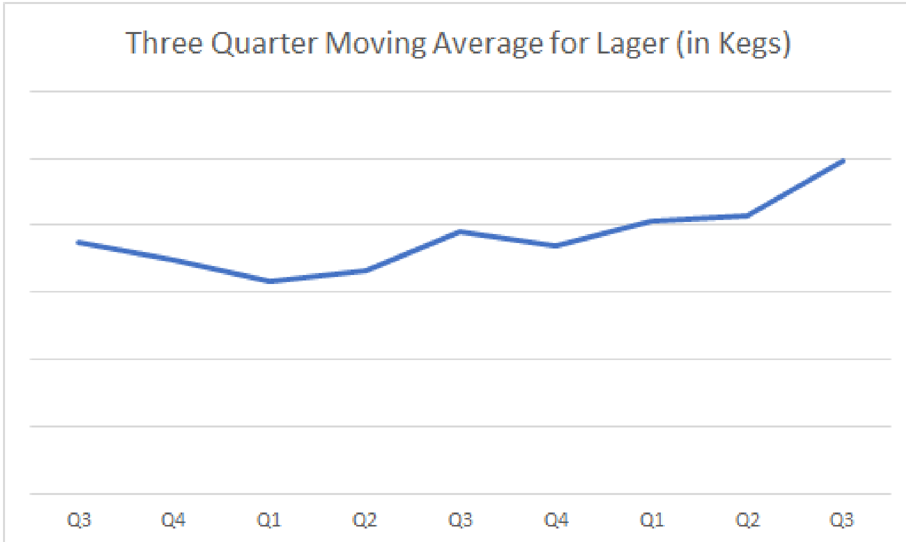


Figure 21: Three quarter moving average for Harvard Lager

The three quarter moving average for Harvard Lager also shows a spike in demand in the second Q3 displayed in the graph above. This spike in demand is similar to that in the Figures 5-7 for Blonde Ale. This signifies that Rapscallion perhaps produced more of each of these two beers that quarter in order to satisfy the demand.

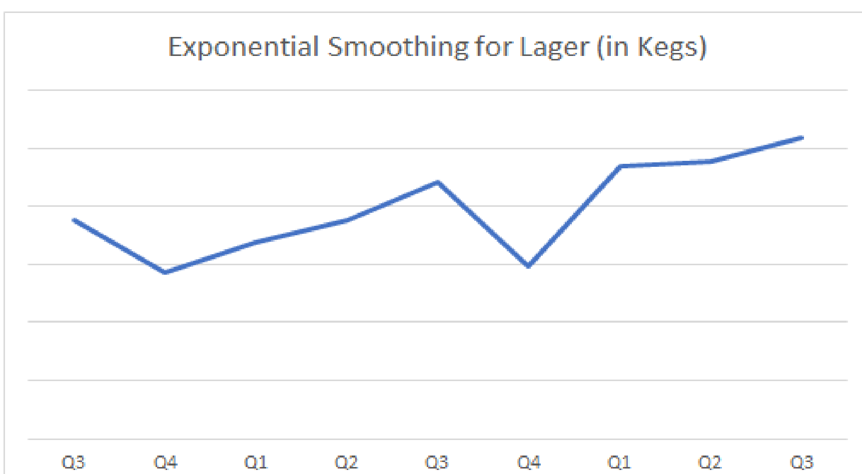


Figure 22: Exponential smoothing for Harvard Lager

The exponential smoothing forecast for Harvard Lager shows a peak at the second Q3, a very significant dip at Q4, and a sharp peak again at Q1. This shows that perhaps an unexpected issue may have occurred with brewing of Harvard Lager as Q4 is usually the busy season and Q1 is the slower season.

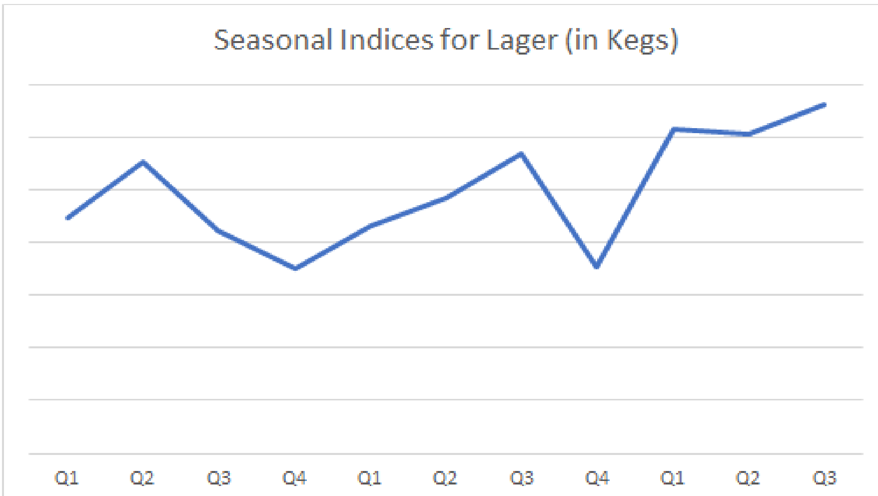


Figure 23: Seasonal indices for Harvard Lager

The seasonal index graph for Harvard Lager shows that there is a decline in the demand for during Q4 of both years and spike in demand during Q2 of both years.

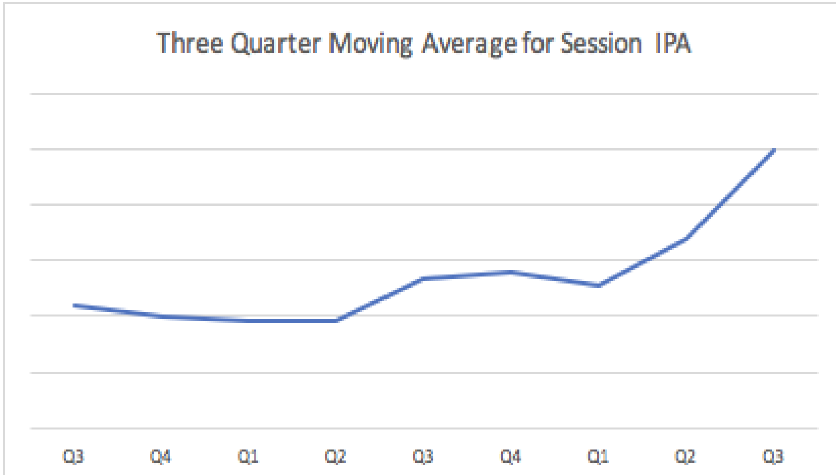


Figure 24: Three quarter moving average for Acton Session IPA

The three quarter moving average for Acton Session IPA shows a plateau in sales for the first four quarters and then an overall gradual rise in the following quarters.

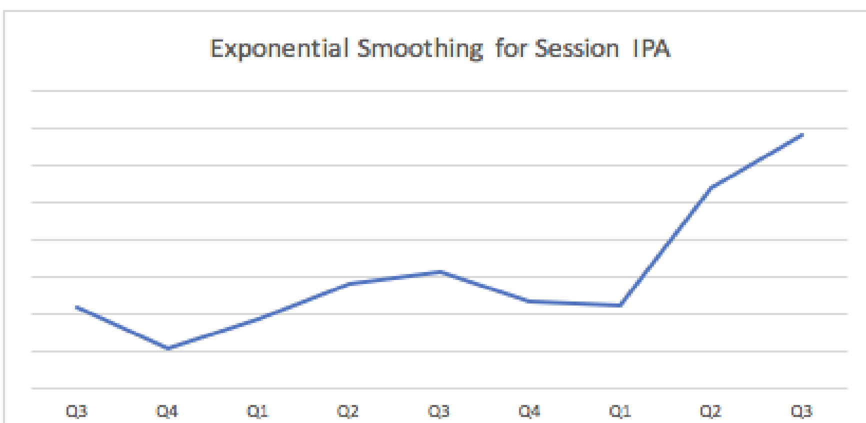


Figure 25: Exponential smoothing for Acton Session IPA

The exponential smoothing for Acton Session IPA shows a very different trend in sales from the previously analyzed beers. In this graph, the peaks and dips are much more distinct than that of the three quarter moving average graph. More weight is placed on the newer data, and we can see dips in both Q4's and peaks in all of the Q3's that are shown on this graph.

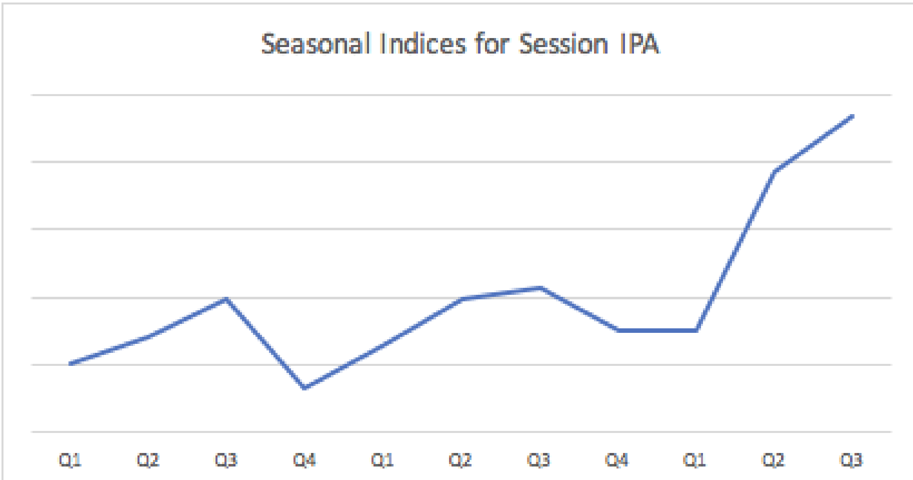


Figure 26: Seasonal indices for Acton Session IPA

The seasonal indices for Session IPA shows a pattern that somewhat follows the typical seasonal trends for craft beer but in some cases does not. For example, the rise in demand in Q3 is typical but the large drop in sales in Q4 is atypical as Q4 is the busy season for beer. The rise in Q1 is also unusual, especially for a craft brewery located in the Northeast, but the rise in Q2, especially in the last Q2 depicted in the graph, is typical.

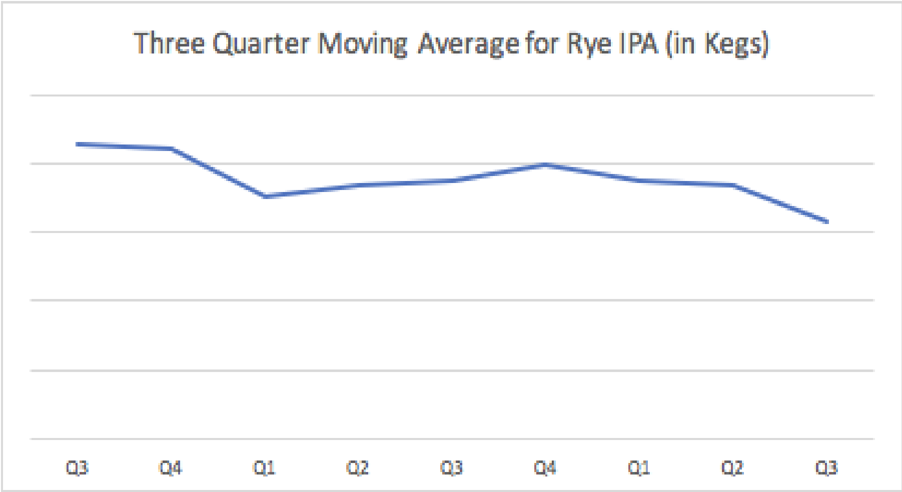


Figure 27: Three quarter moving average for Rye IPA

The three quarter moving average graph for Rye IPA shows a mostly linear trend with a negative correlation. This means that demand and sales has only gone down as time has gone by.

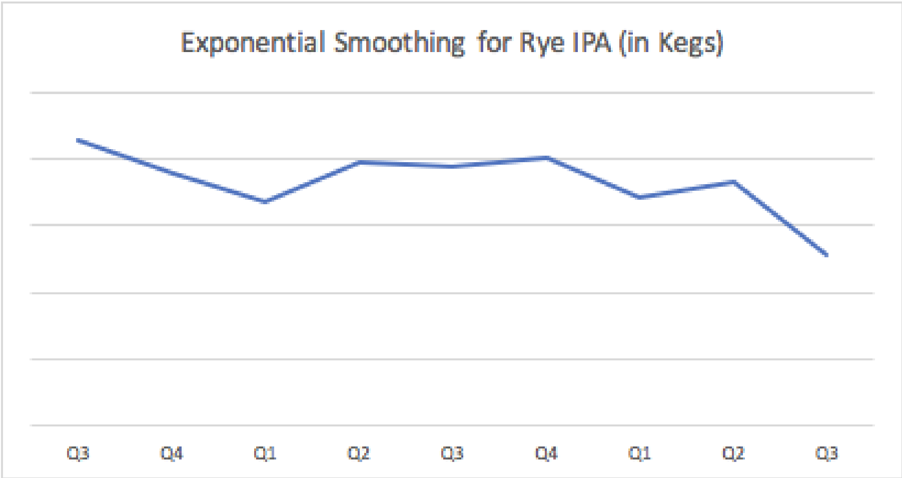


Figure 28: Exponential smoothing for Rye IPA

The exponential smoothing forecast for Rye IPA also shows the steady decline in sales. This is indicative that the decline for Rye IPA has gone down. This could be due to the fact that

Rapscallion has added other more popular seasonal beers. One thing that Rapscallion could consider is brewing Rye IPA only a few times a year instead of always having it available on tap.

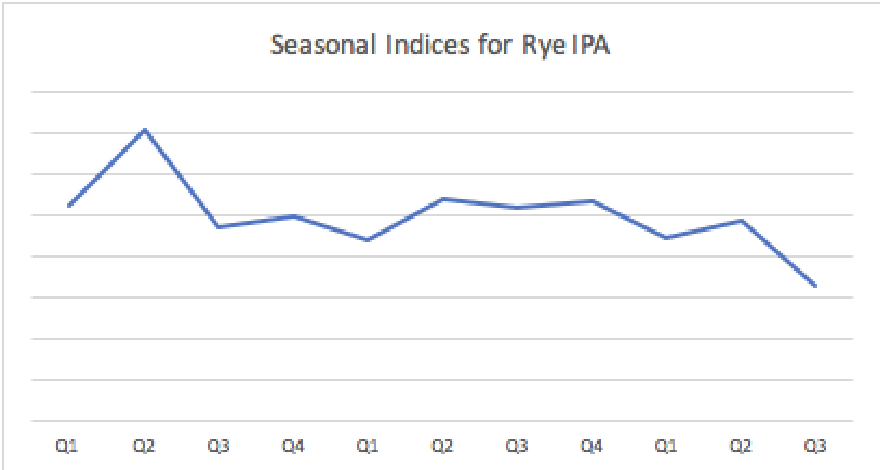


Figure 29: Seasonal indices for Rye IPA

The seasonal indices for Rye IPA do not show much of a change in demand due to seasonality. As mentioned before, the overall demand of Rye IPA is declining as time goes by but seasonality does not seem to play much of a role in this case.

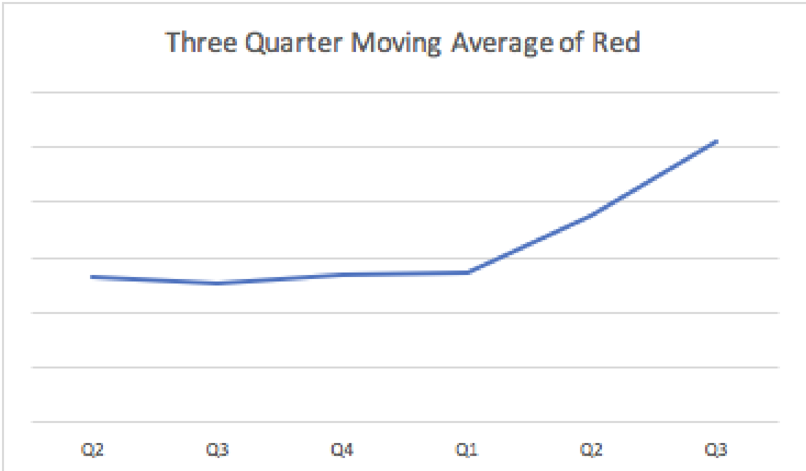


Figure 30: Three quarter moving average for Red

The three quarter moving average for Red shows a very steady demand from the first Q2 to the first Q1 shown and then a steady increase from the last Q1 to Q3.

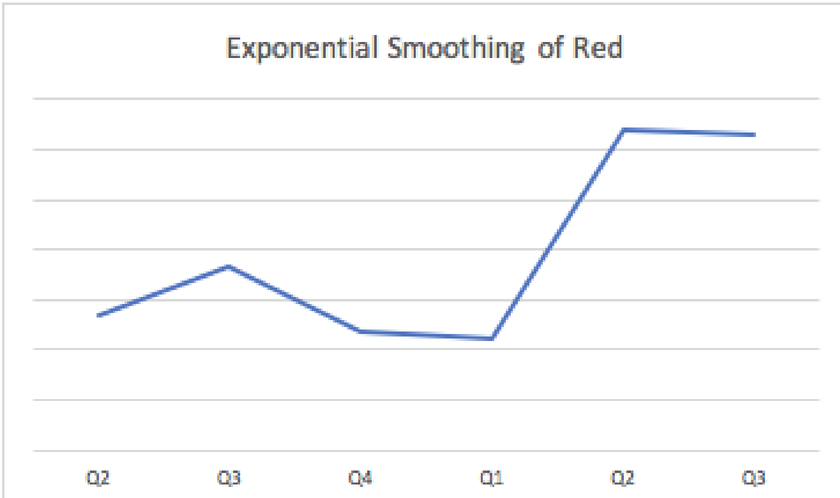


Figure 31: Exponential smoothing of Red

The exponential smoothing for Red shows a very dramatic increase in demand from Q1 to Q2. This indicates that the demand for Red has increased recently.

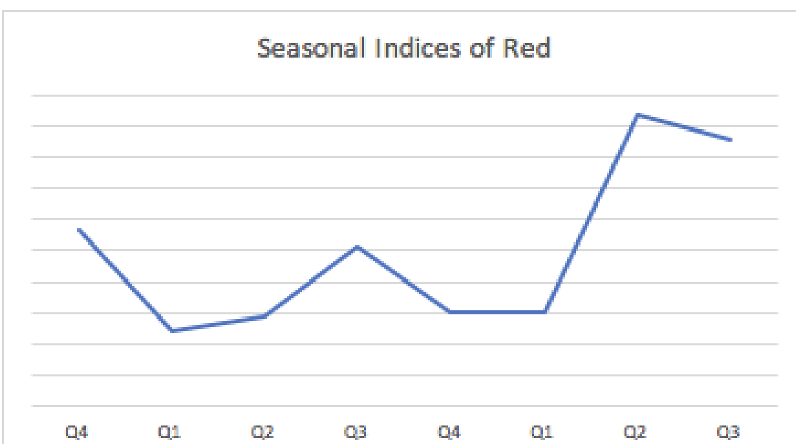


Figure 32: Seasonal Indices of Red

The seasonal indices of Red have very dramatic spikes and troughs in the demand for Red. This means that the demand is very much affected by seasonality. Rapscallion could consider brewing Red only during the quarters where sales have been high in the past.

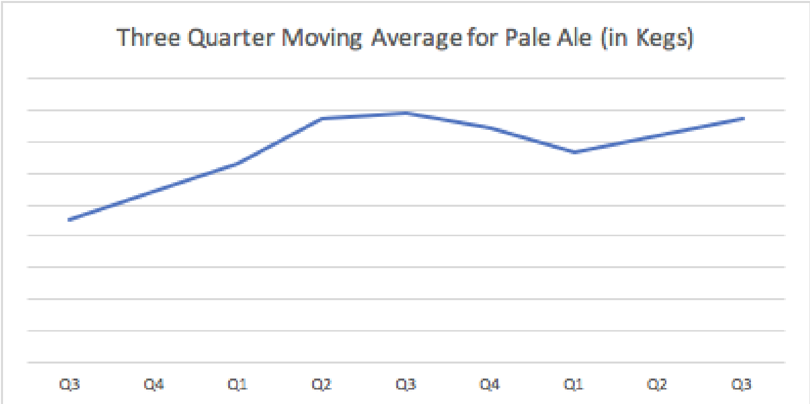


Figure 33: Three quarter moving average for IPA

The three quarter moving average for IPA shows an overall linear trend with a peak in the middle during Q1-Q4. This graph has a positive correlation, meaning that demand has continued to rise overall.

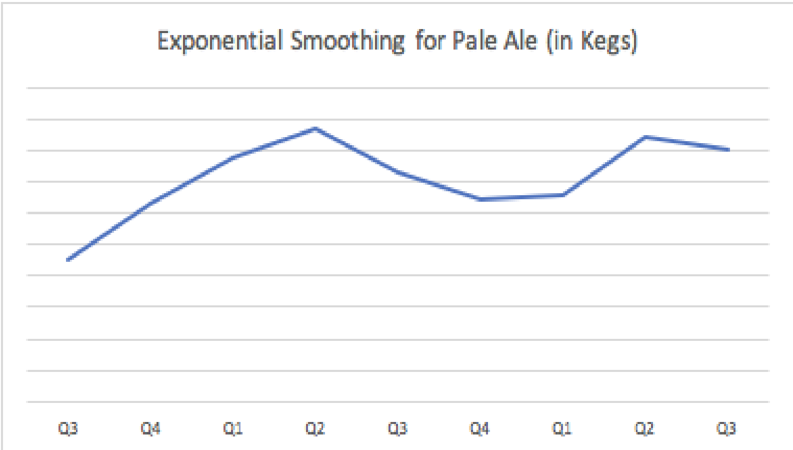


Figure 34: Exponential Smoothing for IPA

The exponential smoothing graph for IPA shows characteristics of both normal and unusual beer trends in the beer industry. This graph shows a rise in Q2 which is the springtime, and then a decline in Q3 which is unusual.

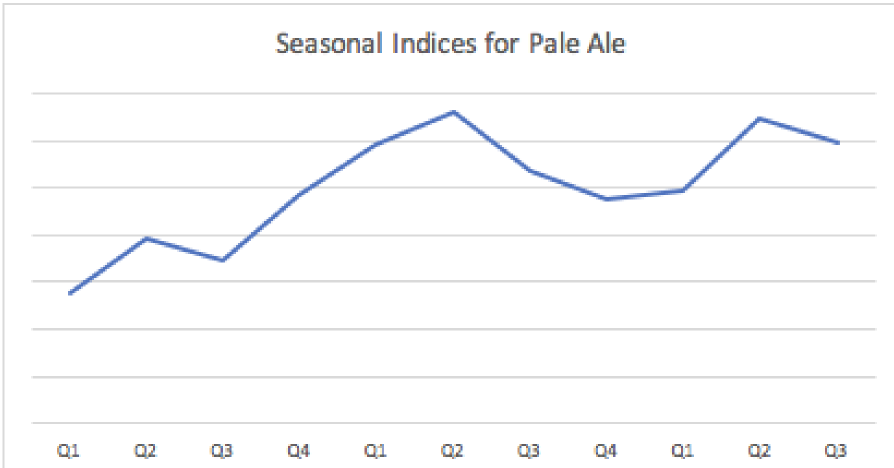


Figure 35: Seasonal Indices for IPA

The seasonal indices for IPA show an overall rise in demand. The peaks and dips that are displayed show that the demand for IPA (Pale Ale) is significantly affected by seasonality.

4.2 Process Analyzer (PAN)

Process Analyzer (PAN) was utilized as part of the analysis to validate the addition of Rapscallion's two new fermenting tanks and new brite tank. PAN was also used to see the effect of adding even more fermenting tanks would have on the number of batches of beer they brew. The results of this analysis show that while Rapscallion should definitely implement the new fermenting and brite tanks that they had planned on, two new 20 keg fermenting tanks and one

20 keg brite tank, they should not implement any more until the overall demand for their beer rises.

	Scenario Properties				Controls							Response
	S	Name	Program File	Reps	80 Tank 1	80 Tank 2	30 Tank 1	20 Tank 1	20 Tank 2	80 Brite Tank 1	20 Brite Tank 2	Batch of Beer.Number
1		Current Capacity	9 : MQP_Rapscallion Updated.p	1	4.0000	4.0000	1.5000	1.0000	1.0000	4.0000	1.0000	118.000
2		New Capacity	9 : MQP_Rapscallion Updated.p	1	4.0000	4.0000	1.5000	2.0000	2.0000	4.0000	2.0000	137.000
3		Potential Tank Additions	9 : MQP_Rapscallion Updated.p	1	8.0000	4.0000	1.5000	2.0000	2.0000	8.0000	2.0000	137.000

Figure 36: Process Analyzer (PAN) results

The results of the PAN analysis show that the old capacity would yield 118 batches of beer annually. With the addition of the new fermenting tanks and new brite tanks, 137 batches would be brewed based on the demand. Interestingly, with the addition of one new 80 keg fermenting tank and one 80 keg brite tank in addition to the new tanks that Rapscallion already has planned, the result is still 137 batches. This is because the model is based on Rapscallion's demand as given by their sales data meaning that they should not add any further tanks at this time other than the ones that they have already planned to add until the demand for their beer as a whole increases.

Chapter 5: Recommendations

This section of the report describes the recommendations that we have for Rapscallion Brewery based on both market research on trends in the craft beer industry, seasonal trends in the beverage industry, and the analysis done on the forecasts, Arena simulation model, and PAN.

While production of beer is not the only factor that affects Rapscallion's sales, it is one of the key elements. Rapscallion produces an average of around 25 batches of beer per quarter currently. The addition of the fermenting and brite tanks will increase the amount of batches they are able to brew per quarter. This was confirmed by the PAN analysis. The number of batches produced annually increased from 118 to 137 when the new tanks were added into the model, therefore, we recommend Rapscallion implement these new tanks as soon as possible in order to increase their sales because the demand is there. Before the implementation of these fermenting tanks into the model there was a queue that would build up as a result of the processes inability to meet the current demand. Although we recommend that Rapscallion go ahead with their planned increase in tanks, Rapscallion should not increase the number of tanks any further until their sales increase enough to warrant it.

With the increase in production capacity, Rapscallion can choose to either produce more of the beers that are constantly in demand or experiment with different beers. One of our recommendations is that Rapscallion uses this increase in capacity to produce more of their Honey Ale since that is their most popular beer both in both of their locations and it is the only beer that they sell to outside distributors. Another recommendation we are making based on the analysis of the forecasts for is for Rapscallion to perhaps make Rye IPA a seasonal beer or have it brewed a few times per year instead of always having it on tap. This is due to the fact the sales of Rye IPA have only gone down as time has gone by. This is illustrated by the graphs in Figures 28-30.

Another recommendation that we have for Rapscallion is that they continue to host public events at their brewery such as trivia nights, live music, and beer festivals such as Oktoberfest. We recommend that they host more of the public events that are most popular, during the busy season for craft breweries, Q2 and Q3. These events should could take place on both weekdays and weekends but perhaps be longer on the weekends to accommodate a diverse customer base.

5.1 Recommendations for Future Projects

Rapscallion Brewery has expressed interest in continuing the project with students from Worcester Polytechnic Institute (WPI). While we were able to conduct a successful project that accomplished our goals for forecasting and process simulation, we believe that there are areas that could be improved for an increase in accuracy. We suggest that future work on forecasts should conducted with monthly data as that would allow for more accurate projections. Some of our forecasts for beers that were produced a few times had a high error percentage as there was not enough data to create accurate forecasts. We also suggest that other projects expand the simulation to incorporate sales of crowlers and a potential canning process. Rapscallion Brewery has expressed interest in expanding their current operation to incorporate a canning line. This would greatly affect the demand as well as the kegging process as there would be more competition for the limited resources.

Chapter 6: Reflection

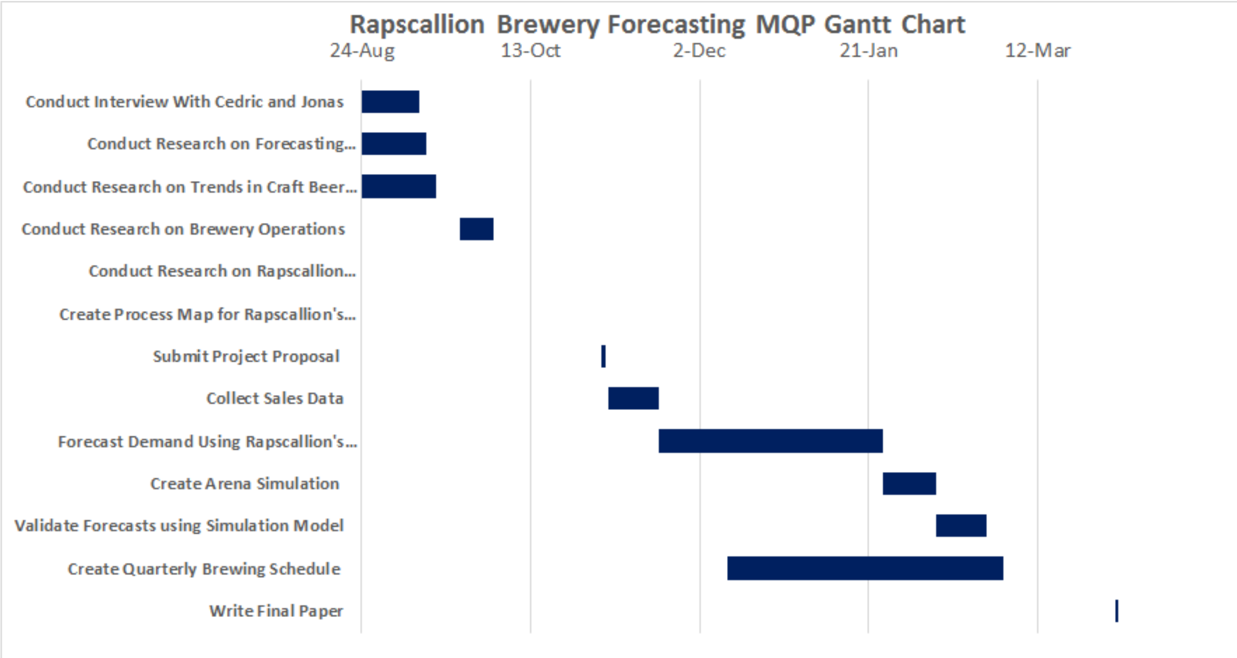
Our project with Rapscallion Brewery required an engineering design that incorporated multiple industrial engineering practices. The design that we used incorporated processes analysis, process simulation, and forecasting. We used the simulation software Arena and its subprogram PAN in order to test different systems for the brewery, such as the addition of two fermenting tanks and one brite in the future and how that would impact their beer production. We also simulated how their production would increase if they also added one 80 keg brite tank and one 80 keg fermenting tank in addition to the already outlined additions. We used three forecasting techniques on the three years of quarterly sales data we were given: simple moving average, exponential smoothing, and seasonal index. Through these forecasting methods, we were able to compare different results and find patterns in their past sales to project accurate forecasts of their future beer sales. We combined these forecasting techniques with our simulation in order to get accurate results.

Constraints considered in the design of our project are economic, manufacturability, and sustainability. When giving our recommendations, we needed to consider the cost of implementing new equipment into their system. For example, what are the implications of installing one brite tank and two fermenting tanks? Will they need to halt production temporarily? And if so, how much would that cost them? It is essential that we consider the economic implications of installing new equipment and how it will increase their profit over time. When forecasting their future sales of beer, we needed to consider manufacturability constraints to know if our recommendations are feasible. If we forecast that they can sell a certain amount of beer per quarter, does reaching that goal restrict other beers from reaching their recommended sales amount? What is the best balance of beer sales that will maximize their revenue and also be feasible? These questions needed to be considered in the design of our simulation and forecasting techniques. Sustainability is a constraint in our design because we need our recommendations to be able to be used in the future without an end date. Our forecasting techniques found seasonal trends in their beer sales, so our recommendations are able to repeat yearly due to forecasting seasonally by quarter.

Our project group has garnered a lot of personal and business related experience throughout our work. We have discovered that no amount of coursework can cover everything you may encounter in a real-life project and the ability to think logically and educate one's self along the way is imperative. One problem we came across in the beginning of our project was waiting to acquire raw sales data from our project sponsor. We had done background research on the company and project and were ready to analyze the data and produce results. Our sponsor was very busy and not having data to analyze for a project is not covered in the WPI coursework. So, we set up a meeting and went to the sponsor to discuss the problem and find a solution. Our sponsor was very responsive and gave us the data we needed, commending us on being persistent and how valuable that trait was in doing business in industry. During our work experiences we discovered again and again we must teach ourselves a technique or do more research on a subject in order to successfully continue our project. The need for lifelong learning is critical for the completion of rewarding, successful work. The realization that to never be satisfied is the best trait one can have in doing project work. Continuous improvement in what we do and achieve in life is something we can take with us after graduating from WPI.

The interdisciplinary aspect of our project combined different methodologies, insights, and theoretical frameworks from multiple industrial engineering disciplines. To support our recommendations to the sponsor, we performed three different forecasting techniques: simple moving average, exponential smoothing, and seasonal index. We used the quarterly sales data from the last three years to yield our results. Combining these forecasting techniques with the simulation allowed us to cross reference our recommendations and develop our arguments to our sponsor. In our simulation, we tested different additions of brite tanks and fermenting tanks to see if it would be an intelligent business decision. Also, if there would be enough demand for the higher amount of supply they could now create. A cultural influence that impacted our decision-making processes was customer satisfaction. Due to the wide selection of beers they offer, our sales forecast could conclude that it is not economically intelligent to brew a certain beer at all and they would be better off without it completely. However, in order to offer their customers new beer every once in a while and keep satisfaction high, the brewery will offer one-time brews or once a year brews. This factor affected our decision making process to take into account non-economic influences. Different fields of study used in our project include forecasting, simulation, and process analysis.

Appendix A: Project Gantt Chart



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