Designing a Production Planning Software for YO Sperm Test

A Major Qualifying Project
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Worcester Polytechnic Institute

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Submitted to:

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Abstract

Medical Electronic Systems, Ltd. (MES) is a medical device company located in Caesarea, Israel. For over 20 years, the company has been developing automated semen analyzers for commercial use in hospitals and labs. In 2017, MES entered the consumer market with the YO Sperm Test, an over-the-counter at-home semen analysis device. This project's goal was to design a production planning software for YO that calculates the daily production order, shipping quantity, and shipping schedule. I created a macro-enabled software in Microsoft Excel.

Executive Summary

Production planning is a critical aspect of efficient manufacturing. Production planning ensures that a company is able to fulfill its orders and allows the company to correctly plan for future sales. Too much inventory or not enough inventory can be costly for a company and negatively impact profits and future sales. My MQP focused on designing a production planning software for Medical Electronic Systems, Ltd. (MES) for their product, YO Sperm Test (YO).

MES is a medical device company located in Caesarea, Israel that designs and manufactures automated semen analyzers. Since 1993, the company has been making devices called Sperm Quality Analyzers (SQA) for commercial applications in hospitals, reproductive centers, laboratories, and cryobanks. In 2017, MES introduced a new product called YO Sperm Test for the consumer market. While there is a production planning system in place for the SQA, a separate production planning software design is needed for YO since the product market differs greatly from the SQA. MES did not have a production planning software in place yet for YO since it was such a new product and was unable to use the SQA's production planning software.

The goal of my project was to design an in-house production planning software for YO that calculates the daily:

- Production Order
- Shipping Quantity
- Shipping Schedule

The three main objectives for this project were:

1. To understand the relationships between production planning inputs and outputs for the software

2. To identify an algorithm which relates production planning inputs with outputs for YO

3. To create a working example linking the algorithm with data

For the first objective, I worked to understand the needs and requirements of the software. An important part of designing a useful software is to understand the needs of the stakeholders. I spoke extensively with the users and stakeholders of the software to learn their different needs. The main users and stakeholders of the software are the Director of Engineering and Operations and the Plant Engineer. It was important for the software to be simple and flexible. I identified the following inputs for the software: sales history, shipping time, sales promotions, production rate, and the stock levels both at MES'

warehouses in Israel and internationally. The outputs of the software are the daily production order, shipping amounts, and shipping schedule.

For the second objective, I first researched and learned more about different production planning methods. After referencing internal MES production planning files for the SQA and textbooks, I was able to identify the algorithms for the software needed to relate the production planning inputs with the outputs. These equations were then applied to create a working model of the software.

For the third objective, I designed a working model of the software. I created the model using Microsoft Excel as it is a calculation and data handling software. Microsoft Excel is also a software that is already used extensively throughout MES. The software needed to be simple and flexible so using a software that was familiar with the end users was important. I also used the embedded Visual Basic for Applications in Excel to create macros to automate calculations. When I designed the layout of the software in Excel, I ensured that the software was modular and allowed for additional products and sales data to be added. The software is designed to run the calculations for one warehouse location at a time, but can accommodate any number of products and any amount of sales data. The same software is run individually for each warehouse location. By running the calculations by warehouse location rather than product type, the software is easier to use since most inputs are shared between products at the same warehouse locations. I was able to create a working model using sales data from MES' internal database called YO Manage from September 1, 2017 through January 31, 2018 for the United States.

Going forward, improvements can be made to the YO production planning software. The accuracy of the forecasting method can be improved as time goes on since the predicted sales value of the software can be compared with the actual sales value. Another improvement that can be made to the software is the incorporation of automatic data retrieval from the YO Manage database instead of the current method where data needs to be copied and entered manually. Currently, the component purchasing system is held in the company's existing ERP system. A future goal would be to connect the production planning software with the component purchasing system. The ultimate goal of this project was to create a prototype for this standalone software. This standalone software can incorporate both the automatic data retrieval and component purchasing system. The software can also include a graphic user interface and convey information through the incorporation of visuals. Eventually, both the production planning software and component purchasing system could be incorporated into the YO Manage to combine these separate programs into one.

Acknowledgments

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1. Introduction

Production planning is a critical aspect of efficient manufacturing. Production planning ensures that a company is able to fulfill its orders and allows the company to correctly plan for future sales. Too much inventory or not enough inventory can be costly for a company and can negatively impact profits and future sales. My MQP focused on designing a production planning software for Medical Electronic Systems, Ltd. (MES) for their product, YO Sperm Test (YO).

MES is a medical device company located in Caesarea, Israel that makes automated semen analyzers. Since 1993, the company has been making devices called Sperm Quality Analyzers (SQA) for commercial applications in hospitals, reproductive centers, laboratories, and cryobanks. In 2017, MES came out with a new product called YO Sperm Test for the consumer market. MES designs and assembles YO Sperm Test at their office in Caesarea, Israel and then ships the finished product to five warehouse distributors around the world: three in the United States, one in the United Kingdom, and one in India. YO is currently sold through its own website (www.yospermtest.com), Amazon, and eBay. While there is a production planning system in place for the SQA, a separate production planning software design is needed for YO since the product market differs greatly from the SQA. MES did not have a production planning software in place yet for YO since it was such a new product and was unable to use the SQA's production planning software.

The goal of my project was to design an in-house production planning software for YO that calculates the daily:

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2. Background

The following chapter will provide background for the report with an introduction to the medical device industry in Israel, Medical Electronic Systems, YO Sperm Test, and a review of production planning.

2.1. Medical Device Industry in Israel

Despite being a small country, which has only been independent for 70 years and has a population of only 8.6 million people, Israel's strong sense of entrepreneurship and technological advances have earned it the nickname, "Start Up Nation" (Central Bureau of Statistics, 2018). Israel has the most startups per capita and the most scientists, technicians, and engineers per capita, leading to an innovative medical device industry in Israel (Beyar, R., Prof, Zeevi, B., MD, & Rechavi, G., MD., 2017). There is also a strong entrepreneurial culture in Israel which helps to drive innovation and leads to new startups. Israel is also one of leading countries in Research and Development (R&D) spending per capita. In 2013, 4.40% of gross domestic product was spent on R&D (Sackman, J. E., & Kuchenreuther, M., 2013). Of all of the life science companies in Israel, 52.5% are medical device companies, which in 2015 was 725 companies (Beyar, R., Prof, Zeevi, B., MD, & Rechavi, G., MD., 2017).

2.2. Introduction to Medical Electronic Systems, Ltd.

Medical Electronic Systems, Ltd. (MES) is a medical device company based in Caesarea, Israel. Caesarea is located on the Mediterranean Sea about halfway between two major Israeli cities, Tel Aviv and Haifa (see Figure 1 below).

Figure 1: Map of Israel with Pin on Caesarea (Google Maps, 2018)

Since 1993, MES has been making automatic semen analyzers for both human and veterinary applications. These devices, called Sperm Quality Analyzers (SQA), are laboratory devices that are located in hospitals, reproductive centers, labs, and cryobanks. According to MES, there are more than 4,000 SQA devices located in over 50 countries across the world. Over the years, multiple versions of SQAs have been developed with the newest version being the SQA-Vision, shown in Figure 2 below ("Automated Sperm Quality Analyzers", 2017).

The SQA tests semen for a variety of characteristics that are important for determining a male's fertility. These characteristics include sperm concentration, sperm motility, and sperm morphology (Medical Electronic Systems, 2015). A specially trained laboratory technician can test for these characteristics manually using a microscope, but the tests can take an hour to complete and the results are subject to interpretation. The SQA provides results that are more objective and produced in just 75 seconds (Lammers, Splingart, Barrière, Jean, & Fréour, 2014).

Figure 2: SQA-Vision (Medical Electronic Systems, Ltd., 2017)

2.3. Introduction to YO Sperm Test

At the beginning of 2017, MES released a new product called YO Sperm Test (YO), which is an over-the-counter sperm test kit for use at home and is approved by both the United States Food and Drug Administration (FDA) and Conformité Européenne (CE) ("About YO", 2017). Each kit contains a clip that attaches to the customer's smartphone as shown below in Figure 3 which acts as a microscope and magnifies the sperm to a cellular level, enabling the sperm to be viewable using the phone's camera.

Figure 3: Samsung Galaxy S7 Edge with YO Sperm Test Clip (Medical Electronic Systems, 2018)

Through the use of the YO Sperm Test smartphone application (see Figure 4below), customers are able to test their samples for motile sperm concentration which is the amount of moving sperm cells in one milliliter of the sample. Results are available in less than three minutes and are stored in the application for future viewing. A recording of the sperm's movement during the test is also saved ("Frequently Asked Questions", 2017). Each kit comes with supplies for two tests so consumers can confirm and compare their results over time. ("How It Works", 2017). While YO is currently phone specific, there are plans to have YO operate as a standalone device in the future. As of February 2018, YO is available for thirteen different Apple, Samsung, and LG smartphones. A two-pack and a four-pack refill kit with supplies to run additional tests are also available.
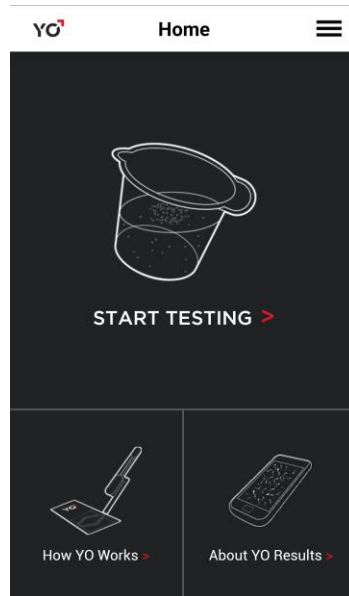
Figure 4: Screenshot of the YO Sperm Test Smartphone Application

2.4. Review of Production Planning

Proper production planning is crucial for a company to lower production costs and to meet demand. Production planning is part of a company's overall manufacturing planning and control system. Aspects of a manufacturing planning and control system include a strategic business plan, production plan, master production schedule, material requirements plan (MRP), and production activity control and purchasing (Arnold, Chapman, & Clive, 2012). A strategic business plan is created by executives in a company to plan for two to ten years into the future. The strategic business plan creates goals and objectives for multiple aspects in a company like marketing plans, financial plans, engineering plans, and production plans (Arnold, Chapman, & Clive, 2012). The production planning aspect which includes the amount of products needed to be produced to meet forecasted demand is the focus of this project. The master production schedule incorporates production planning but adds additional details such as incorporating purchasing lead times. The MRP is a high-detail plan that uses the master production schedule to plan the production schedule and purchasing schedule of the components that make a product (Arnold, Chapman, & Clive, 2012). Purchasing and production activity control executes the master production schedule and MRP. It establishes and maintains control of production to ensure production demand is met.

Forecasting for future production is a critical aspect of production planning. There are three main forecasting time period: short-range, medium-range, and long-range (Heizer, Render, & Munson, 2017). Short-range forecasting is forecasts that are up to a year in length but are usually less than three months. Medium-range forecasts can range from three months to three years. Long-range forecasts are three years or longer (Heizer, Render, & Munson, 2017). The YO production planning software will focus on short-range forecasts to forecast the future product demand for the near future. Another concept within production planning is called dependent demand. Dependent demand is the concept that demand for part components do not need to be forecasted for. The demand for the product components can be based off of the finished product demand (Russell & Taylor, 2011). For this reason, YO production planning software will not incorporate component forecasting. Additionally, MES has a component purchasing system already in place within their existing enterprise resource planning (ERP) software. While there are many production planning softwares currently available on the market, the creation of a custom internal software allows for greater customization and flexibility for the specific needs of a company.

3. Methodology

The following chapter reviews the methodology used to achieve the project's goal and each of the objectives stated in Section 1.

3.1. Objective 1

To understand the relationships between inputs and outputs for the production planning software

For this objective, I worked to understand the needs and requirements of the software. An important part of designing a useful software is to understand the needs of the stakeholders. I first looked extensively at the production planning software and documentation for the SQA. While the SQA is a commercial product and YO Sperm Test is a consumer product, I wanted to study the system that was currently in place. I spoke extensively with the users and stakeholders of the software to learn their different needs. The main users and stakeholders of the software are the Director of Engineering and Operations and the Plant Engineer. I wanted to understand the entire YO production process, starting with the product design through when the kit arrives to the customer. I was able to gain a thorough knowledge of all aspects of the product. Through this understanding, I began to identify different inputs that were important to the system such as shipping time and current inventory stock levels. I also learned about the various factors that can affect the sales of YO and also how those factors are different from the SQA. I also had to learn more about special factors that need to be considered in production planning because of the company's location in Israel. Also through these conversations with the stakeholders, I was able to gain an understanding of the different outputs that they wanted from the software. Once I had this understanding of the different inputs and outputs for the software, I created an input-process-output diagram that showed the relationship between the inputs and outputs. I also conducted analysis on the inputs to narrow down the number of inputs. Figure 5, located in Section 4.1., shows the input-process-output diagram which aided in the development of the software.

3.2. Objective 2

To identify an algorithm which relates production planning inputs with outputs for YO

For this objective, I first researched and learned more about different production planning methods. I wanted to increase my knowledge and understanding of production planning in order to create the algorithm needs to connect the inputs and outputs.

I referenced internal MES production planning files for the SQA to get a better understanding of the system that is currently in place. I also used a variety of textbooks to begin to identify the algorithms for the software. I referenced textbooks such as *Introduction to Materials Management* (7th ed.) by Arnold, J. R. T., Chapman, S. N., & Clive, L. M. (2012), *Operations Management* (12th ed.) by Heizer, J. H., Render, B., & Munson, C. (2017), and *Operations Management* (7th ed.) by Russell, R. S., & Taylor, B. W. (2011).

I discovered multiple methods and equations to calculate the values needed for the YO production planning software. I analyzed each equation and then chose the best ones for this software. For example, there are multiple equations that can be used to calculate safety stock with variance in the way demand and lead time are used. The equation differs depending whether demand and lead time are constant or vary. Since YO is such a new product, demand has not been constant but has been increasing. Additionally, there is variation with lead times when shipping internationally from Israel. The results of this objective are discussed in Section 4.2.

3.3. Objective 3

To create a working example linking the algorithm with data

The culmination of this project was to design a working model of the software. I created the model using Microsoft Excel as it is a calculation and data handling software. Microsoft Excel is also a software that is already used extensively throughout MES. The software needed to be simple and flexible so using a software that was familiar with the production planning software users was important. I also utilized the embedded Visual Basic for Applications in Excel to create macros to increase the simplicity of the software. When I designed the layout of the software in Excel, I ensured that the software was modular and allowed for additional products and sales data to be added. The software is designed to run the calculations for one warehouse location at a time, but can accommodate any number of products and any amount of sales data. The same software is run individually for each warehouse location. By running the calculations by warehouse location rather than product type, the software is easier to use since most inputs are shared between products at the same warehouse locations.

After completing the software design, I wanted to test out the software. I obtained sales data and inventory from September 1, 2017 through January 31, 2018 for ten different YO kits from YO Manage. YO Manage is an internal database at MES that contains sales data and inventory data for YO for all products and warehouse locations.

4. Results

The following chapter discusses the results of the project through following the methodology in Chapter 3.

4.1. Objective 1 Results

For my first objective, I identified the various inputs and outputs that the software needed to include. The first input I identified was sales history which uses data and trends from past sales data. I made the software flexible so it can accommodate any amount of dates needed. Another input I identified was the production rate and failure rate. This is defined as the rate at which clips can be produced taking into consideration failures. I also included shipping time as an input which was the number of the days that it took for a shipment from Israel to arrive and be unpacked and ready to fulfill orders at a warehouse. Another input is the current stock level of kits at warehouses outside of Israel. These are the kits that are available to be sent to customers once ordered. One of the main goals for this software is to ensure there is always enough stock at the warehouses to fulfill orders. I also considered the current stock level of kits in Israel as another input. These are the kits that are available to be sent to the warehouses outside of Israel. Sale promotions is another input for the software. For example, marketing might run a sales promotion which would increase the number of kits sold.

When I was originally was identifying the different inputs for the software, I was going to include holidays as an input. Through analysis of the inputs, I found that there was not enough sales data to be able to use holidays as an input. This input was going to take into consideration holidays in each country and forecast how each holiday would potentially affect sales. For example, Black Friday or Valentine's Day could be holidays potentially affecting sales in the United States and need to be taken into consideration for United States warehouses. There is currently only one year of sales data for YO so for any changes in sales around the time of holidays, it is not known if the increase is due to the holiday since there is no baseline of sales to compare it to. Multiple years of sales data are needed to detect a trend in sales during holidays.

I identified two different outputs for the software. The first output was the production order which is the amount of each type of kit that should be produced each day to meet consumer demand. The second output was the shipping quantity and shipping schedule. It is important that YO inventory is stocked at each distribution location and that there is never a shortage of inventory. Due to the instability of the political climate in the Middle East, there can be external factors that affect the shipping time so it is important to have enough safety stock inventory on hand at each warehouse. For example, there is only one international airport in Israel that flies directly to the United States, Ben-Gurion International Airport

near Tel Aviv, and it is not possible to take the inventory and ship it to neighboring countries to send from there, so if there is ever a closure of the airport ensuring there is always ample safety stock is crucial. Additionally, other events such as a labor strike at the airport could affect the company's ability to send inventory out of Israel.

After I identified the inputs and outputs, I created an input-process-output diagram as shown in Figure 3. All of the inputs and outputs discussed above are included in this diagram, including holidays which is crossed off. Also, included is a purchasing schedule output, which was not included in my software because the information can be taken from MES' enterprise resource planning (ERP) software which is already in place.

Input-Process-Output Diagram for the YO Production Planning Software

Inputs

Sales History
- Data and trends from past sales

Shipping Time
- Number of days that it takes for a shipment from Israel to arrive at each warehouse

Sales Promotions
- The effect of sales promotions and marketing campaigns on the amount sales of each kit from each warehouse location

Holidays
- ~~The effect of different holidays in each country on the sales of kits~~

Production Rate and Failure Rate
- The rate at which clips can be produced taking into consideration failures from quality issues

Current Stock Level of Kits at Warehouses
- Current level of inventory for each kit at each warehouse while ensuring minimum safety stock requirements are met

Current Stock Level of Kits in Israel
- Current level of inventory for each kit in Israel while ensuring minimum safety stock requirements are met

Process

Processing Software
- Processes inputs according to inventory control equations to calculate the outputs

Outputs

Purchasing Schedule
- Created using existing program

Production Order
- The amount of each kit type to produce each day

Shipping Amounts and Shipping Schedule
- The amount of kits to ship to each warehouse
- When to ship the kits to ensure that all warehouses are adequately stocked

Figure 5: Input-Process-Output Diagram

4.2. Objective 2 Results

The following equations were used to calculate the production order, shipping quantity, and shipping schedule. The equations are applied in the Microsoft Excel software as seen in Figure 9 in Section 4.3.

Equation 1:

$$Avg. Shipping\ Time = \frac{1}{X}\sum_{n=1}^{X} Shipping\ Date(n) - Warehouse\ Arrival\ Date\ (n) + SD + Buffer$$

$$where\ X = number\ of\ past\ shipments,$$
$$SD = standard\ deviation\ of\ shipping\ times$$

To calculate the average shipping time from MES in Israel to an international warehouse location, I used Equation 1 above. Shipping date refers to when the shipment left MES in Israel and warehouse arrival date refers to when the shipment is unpacked at the warehouse and ready to fulfill orders. The software is able to accommodate up to 10 past shipment data. This allows for a variety of past shipment data to be used. Shipping times from Israel to the warehouse can vary so it is important to take into consideration multiple shipping data times. The software takes the average of the number of days the shipment took to arrive and then adds the standard deviation of the shipping time. Since the shipping time can vary, the standard deviation is added to try to account for that variance. There is also an option to manually input additional days to the shipment to act as an additional buffer. The average shipping time value is used for all kits going to the same warehouse location.

Equation 2:

$$Avg. Total\ Lead\ Time\ (ALT) = Avg. Shipping\ Time + Production\ Time$$

To calculate the average total lead time, the average shipping time is added to the production time. The production time value can be obtained from the Plant Engineer and should be in the unit of days. The total lead time value is used for all kits going to the same warehouse location.

Equation 3:

$$Average\ Daily\ Sales\ (ADS) = \frac{Total\ Number\ of\ Kits\ Sold\ in\ X\ days}{X\ days} + SD$$

$$where\ SD = standard\ deviation\ of\ daily\ kits\ sold$$

To calculate the average daily sales, the total number of kits sold in a given period of time is divided by the number of days in that period of time. To help account for variation in sales since YO is such a new product, the standard deviation of sales is also added. The average daily sales value is calculated individually for each kit type.

Equation 4:

$$Forecasted\ Sales\ Increase = \frac{FP\ \times (FP - 1) \times Mx}{2}$$

$$where\ FP = forecasting\ period\ (in\ days),$$

$$Mx = slope\ of\ daily\ sales$$

To calculate the forecasted sales increase, I used Equation 4 above, which is based off of an arithmetic progression. This equation was already being used internally at MES for YO, so I applied it to my production planning software.

Equation 5:

$$Expected\ Addtional\ Sales\ (EAS) = FSI\ +\ MP$$

$$where\ FSI = forecasted\ sales\ increase\ (see\ Equation\ 4),$$

$$MP = marketing\ prediction\ of\ additional\ sales$$

To calculate the total expected additional sales, a formula that adds the forecasted sales increase with the marketing prediction of additional sales is used. The marketing prediction of additional sales refers to a value that can be obtained from marketing that accounts for additional sales due to marketing promotions.

Equation 6:

$$Safety\ Stock\ (SS) = Z \times \sqrt{(ALT \times SDD^2) + (ADS^2 \times SDLT^2)} + EAS$$

$$where\ Z = z - value,$$

$$where\ ALT = avg.\ total\ lead\ time\ (see\ Equation\ 2),$$

$$SDD = standard\ deviation\ of\ daily\ sales,$$

$$ADS = avg.\ daily\ sales (see\ Equation\ 3),$$

$$SDLT = standard\ deviation\ of\ lead\ time,$$

$$EAS = expected\ additonal\ sales\ (see\ Equation\ 5)$$

To calculate safety stock, a formula that takes into account a varied demand and lead time was used. Since YO is a new product, sales have been rapidly increasing which means demand is varied. Additionally, there is significant variability in lead time shipping from Israel to warehouse locations. It was important to use a safety stock formula that took into account both the variation in demand and lead time.

Equation 7:

$$Warehouse\ Inventory\ Requirement\ (WIR) = ADS \times FP + SS$$

$$where\ ADS = average\ daily\ sales\ (see\ Equation\ 3),$$

$$FP = forecasting\ period\ (in\ days),$$

$$SS = safety\ stock\ (see\ Equation\ 6)$$

The warehouse inventory requirement is the amount of inventory that is predicted to be needed to fulfill orders during the forecasting period. Equation 7 multiplies the average daily sales by the forecasting period and then adds the safety stock value to account for possible variation in sales and lead time.

Equation 8:

$$Additional\ Needed\ Inventory = WIR - WI - IT$$
$$where\ WIR = warehouse\ inventory\ requirement\ (see\ Equation\ 7),$$
$$WI = warehouse\ inventory,$$
$$IT = in-transit\ kits$$

The additional needed inventory is the amount of inventory that needs to be sent to the international warehouse from the Israel warehouse in order to meet demand during the forecasting period. The values for warehouse inventory and in-transit kits are entered into the software on the "Input" sheet.

Equation 9:

$$Remaining\ Inventory = WI - WIR$$
$$where\ WI = warehouse\ inventory,$$
$$WIR = warehouse\ inventory\ requirement\ (see\ Equation\ 7),$$

The remaining inventory is the amount of kits that are predicted to be remaining at the end of the forecasting period. Equation 9 subtracts the warehouse inventory requirement which is the amount of kits that are predicted to be sold during the forecasting period from the warehouse inventory at the beginning of the forecasting period.

Equation 10:

$$Reorder\ Point\ (ROP) = ALT \times ADS + SS$$
$$where\ ALT = avg.\ total\ lead\ time\ (see\ Equation\ 2),$$
$$ADS = average\ daily\ sales\ (see\ Equation\ 3),$$
$$SS = safety\ stock\ (see\ Equation\ 6)$$

The reorder point is the point at which the international warehouse inventory level reaches a level that alerts the Plant Manager that more kits need to be sent to that warehouse from the Israel warehouse. The reorder point ensures that these additional kits will arrive before the warehouse runs out of kits.

Equation 11:

$$Days\ until\ Reorder\ Point = \frac{WIR - ROP}{ADS}$$

$$where\ WIR = warehouse\ inventory\ requirement\ (see\ Equation\ 7),$$

$$ROP = reorder\ point\ (see\ Equation\ 10),$$

$$ADS = average\ daily\ sales\ (see\ Equation\ 3)$$

The days until reorder point refers to how many days after the forecasting period starts that more kits will need to be sent to the international warehouse from Israel. This allows MES to plan out its future production and to be prepared with the shipments as the reorder point arrives.

4.3. Objective 3 Results

   After the software design discussed in Section 3.3. and Section 4.2., I created a test model of the software. For my prototype model, I used sales data from September 1, 2017 through January 31, 2018 for the United States because it was the most complete and recent data and therefore would be the most useful. I pulled the data from a MES' internal database called YO Manage as a CSV file and then was able to import that data into my software. I ended up creating the shipment dates and warehouse arrival dates. I made sure to keep the total shipping time for each shipment within the range of shipment times mentioned during my conversations with the stakeholders. The software must be run separately for each warehouse but is able to calculate the outputs for each individual device per warehouse in one run.

   Within the "Inputs" sheet (see Figure 6), the forecasting period is first entered in the software in the unit of days. For the prototype model, I set the forecasting period to 60 days. Next, the shipment dates and warehouse arrival dates as well as any additional shipment buffer are inputted. The next input of the software is the production time. This value is entered in the unit of days and can be obtained from the Plant Engineer. For my prototype, I used a production time of 5 days. The next input of the software is the service level which is entered as a percentage. I used a service level of 95%, which means that 95% of the time, there will not be a stock out. Next, data for each individual device needed to be inputted into the software. The software needs the amount of kits in warehouse inventory, amount of kits in Israel warehouse inventory, amount of kits that are in-transit to the warehouse, and the amount of additional expected sales for each kit which should be obtained from marketing.

   Next on the "Sales Data" sheet (see Figure 7), the daily sales data for each kit type needs to be inputted. The software can take any amount of days that MES wants to use for its forecasting. I created a macro and incorporated it into the software which is able to automatically detect the amount of days that were inputted and no adjustments needs to be made on the users' part to account for the amount of change in the data. For my prototype, I entered in sales data from September 1, 2017 through January 31, 2018 in the United States for ten products: Apple iPhone 5, iPhone 6, iPhone 6+, iPhone 7, iPhone 7+, Samsung Galaxy S6, Galaxy S7, Galaxy S7 Edge, YO 2 tests refill kit, and YO 4 tests refill kit. The software then creates a summary of the sales' data by phone type and month into a table and also creates a bar graph of the same data both located in the "Sales Data Summary" sheet (see Figure 8).

   Next on the "Output" sheet (see Figure 10), the software restates current Israel warehouse inventory level, current warehouse inventory level, and in-transit kits. The software also indicates the required inventory needed at the warehouse for the forecasting period and remaining inventory at the warehouse after the forecasting period concludes. The software will give an alert if it will be out of stock

at the end of the forecasting period. The software also indicates the reorder point (ROP) and days until the reorder point is reached. If the ROP will be reached during the forecasting period, the software will give an alert.

Additionally, on each sheet there are navigation buttons that guide the user through the software to increase the simplicity of using the software. For a more detailed guide on the software, see the YO Production Planning Software User Manual in Appendix A.

FILE | HOME | INSERT | PAGE LAYOUT | FORMULAS | DATA | REVIEW | VIEW | DEVELOPER

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A1

How many days forward do you want to forecast?

60 days

Input additional shipping time buffer

0 days

Input data

	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
Warehouse inventory (kits)	1226	1588	55	924	61	1444	873	40	311	31
Israel warehouse inventory (kits)	489	2810	74	2220	90	2238	2422	95	268	90
In-transit inventory (kits)	0	0	0	0	0	0	0	0	0	0
Additional expected sales from marketing	5	10	2	7	6	9	10	7	6	3

Input the past 10 shipping dates and warehouse arrival dates

	Shipping Date	Warehouse Arrival Date
1	5/2/2017	5/23/2017
2	5/25/2017	6/6/2017
3	6/9/2017	6/26/2017
4	7/1/2017	7/20/2017
5	7/11/2017	8/2/2017
6	7/20/2017	8/13/2017
7	7/30/2017	8/17/2017
8	8/5/2017	8/18/2017
9	8/12/2017	8/27/2017
10	8/13/2017	8/30/2017

Input production time

5 days

Input service level (as percentage)

95%

Continue to Sales Data

About | Input | Sales Data | Sales Data Summary | Calculations | Output

READY

77%

Figure 6: YO Production Planning Software "Input" Sheet

	A	B	C	D	E	F	G	H	I	J	K
1	Date	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
2	9/1/2017	0	1	0	0	0	0	0	0	0	0
3	9/2/2017	0	0	0	0	0	0	0	0	0	0
4	9/3/2017	0	0	0	0	0	0	0	0	0	0
5	9/4/2017	0	0	0	0	0	0	0	0	0	0
6	9/5/2017	0	0	0	0	0	0	0	0	0	0
7	9/6/2017	0	1	0	0	0	0	0	0	0	0
8	9/7/2017	0	0	0	0	0	0	0	0	0	0
9	9/8/2017	0	0	0	1	0	0	0	0	0	0
10	9/9/2017	0	0	0	0	0	0	0	0	0	0
11	9/10/2017	0	0	0	0	0	0	0	0	0	0
12	9/11/2017	0	1	0	0	0	0	0	0	0	0
13	9/12/2017	0	0	0	0	0	0	0	0	0	0
14	9/13/2017	0	0	0	0	0	0	0	0	0	0
15	9/14/2017	0	1	0	0	0	0	0	0	0	0
16	9/15/2017	0	1	0	0	0	0	0	0	1	0
17	9/16/2017	0	1	0	0	0	0	0	0	0	0
18	9/17/2017	0	0	0	0	0	0	0	0	0	0
19	9/18/2017	1	0	0	0	0	0	0	0	0	0
20	9/19/2017	0	1	0	0	0	0	0	0	0	0
21	9/20/2017	0	0	0	2	0	0	0	0	0	0
22	9/21/2017	0	0	0	1	0	0	0	0	0	0
23	9/22/2017	0	1	0	0	0	0	0	0	0	0
24	9/23/2017	0	0	0	0	0	0	0	0	0	0
25	9/24/2017	0	0	0	1	0	0	0	0	0	0
26	9/25/2017	0	0	0	1	0	0	0	0	0	0
27	9/26/2017	0	1	0	0	0	0	0	0	0	0
28	9/27/2017	0	1	0	0	0	0	0	0	0	0
29	9/28/2017	0	0	0	0	0	0	0	0	0	0
30	9/29/2017	0	2	0	0	0	1	0	0	0	0
31	9/30/2017	0	0	0	0	0	0	0	0	0	0
32	10/1/2017	0	0	0	1	0	0	0	0	0	0

Continue to Sales Data Summary

Return to Inputs

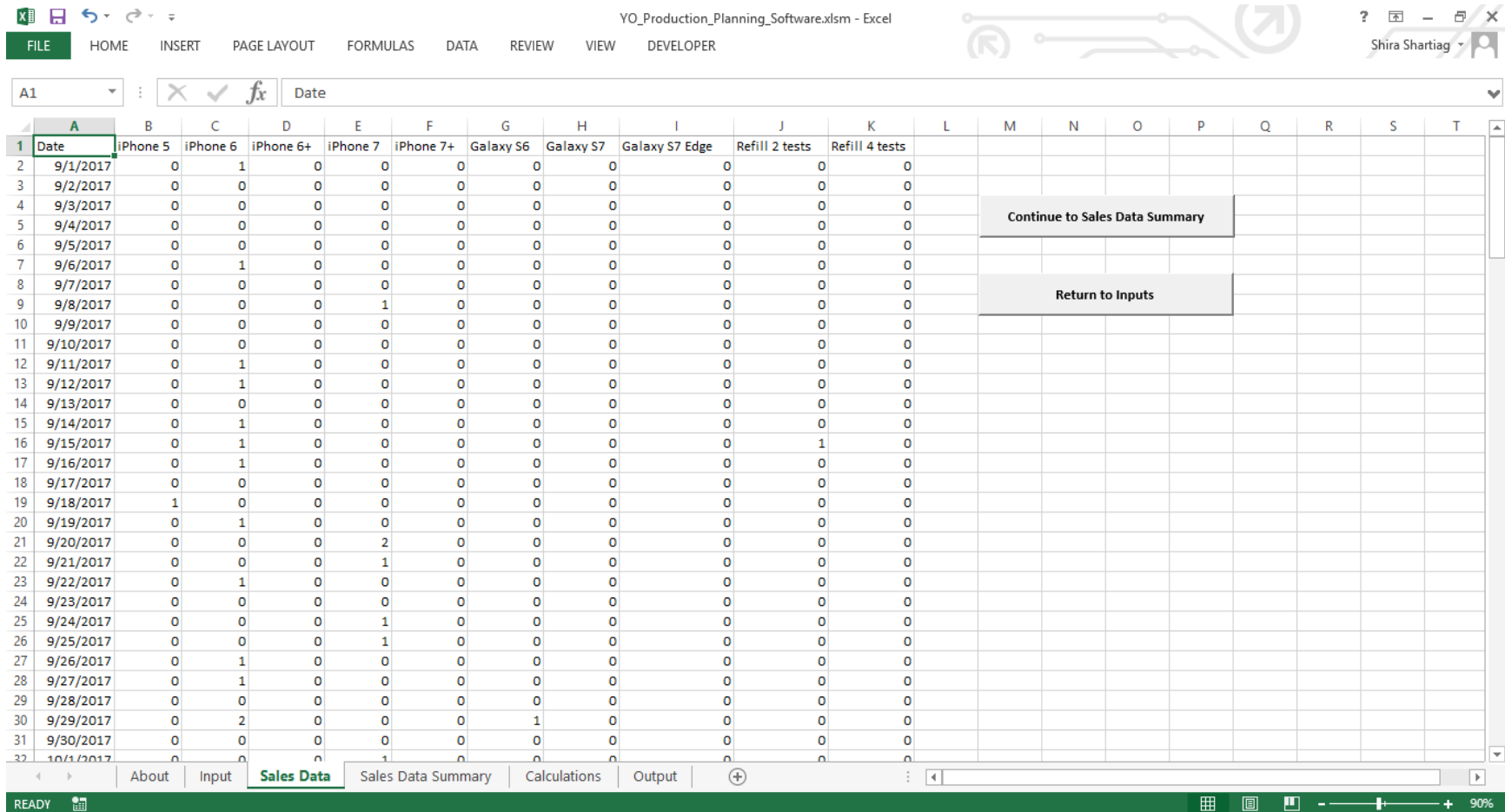Sheets: About | Input | **Sales Data** | Sales Data Summary | Calculations | Output

Figure 7: YO Production Planning Software "Sales Data" Sheet

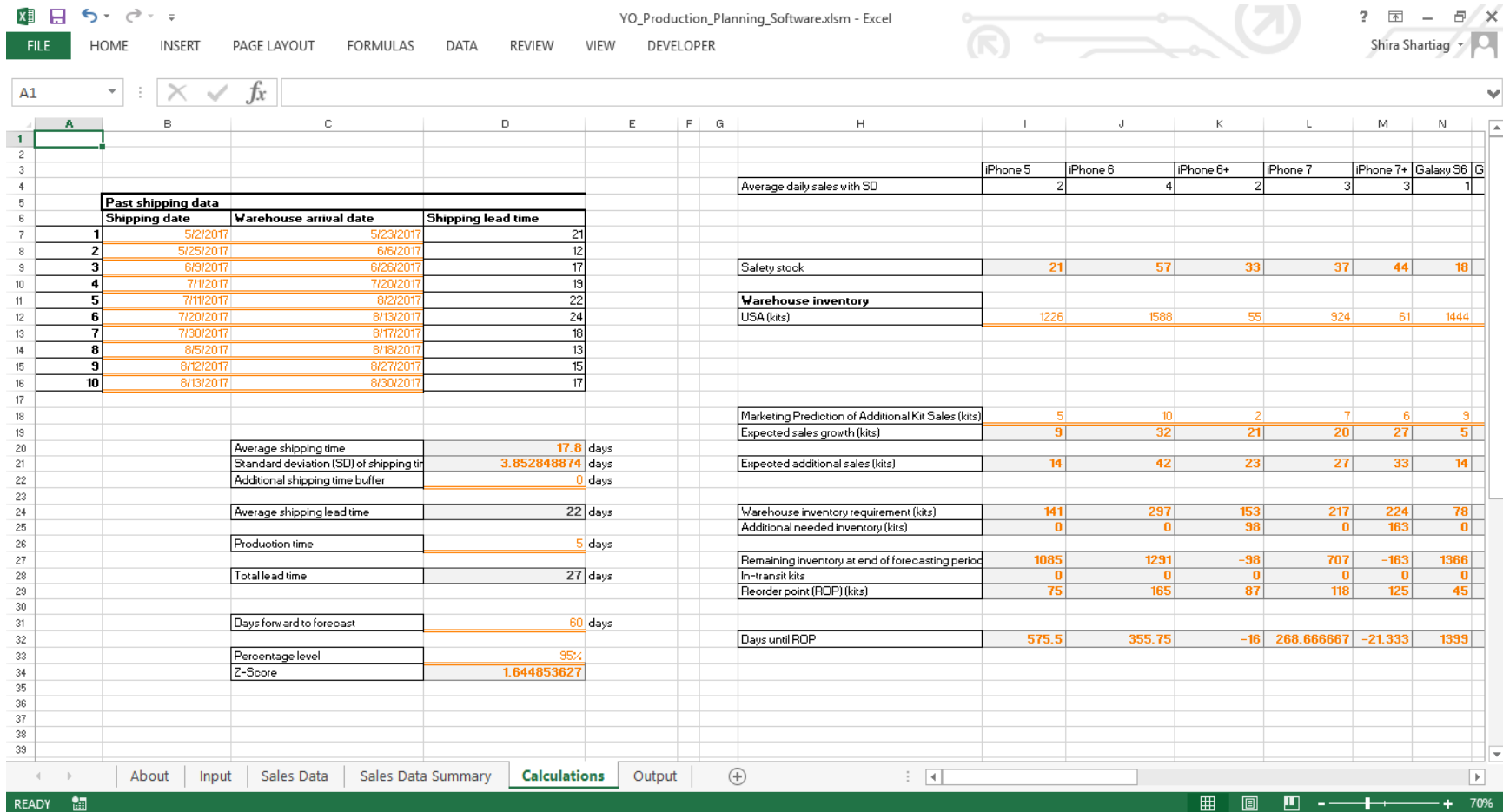*Figure 8: YO Production Planning Software "Sales Data Summary" Sheet*

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER

	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6
Average daily sales with SD	2	4	2	3	3	1

Past shipping data

	Shipping date	Warehouse arrival date	Shipping lead time
1	5/2/2017	5/23/2017	21
2	5/25/2017	6/6/2017	12
3	6/9/2017	6/26/2017	17
4	7/1/2017	7/20/2017	19
5	7/11/2017	8/2/2017	22
6	7/20/2017	8/13/2017	24
7	7/30/2017	8/17/2017	18
8	8/5/2017	8/18/2017	13
9	8/12/2017	8/27/2017	15
10	8/13/2017	8/30/2017	17

Safety stock	21	57	33	37	44	18

Warehouse inventory

USA (kits)	1226	1588	55	924	61	1444

Average shipping time	17.8	days
Standard deviation (SD) of shipping tir	3.852848874	days
Additional shipping time buffer	0	days

Marketing Prediction of Additional Kit Sales (kits)	5	10	2	7	6	9
Expected sales growth (kits)	9	32	21	20	27	5

Average shipping lead time	22	days

Expected additional sales (kits)	14	42	23	27	33	14

Production time	5	days

Warehouse inventory requirement (kits)	141	297	153	217	224	78
Additional needed inventory (kits)	0	0	98	0	163	0

Total lead time	27	days

Remaining inventory at end of forecasting period	1085	1291	-98	707	-163	1366
In-transit kits	0	0	0	0	0	0
Reorder point (ROP) (kits)	75	165	87	118	125	45

Days forward to forecast	60	days

Days until ROP	575.5	355.75	-16	268.666667	-21.333	1399

Percentage level	95%
Z-Score	1.644853627

About | Input | Sales Data | Sales Data Summary | **Calculations** | Output

Figure 9: YO Production Planning Software "Calculations" Sheet

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	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
11 Current Israel warehouse inventory level (kits)	489	2810	74	2220	90	2238	2422	95	268	90
12 Current US warehouse inventory level (kits)	1226	1588	55	924	61	1444	873	40	311	31
13 In-transit kits	0	0	0	0	0	0	0	0	0	0
14										
15 Required inventory needed at US warehouse for forecast period (kits)	141	297	153	217	224	78	153	82	75	71
16 Remaining inventory at US warehouse after forecast period (kits)	1085	1291	Out of Stock	707	Out of Stock	1366	720	Out of Stock	236	Out of Stock
17										
18 Reorder point (ROP) (kits)	75	165	87	118	125	45	87	49	42	38
19 Days until ROP is reached	576	356	ROP Reached	269	ROP Reached	1399	393	ROP Reached	269	ROP Reached

Results for a forecast length of 60 days

Return to Sales Data

Return to Inputs

Figure 10: YO Production Planning Software "Output" Sheet

5. Recommended Future Steps

Going forward, the accuracy of the forecasting method needs to be improved. Since YO is such a new product, there is an expectation that sales will continue to greatly increase as YO spends more time on the market. Should there be a significant discrepancy between actual sales and forecasted sales, the software contains an equation that can be modified to improve the accuracy of the forecasted sales (see Equation 4 in Section 4.2.). This equation inside the software is trying to account for these additional sales by using past sales, thus an adjustment can be made to the equation involved in the calculation.

Another improvement that can be made to the software is the incorporation of automatic data retrieval from the YO Manage database. Currently, all the sales and inventory data needs to be entered by manually copying the data located inside of YO Manage. The automatic data retrieval will reduce the time it takes to use the software and make the software easier to use.

Currently, the component purchasing system is held in the company's existing ERP system. A future goal would be to connect the production planning software with the component purchasing system. Therefore, the manufacturing process can be simplified and made more efficient. The ultimate goal of this project was to create a prototype for this standalone software. This standalone software can incorporate both the automatic data retrieval and component purchasing system. The software can also include a graphic user interface and convey information through the incorporation of visuals. Eventually, both the production planning software and component purchasing system could be incorporated into the YO Manage to combine these separate programs into one.

6. Reflection

The MQP is a senior capstone project that is to incorporate design. For my MQP, I designed a production planning tool using Microsoft Excel and as a prototype for an eventual standalone software. When I first arrived in Israel, I received the background on the project from MES and began to better define the problem needing a solution- a production planning software for their new product, YO Sperm Test. Next, I carried out background research on production planning topics such as MRP. I also worked to gain a better understanding of YO through various conversations with stakeholders. I was able to specify the requirements of the production planning software. I also was able to identify the inputs and outputs that the software needed to address. Afterwards, I developed an algorithm and prototype of the software.

An important requirement for my production planning tool, was the need for simplicity and flexibility. It was imperative for MES that the software be easy to use and be able to be adjusted and modified as the product develops and have the software develop with the product. I created the software in Microsoft Excel since the users of the production planning tool already had extensive experience with Excel. Excel is also a good platform to make a flexible software since it is easy to adjust, add, and modify as needed. Other factors that I had to take into consideration were the issues concerning the geopolitical landscape of the Middle East which I discussed above Section 4.1. For example, Just-in-Time (JIT) is a common production method, but it is not possible to use the method when producing in Israel. It is too expensive and there is too great of a possibility of an interruption to the supply chain that could cause a stock out. On the other hand, JIT is very common in the United States.

During the entirety of my project I was working in a professional environment in Israel. Being immersed in a company provides for such a different experience compared to coursework. While everyone I worked with spoke English, outside of my project I had on occasion needed to communicate in Hebrew. I enjoyed the opportunity to practice and improve my Hebrew skills. I have been studying Hebrew since I was five years old and realized that I knew more Hebrew than I had thought. I also enjoyed being able to work in such a different environment than in the United States. For example, in Israel when giving a presentation it is common to be interrupted by a question mid-presentation but in the United States, questions are always asked at the end of a presentation. Israelis are also much more straight-forward than Americans. Overall, Israel's culture and workplace culture is much more informal than in the United States. Also, since Israel is the only Jewish state in the world, there are also Jewish religious customs intertwined into society. For example, the work week in Israel starts on Sunday and ends on

Thursday since Shabbat, the Jewish Sabbath, starts on Friday evening at sundown and lasts until Saturday evening at sundown.

Israel also has so much history that is fascinating to visit. There are many ancient archeological sites all over the country that I had the opportunity to see. In Caesarea, where MES is located, there is an ancient harbor and city that was built in 25 BCE that I was able to visit. I was also able to go visit many museums throughout the country, ranging from history, art, and even ecological. I enjoyed the opportunity to live in a different country and experience its culture. I am very grateful for the opportunity to complete my project in Israel.

7. References

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YO Production Planning Software User Manual


Created by Shira Shartiag

February 2018

*Created as part of a WPI MQP (senior capstone design project)*

NOTE: The YO Production Planning Software is designed to run the calculations for one warehouse location at a time, but can accommodate any number of products and any amount of sales data. The software must be run individually for each warehouse location.
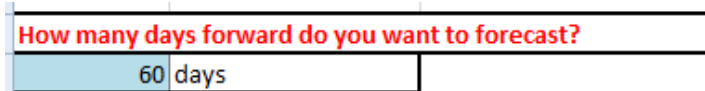
1. Open the file: YO_Production_Planning_Software.xlsm.

2. Enable the macros by clicking "Enable Content".
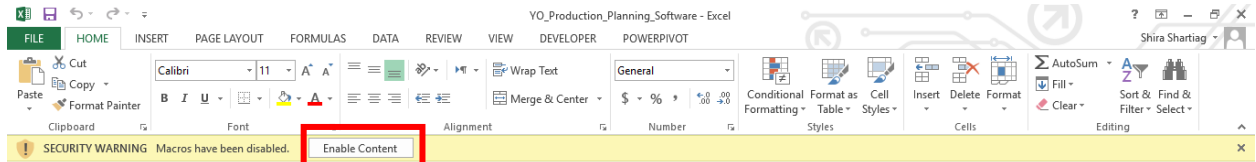
3. Go to the "Input" sheet.
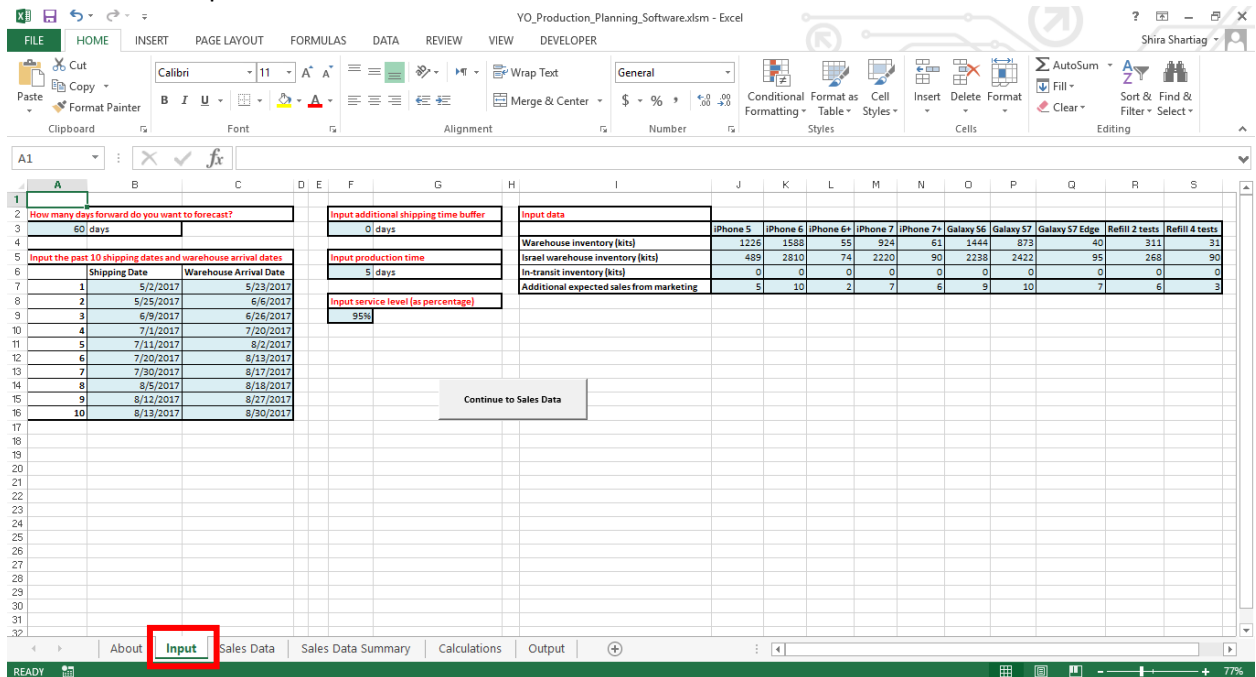
4. Enter the desired forecasting period (in days).

5. Enter up to the past 10 shipping dates and warehouse arrival dates in any order. Shipping dates refer to when the shipment left MES in Israel and warehouse arrival date refers to when the shipment is unpacked at the warehouse and ready to fulfill orders. If less than 10 shipments are used, leave the extra cells blank.

Input the past 10 shipping dates and warehouse arrival dates		
	Shipping Date	Warehouse Arrival Date
1	5/2/2017	5/23/2017
2	5/25/2017	6/6/2017
3	6/9/2017	6/26/2017
4	7/1/2017	7/20/2017
5	7/11/2017	8/2/2017
6	7/20/2017	8/13/2017
7	7/30/2017	8/17/2017
8	8/5/2017	8/18/2017
9	8/12/2017	8/27/2017
10	8/13/2017	8/30/2017

Example with 10 shipment dates

Input the past 10 shipping dates and warehouse arrival dates		
	Shipping Date	Warehouse Arrival Date
1	5/2/2017	5/23/2017
2	5/25/2017	6/6/2017
3	6/9/2017	6/26/2017
4	7/1/2017	7/20/2017
5	7/11/2017	8/2/2017
6	7/20/2017	8/13/2017
7	7/30/2017	8/17/2017
8		
9		
10		

Example with 7 shipment dates

6. Enter the desired additional shipping time buffer in days. This value is added to the calculated shipping time and is added as an additional buffer.

Input additional shipping time buffer
0 days

7. Enter the production time in days.

Input production time
5 days

8. Enter the service level as a percentage. The software uses the service level to calculate the z-value which is needed to calculate the safety stock.

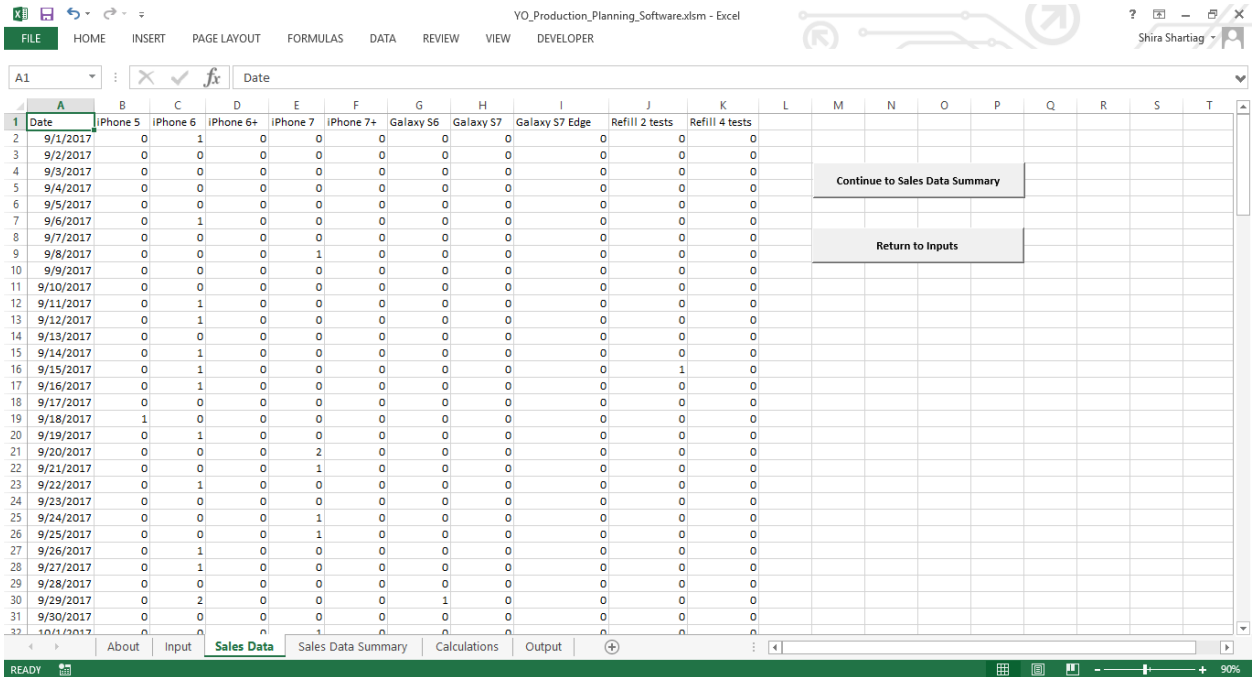| Input service level (as percentage) |
|---|
| 95% |

9. Input the following data for each product

Input data	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
Warehouse inventory (kits)	1226	1588	55	924	61	1444	873	40	311	31
Israel warehouse inventory (kits)	489	2810	74	2220	90	2238	2422	95	268	90
In-transit inventory (kits)	0	0	0	0	0	0	0	0	0	0
Additional expected sales from marketing	5	10	2	7	6	9	10	7	6	3

- "Warehouse inventory (kits)" is the number of kits currently in stock at the warehouse outside of Israel.
- "Israel warehouse inventory (kits)" is the number of finished kits that are ready to be shipped.
- "In-transit inventory (kits)" is the number of kits that have been shipped from MES in Israel but have not yet arrived at the warehouse.
- "Additional expected sales from marketing" is the number of additional kits that marketing expects to be sold during the forecasting period due to a sales promotion.
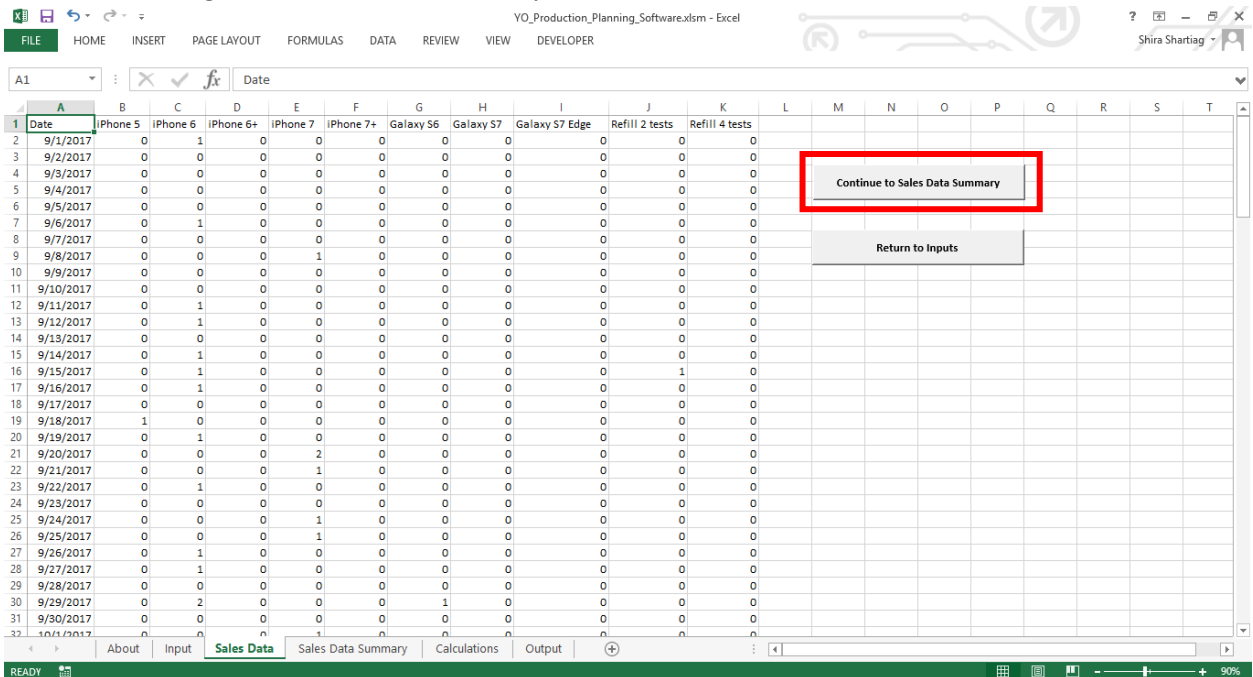
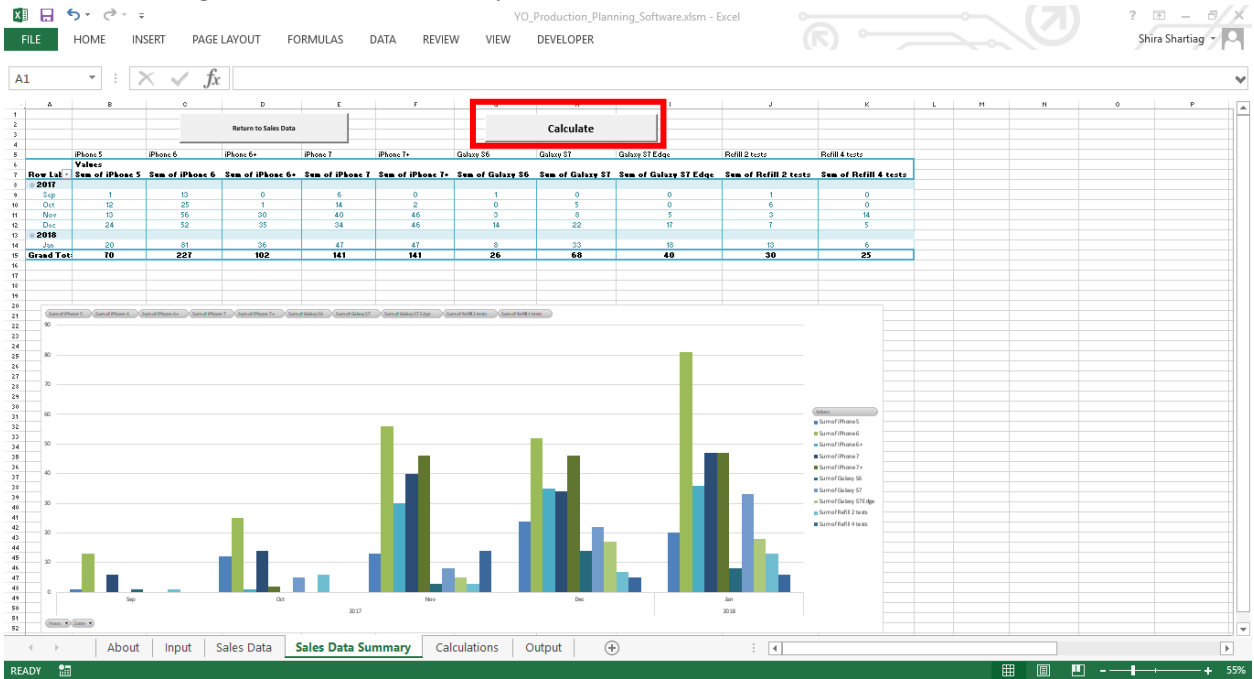10. To continue, click "Continue to Sales Data".
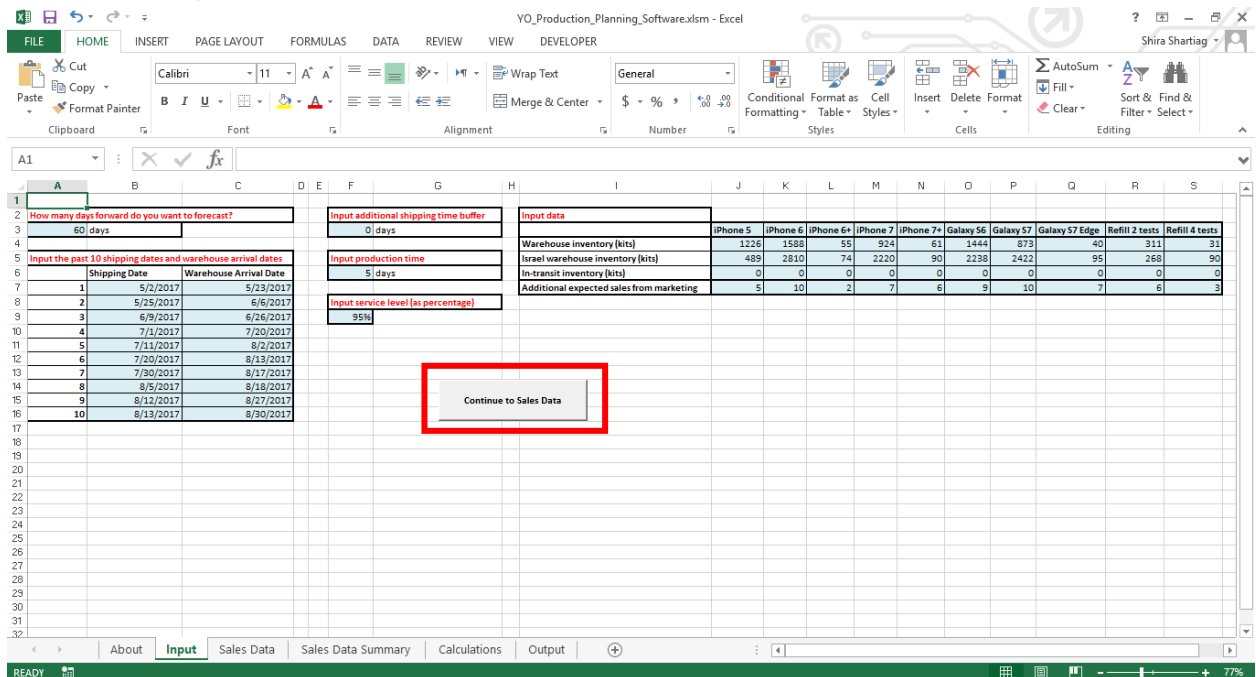
11. Enter past sales data by date for each product type. The software is able to accommodate any amount of days desired.

Date	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
9/1/2017	0	1	0	0	0	0	0	0	0	0
9/2/2017	0	0	0	0	0	0	0	0	0	0
9/3/2017	0	0	0	0	0	0	0	0	0	0
9/4/2017	0	0	0	0	0	0	0	0	0	0
9/5/2017	0	0	0	0	0	0	0	0	0	0
9/6/2017	0	1	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0
9/8/2017	0	0	0	1	0	0	0	0	0	0
9/9/2017	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0
9/11/2017	0	1	0	0	0	0	0	0	0	0
9/12/2017	0	1	0	0	0	0	0	0	0	0
9/13/2017	0	0	0	0	0	0	0	0	0	0
9/14/2017	0	1	0	0	0	0	0	0	0	0
9/15/2017	0	1	0	0	0	0	0	0	1	0
9/16/2017	0	1	0	0	0	0	0	0	0	0
9/17/2017	0	0	0	0	0	0	0	0	0	0
9/18/2017	1	0	0	0	0	0	0	0	0	0
9/19/2017	0	1	0	0	0	0	0	0	0	0
9/20/2017	0	0	0	2	0	0	0	0	0	0
9/21/2017	0	0	0	1	0	0	0	0	0	0
9/22/2017	0	1	0	0	0	0	0	0	0	0
9/23/2017	0	0	0	0	0	0	0	0	0	0
9/24/2017	0	0	0	1	0	0	0	0	0	0
9/25/2017	0	0	0	1	0	0	0	0	0	0
9/26/2017	0	1	0	0	0	0	0	0	0	0
9/27/2017	0	1	0	0	0	0	0	0	0	0
9/28/2017	0	0	0	0	0	0	0	0	0	0
9/29/2017	0	2	0	0	0	1	0	0	0	0
9/30/2017	0	0	0	0	0	0	0	0	0	0

[Excel worksheet tabs: About | Input | Sales Data | Sales Data Summary | Calculations | Output. Buttons: "Continue to Sales Data Summary", "Return to Inputs"]

12. To continue, click "Continue to Sales Data Summary". When this button is clicked, a macro is run in the background that determines the number of days of sales data and number of products entered before continuing to the Sales Data Summary.

Date	iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
9/1/2017	0	1	0	0	0	0	0	0	0	0
9/2/2017	0	0	0	0	0	0	0	0	0	0
9/3/2017	0	0	0	0	0	0	0	0	0	0
9/4/2017	0	0	0	0	0	0	0	0	0	0
9/5/2017	0	0	0	0	0	0	0	0	0	0
9/6/2017	0	1	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0
9/8/2017	0	0	0	1	0	0	0	0	0	0
9/9/2017	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0
9/11/2017	0	1	0	0	0	0	0	0	0	0
9/12/2017	0	1	0	0	0	0	0	0	0	0
9/13/2017	0	0	0	0	0	0	0	0	0	0
9/14/2017	0	1	0	0	0	0	0	0	0	0
9/15/2017	0	1	0	0	0	0	0	0	1	0
9/16/2017	0	1	0	0	0	0	0	0	0	0
9/17/2017	0	0	0	0	0	0	0	0	0	0
9/18/2017	1	0	0	0	0	0	0	0	0	0
9/19/2017	0	1	0	0	0	0	0	0	0	0
9/20/2017	0	0	0	2	0	0	0	0	0	0
9/21/2017	0	0	0	1	0	0	0	0	0	0
9/22/2017	0	1	0	0	0	0	0	0	0	0
9/23/2017	0	0	0	0	0	0	0	0	0	0
9/24/2017	0	0	0	1	0	0	0	0	0	0
9/25/2017	0	0	0	1	0	0	0	0	0	0
9/26/2017	0	1	0	0	0	0	0	0	0	0
9/27/2017	0	1	0	0	0	0	0	0	0	0
9/28/2017	0	0	0	0	0	0	0	0	0	0
9/29/2017	0	2	0	0	0	1	0	0	0	0
9/30/2017	0	0	0	0	0	0	0	0	0	0

[The "Continue to Sales Data Summary" button is highlighted with a red box. Excel worksheet tabs: About | Input | Sales Data | Sales Data Summary | Calculations | Output]

13. After viewing the Sales Data Summary, click "Calculate" to continue.


14. View the software output. If needed, the inputs can be adjusted by clicking on "Return to Sales Data". The software will then go to the "Sales Data" sheet and these instructions should be followed from Step 11. Also if needed, the inputs can be adjusted by clicking on "Return to Inputs". The software will then go to the "Inputs" sheet and these instructions should be followed from Step 4.


|		iPhone 5	iPhone 6	iPhone 6+	iPhone 7	iPhone 7+	Galaxy S6	Galaxy S7	Galaxy S7 Edge	Refill 2 tests	Refill 4 tests
11	Current Israel warehouse inventory level (kits)	489	2810	74	2220	90	2238	2422	95	268	90
12	Current US warehouse inventory level (kits)	1226	1588	55	924	61	1444	873	40	311	31
13	In-transit kits	0	0	0	0	0	0	0	0	0	0
15	Required inventory needed at US warehouse for forecast period (kits)	141	297	153	217	224	78	153	82	75	71
16	Remaining inventory at US warehouse after forecast period (kits)	1085	1291	Out of Stock	707	Out of Stock	1366	720	Out of Stock	236	Out of Stock
18	Reorder point (ROP) (kits)	75	165	87	118	125	45	87	49	42	38
19	Days until ROP is reached	576	356	ROP Reached	269	ROP Reached	1399	393	ROP Reached	269	ROP Reached

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To add additional products, follow these additional steps:

1. On the "Input" sheet, identify the last product column.
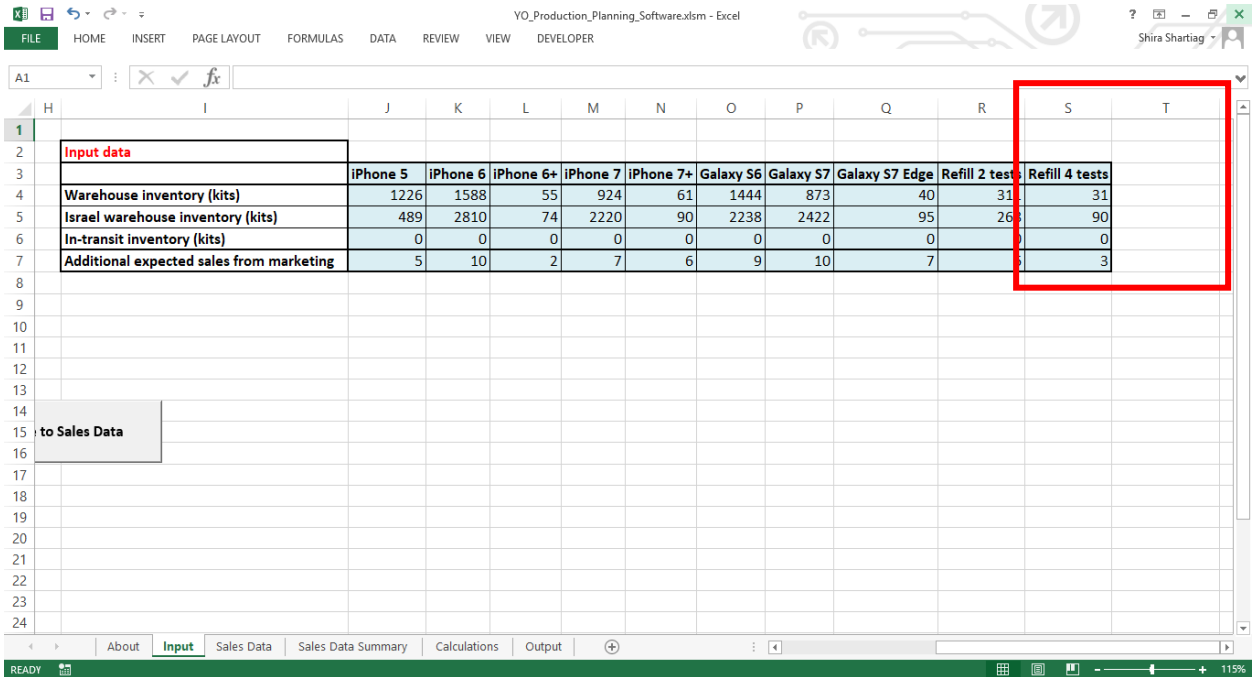
a. Select the last product column on the right.
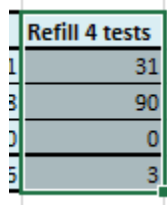
b. Click the bottom right corner and drag to the right.
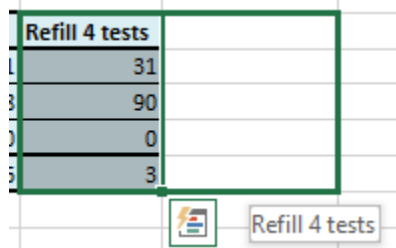
c. Rename the column and enter the data for the additional product.
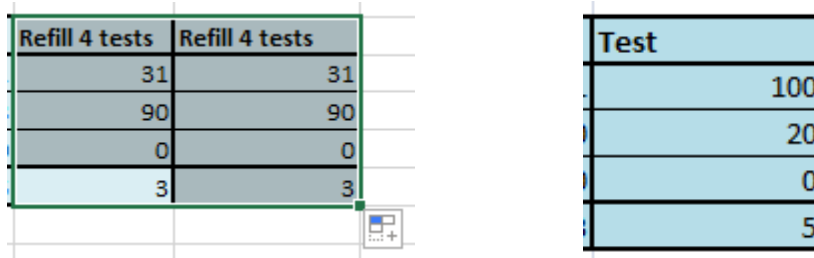
2. On the "Sales Data" sheet, identify the last product column.
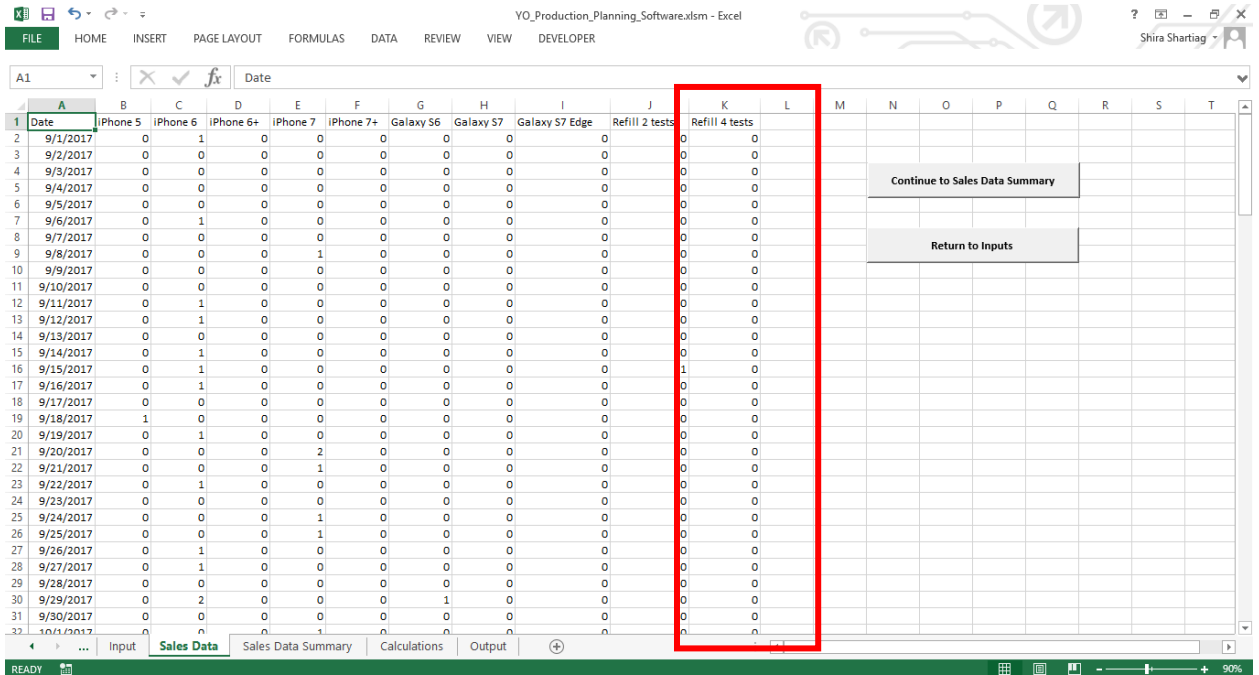
a. Select the last product name in the right column.
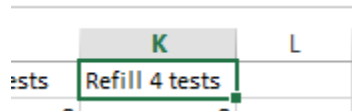
b. Click the bottom right corner and drag to the right.
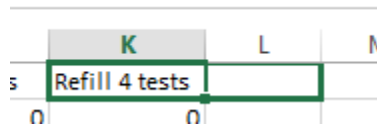
c. The new column should automatically be named. Enter the sales data for the additional product.
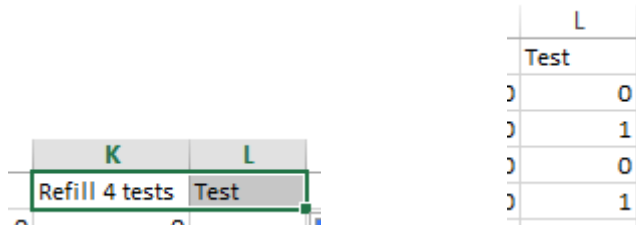
3. On the "Sales Data Summary" sheet, click anywhere within the PivotTable. A "PivotTable Fields" menu will then open on the right of the screen. Click to check and select the name of the additional product.
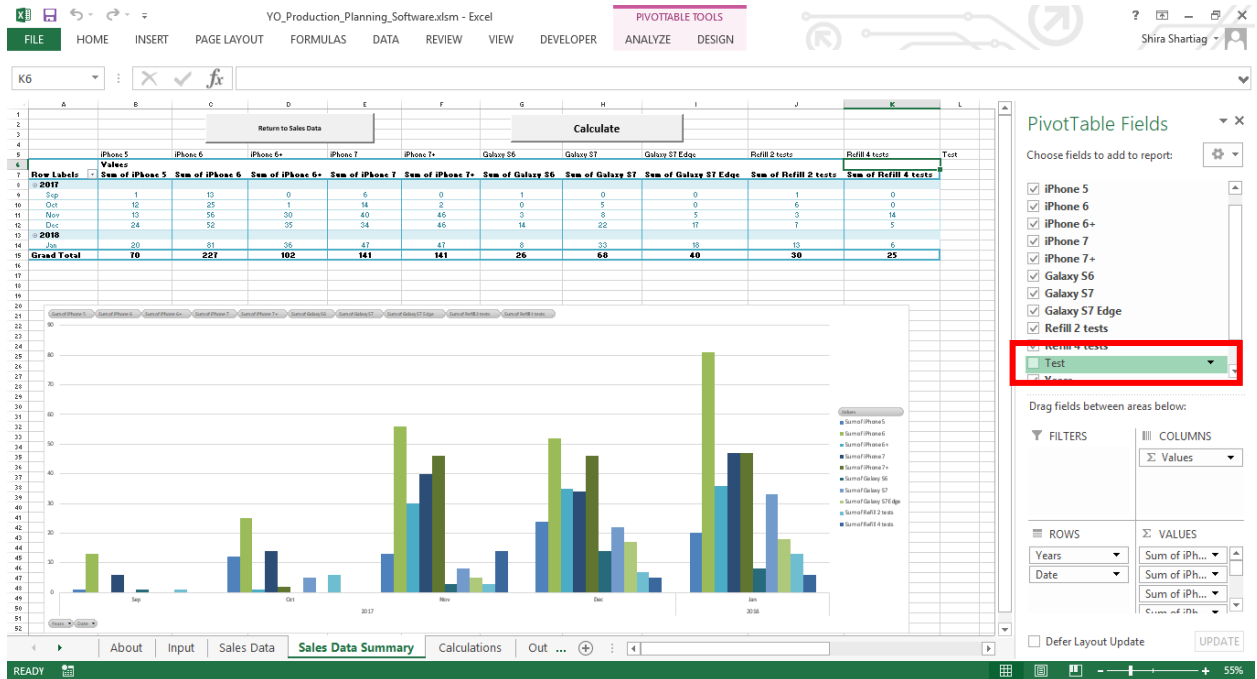
4. Add the "Sum of (additional product name)" in the values column. In this example, it is called "Sum of Test". This will add the additional product to both the PivotTable and the PivotChart.
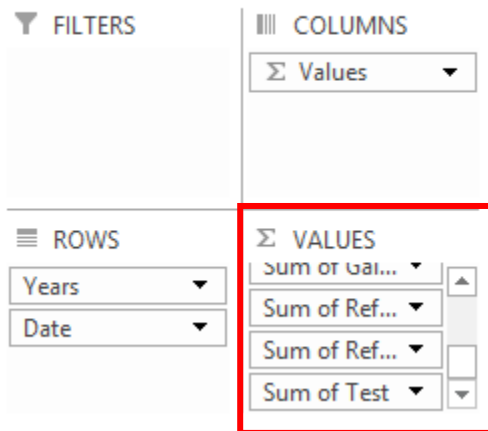
5. On the "Output" sheet, identify the last product column.
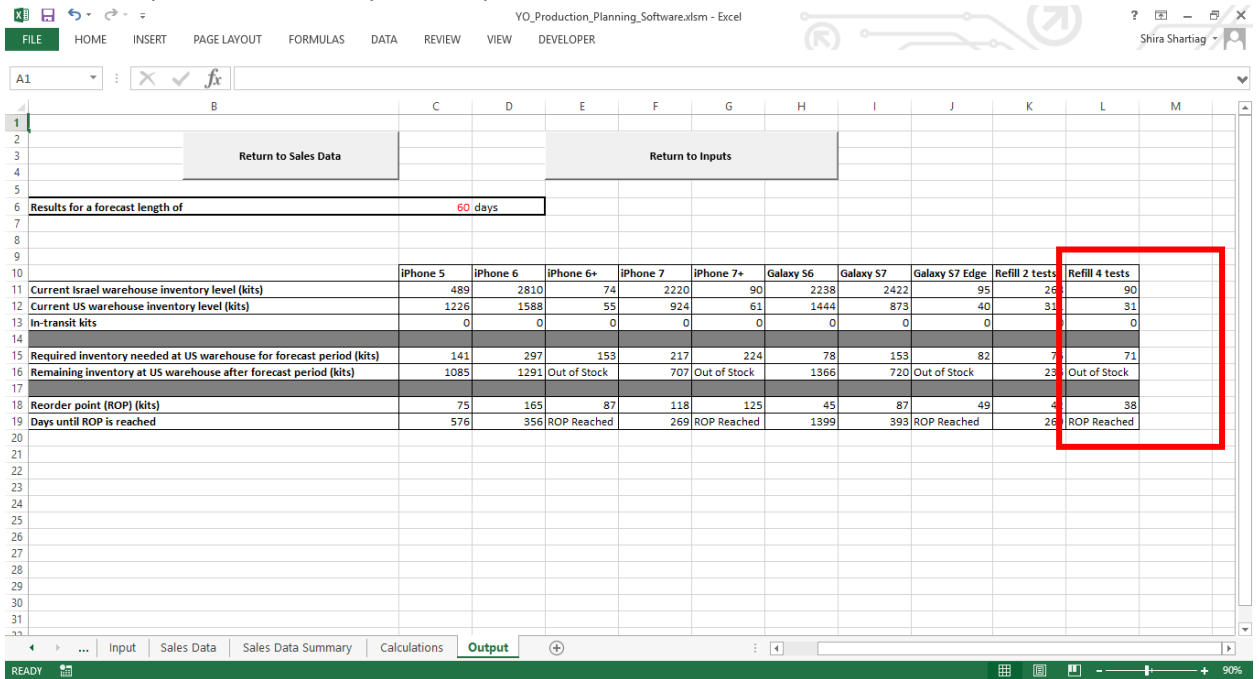
a. Select the last product column on the right.
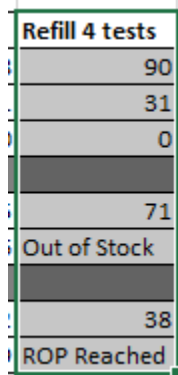
b. Click the bottom right corner and drag to the right.
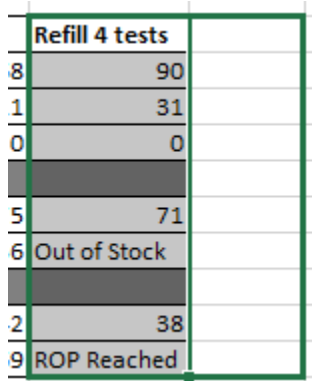
c. The column name and data should automatically fill in.