UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# Stock Optimisation for an online business offering niche products


**Maringa, Palesa (PJ)**

14069815


2018/09/27

Project Report submitted in partial fulfilment of the requirements for the module

**BPJ 420 Project**

at the


**Department of Industrial and Systems Engineering**
**University of Pretoria**

# DECLARATION OF ORIGINALITY

Full names: Palesa Jeanine-Claudia Maringa

Student number: 14069815

**Declaration**

1. I understand what plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this is my own original work
3. Where other people's work has been used (either from a printed source, internet or any other source) this has been carefully acknowledged and referenced in accordance with departmental requirements
4. I have not used another student's past work to hand in as my own
5. I have not allowed and will not allow, anyone to copy my work with the intention of handing it in as his/her own work

Signature: Palesa Maringa

(By typing my name, I pledge that I signed this declaration.)

# EXECUTIVE SUMMARY

ABC Company is a retail business that offers a wide range of niche products. The company is an online business and delivers its products to customers nationwide via a courier. The customers peruse the products on the company's website and select the products that they wish to purchase, they then proceed to make an online payment and the products are delivered to them within four days.

A key performance area for the company is inventory management because they pride themselves in having difficult to source products readily available.

The purpose of this document is to define the problem that the company is currently experiencing and to develop a solution for the company. The solution is based on a literature review that was conducted on inventory management.

The problem that the company is facing is that they do not have a formal stock process to manage their inventory. As a result, they have an oversupply of some products and an undersupply of other products. The oversupply of the items causes the company to have high carrying costs and the undersupply causes the company to order products frequently which leads to high ordering costs. In essence, not having a formal stock process has caused the company to have high inventory costs and frequent stock outs have led to unsatisfied customers.

Two models (part A and part B) were formulated and built on MS Excel in order to solve the problem. Part A was the forecast model using multiple linear regression and part B was an inventory model using linear programming.

The forecast model will predict the customer demand and will take into consideration the seasonality and trend that exists in the demand. The linear programming inventory model will take the demand and inventory costs as an input and will give as an output the size of the order and when to place the order.

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES



## ACRONYMS AND NOTATION

| | |
|---|---|
| EOQ | Economic Order Quantity |
| FIM | Fixed Interval Model |
| MDM | Markov Decision Model |

# Stock optimisation for an online business offering niche products

## 1. Background

The aim of the background is to describe the company environment and the current processes that are being used by the company to source and maintain their inventory.

### 1.1 Industry Background

ABC Company offers firearm accessories. The firearm industry is a regulated and volatile industry. In order to tap into the industry, one has to have a license to do so. The firearm industry can rely heavily on legislations and regulations.

### 1.2 Supply Chain Background

The company has three methods of sourcing their products. They can source their products either from a local agent, an international agent or directly from the factory.

The flow chart below depicts the first option that the company uses when sourcing their products.

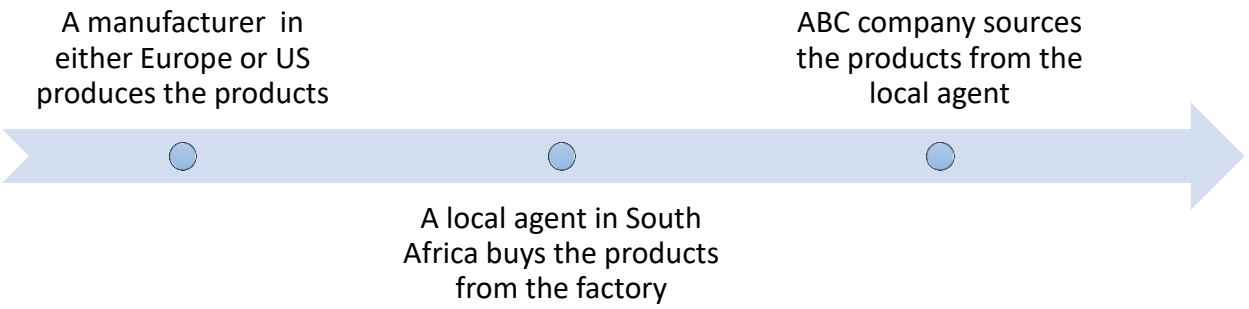



**Figure 1 Option one of sourcing products**

The flow chart below depicts the second option that the company uses to source their products.

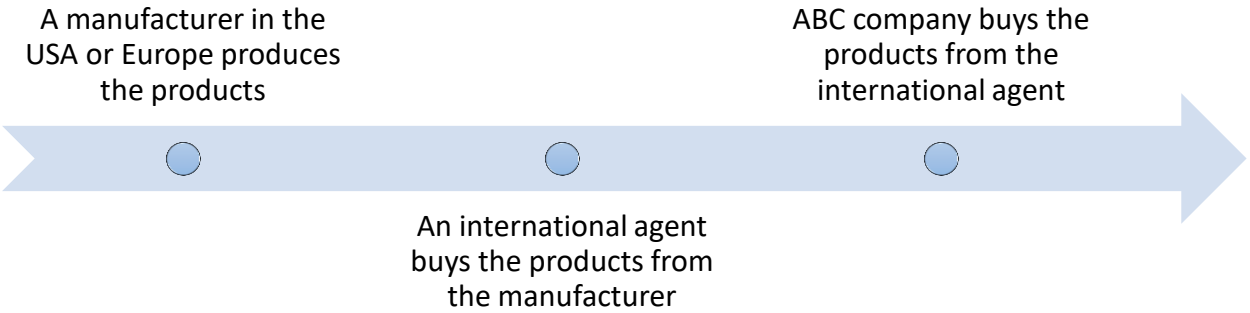



**Figure 2 Option two of sourcing products**

The flow chart below depicts the third option that the company uses to source their products.

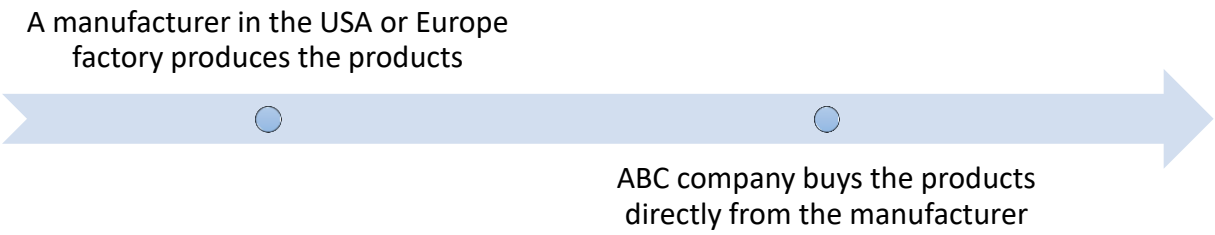



**Figure 3 Option three of sourcing products**

From the supply chains above, it is evident that the company sources many of their products internationally. This means that the lead times of the products are quite long and the company has to place orders in batches.

## 1.3 Company Background

The company was established five years ago. The company is an online business that provides a wide range of niche products to customers. The products are not produced by the company; instead, they sourced from various suppliers. In other words, the company buys and sells products.

The core competency of the company is having difficult to source products available at all times, this makes inventory management essential for the business.

The company is purely an online business, where customers browse through the website and purchase items of their choice. The payments are made online immediately after the items have been selected. The products are delivered to the customers within four days nationwide.

## 1.4 Process Background

The current stock process that the company is using is not a formalised one. It does not take any seasonality or trend into consideration. The stock process that the company uses is described below:

Step 1: Analysis of previous sales

The previous sales for the past few months are analysed.

Step 2:Average Estimation

From the analysis of sales, an average demand for each product is estimated.

Step 3: Order placement

The orders for each product are placed based on the average demand.

The company orders the same amount of stock for the next six months without any additional analysis.

# 2. Problem Statement

## 2.1 Problem definition

The company is currently experiencing two problems because they do not have a formal stock process to manage their inventory.

The first problem is that they have too little stock of some items, which leads to products being out of stock on a regular basis. This means that their reputation of having difficult to source products available is at risk. Stock outs will lead to unsatisfied customers who will take their business to other establishments. Having stock outs also means that they have to reorder items on a regular basis, which leads to high ordering costs.

An analysis on the inventory stock showed that on average 34% of items were out of stock. The figure below illustrates the out of stock data.

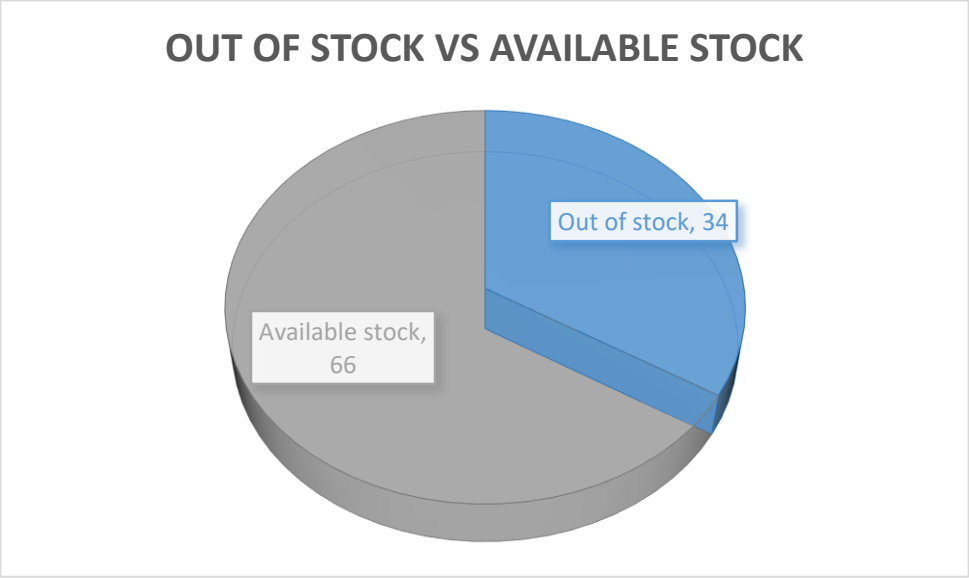



**Figure 4 Out of stock items**

The second problem that the company is experiencing is that they have too much stock of some items. Having too much stock means that the carrying costs are excessively high and capital is being tied up in inventory. If capital is being tied up in inventory, that means that it cannot be used elsewhere, which in essence impedes the growth of the business.

The figure below illustrates the stock on hand vs. how much of the stock was sold.

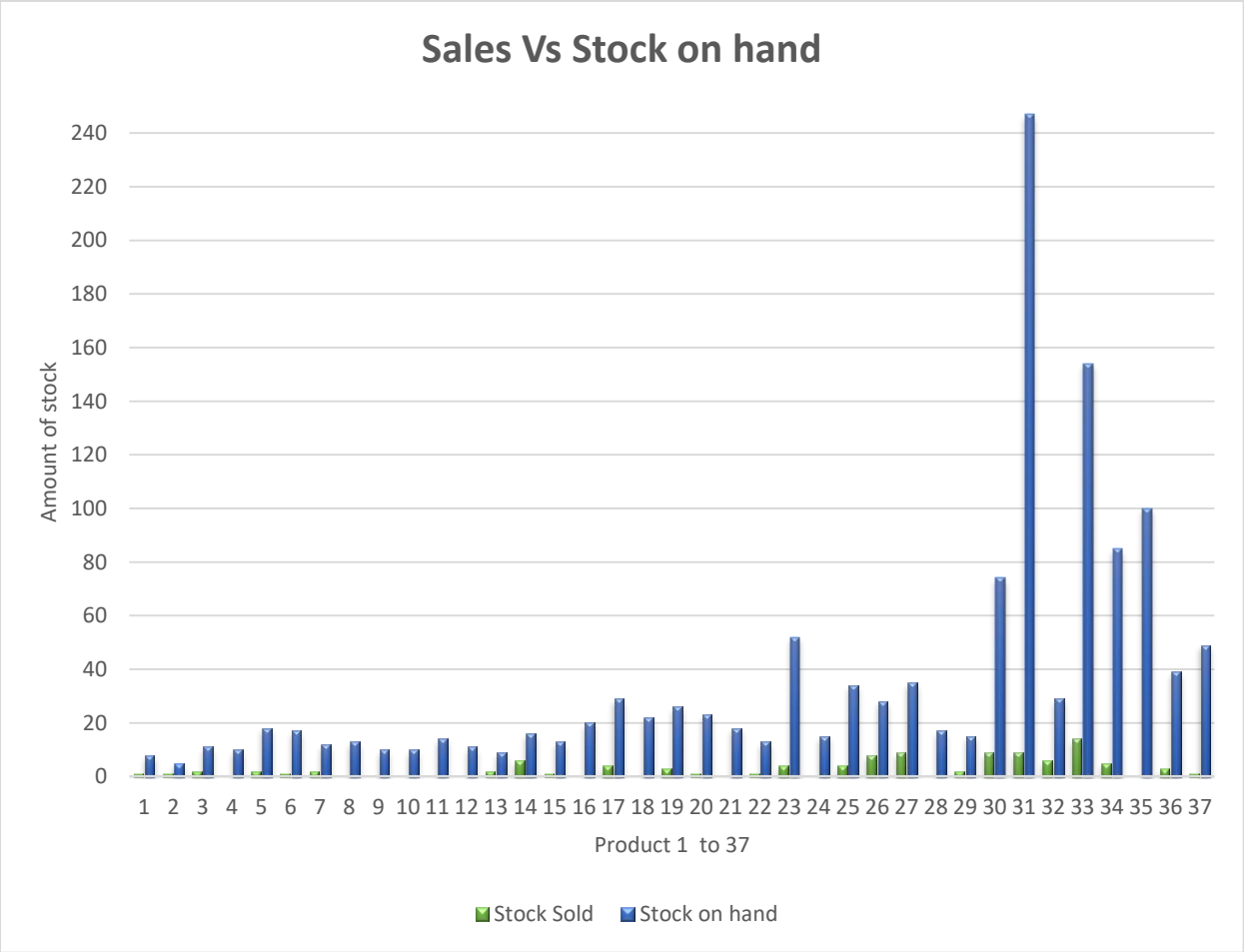



**Figure 5 Stock on hand vs. stock sold**

## 2.2 Problem Motivation

The impact that the problem has on the business is discussed below:

- The problem of experiencing stock outs on a regular basis has a major impact on the goodwill of the business. The company has established the reputation of having products readily available, and having stock outs will dismantle that reputation and the company will lose their customers.
- Stock outs also mean that the company has lost sales that they could have made had they had the products available.
- The company needs to grow on a yearly basis, and having too much stock impedes that growth. Capital that could have been used to grow the business is tied up in the inventory that is not being sold.
- Some products that remain in inventory for a long time lose their value and thus become

obsolete. If that occurs, then the company has lost a profit that they could have made.

The problem has to be addressed immediately because the company is at risk of losing their customers because the firearm industry is a competitive industry.

# 3. Project Aim

The aim of this project is to do the following:

- Formulate and build a forecast model that will predict the demand of the products as accurately as possible. As opposed to just taking an average of the demand for the past few months, the model will take into consideration any trends in the demand.
- Formulate and build an inventory model that will minimise the total inventory costs.

# 4. Scope of the project

## 4.1 Project Scope

The project addresses the inventory management of the company. The main deliverable is to design a model that will indicate how much stock to order and when to order. The model has to help the company to minimise their inventory costs while satisfying the demand of the customers. The project does not include implementing the inventory model in the company; however, it does include handing over a mapped process illustrating how to use the model.

# 5. Literature Review

The purpose of this literature review is to provide background information about inventory management and possible techniques that can be used to solve inventory problems with stochastic demand in the retail industry. Various inventory model approaches with their advantages and disadvantages will be discussed.

## 5.1 What is inventory?

(Samak-Kulkarni and Rajhans, 2013) describes inventory as the stock of items or any resource used in a business, and an inventory system as the set of policies that control and maintain inventory levels.

(Nayak and Padhye) says inventory can also be defined as assets that are intended for sale or are in the process of being produced for sale. There are four main types of inventory namely finished goods, work in process, raw materials and maintenance and operating parts (Gulati). Each type of inventory serves its own purpose and is essential in an organisation.

According to (Farahani et al.), the reasons as to why organisations keep inventory are as follows:

- Inventory is essential for customer satisfaction.
- Inventory is used to protect an organisation against changes in customer demand and lead time.
- Inventory is kept to balance supply and demand, sometimes demand will be more than supply and vice versa so inventory is kept to address that balance.
- Inventory is kept to be used as a buffer in case there are unexpected events taking place

such as a strike.

## 5.2 Inventory Classifications

(Gulati) classifies inventory into three categories according to their usage rate. The categories are as follows:

1. Active inventory – Inventory that is used frequently in an organisation or inventory that has a high demand in an organisation and whose demand can be predicted.
2. Infrequently used inventory – These are items that are not as frequently used as the active inventory, but they are used a few times in the month and their demand can be predicted.
3. Rarely used inventory – These are items that are not used often or sold often in an organisation. Their demand cannot be predicted.

The reason why inventory is classified into different categories is because the manner in which the inventory is controlled and sourced is different for each category. It is therefore imperative to classify the inventory so that different strategies can be applied for each category.

## 5.3 Inventory costs

Inventory costs are those costs that are associated with the acquiring, storing and handling of inventory. The main types of inventory costs are the holding costs, ordering costs and shortage costs. A brief description of each type of cost is described below:

- Ordering costs: Costs that are incurred every time an order is placed (Salvendy).
- Holding costs: Costs that are associated with the holding and handling of inventory in the storage facility. The carrying cost can be expressed as the cost per unit of inventory per unit of time (Salvendy).
- Shortage costs: These are costs that are incurred if a sale was lost (Salvendy).

One of the main objectives of an organisation is to reduce the inventory costs (Yadav and Malik).

## 5.4 Inventory Management

### 5.4.1 Importance of inventory management

(Yadav and Malik) says holding and managing inventory in an efficient and effective manner is imperative for any organisation. If inventory is not properly managed and controlled, organisations will not be able to fulfil their demand, and this will result in poor customer satisfaction. The reputation of the business will be damaged, which might result in cancellation of orders that will in turn cause a loss for the business. The solution to avoid the problem described above is to control and maintain inventory through inventory management.

The project is about inventory management in a retail business. The leading source of revenue in a retail business is the sale of inventory, this implies that inventory that is held for the intention of selling is one of the biggest assets in a retail business (Stevenson, 2014) . It is therefore essential to manage inventory in an effective way because the longevity of the business relies heavily on inventory management.

### 5.4.2 Objectives of inventory management

(Stevenson, 2014) discusses how inadequate management of inventory can lead to both under and overstocking of items. Understocking will lead to loss of sales and unsatisfied customers, while overstocking will result in capital being tied up in inventory and excessive carrying costs.

In order to alleviate the problems described above,(Stevenson, 2014) describes the two main objectives of inventory management as follows:

1. Achieve customer satisfaction by having the right amount of items at the right time.
2. Keep the inventory costs within reasonable bounds.

### 5.4.3 Requirements for efficient inventory management

The following information has to be taken into consideration in order to have an effective inventory management system (Stevenson, 2014):

- A dependable forecast system that will forecast the demand of the products.
  (John J Coyle, 2016) discusses the following about forecasts:
  - A major component in inventory management is to forecast the demand that will be required by the customers.
  - There are several techniques that are used to forecast the demand, but it is important to note that all forecasts are wrong and not 100% accurate.
  - An important factor in forecasting is the forecast error. The key to successful forecasting is minimizing the error between the actual demand and the forecasted demand.
  - There are four types of forecast error methods that can be used to analyse the errors, namely the cumulative sum of forecast errors (CFE), the mean squared error (MSE), the mean absolute deviation (MAD) and the mean absolute percent error (MAPE).
  - Forecasting techniques that can be used are the simple moving average, the weighted moving average, exponential smoothing, exponential smoothing with a trend and multiple linear regression. The exponential smoothing with trend technique is used for demand patterns that have seasonality.
- Knowledge about the lead times and the lead time variability.
  - The lead time is the time interval between when an order is placed and when the order arrives.
  - Information about the lead time is a requirement because you need to know how much safety stock to keep, while waiting for the order to arrive.
- Estimates of the inventory costs.
  - The inventory costs are a requirement in any inventory problem because one of the objectives of inventory management is to minimise the costs.
- Classification of the inventory into different categories.
  - Different control measures are applied to the different categories.

In conclusion, in order to have an efficient inventory management system, a demand forecast system with minimum error is required. The demand forecast system will predict the customer demand as accurately as possible. Information about the inventory costs and lead time is required in order to plan for inventory.

## 5.5 Inventory Models

Inventory models answer the question of how much to order and when to order, this addresses the inventory management objectives of customer satisfaction and cost minimisation. (Yadav and Malik) states that the following factors need to be considered when working with inventory models:

1) Demand: Demand is the number of items that are required in each period. The demand is a key factor when determining which inventory model to use. The demand can be known (deterministic) or it can be unknown (probabilistic). (Samak-Kulkarni and Rajhans, 2013) splits the demand pattern into four types:
    - Deterministic and static with time
    - Deterministic and dynamic with time
    - Probabilistic and static with time
    - Probabilistic and dynamic with time
2) Lead time: The time interval between placing the order and receiving the order.
3) Order Cycle: The time interval between the placement of two successive orders.
4) Periodic Review: In a periodic review, the inventory levels are inspected at regular time intervals. Orders are placed during said time intervals based on the inventory level at the time of the inspection.
5) Continuous Review: In a continuous review, the inventory levels are checked on continuous basis until the reorder point is reached. Orders are placed at the reorder point.

Various inventory models are going to be discussed below.

### 5.5.1 Economic Order Quantity Model with deterministic demand

The economic order quantity (EOQ) model is one of the oldest and most commonly used models in inventory control.

The image below depicts the EOQ model. The figure shows how an EOQ model works. The same quantity of inventory is ordered at the reorder point. The item is consumed on a constant rate, when it reaches the reorder point, the optimal quantity is ordered. The lead time is constant.

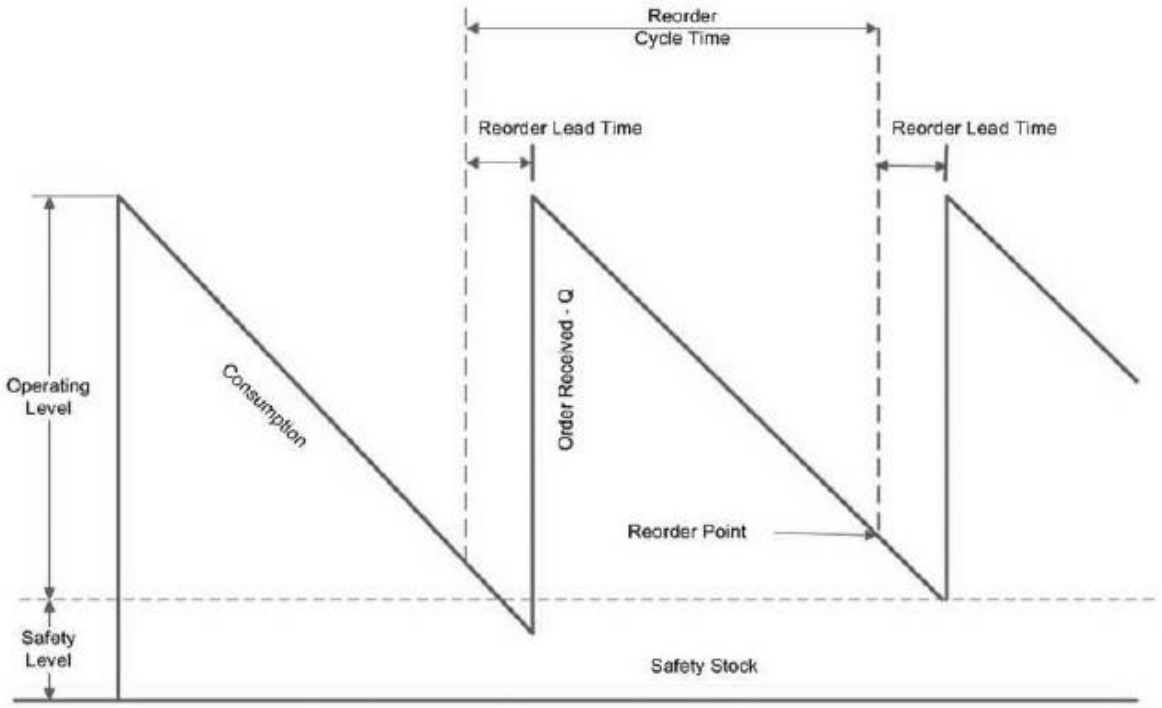



**Figure 6 EOQ Model (Gulati)**

The traditional EOQ model was introduced by Ford W. Harris in 1915 (Farahani et al.). The EOQ model is a deterministic model and has the following assumptions (Yadav and Malik) :

- The demand is known and it is constant.
- Shortages are not allowed.
- The product has abundant availability.
- Lead time is constant.
- The holding cost is equal to the unit cost times the inventory carrying charge expressed as a percentage.

(Farahani et al.) uses the following notations to represent the model:

U = unit cost of the item

H = Holding cost of one unit for one period of time

Q = order quantity (the optimal quantity)

T = cycle time

D = demand of the item

R = order cost of the item

$$Q = \sqrt{\frac{2DR}{H}}$$

The total costs are calculated as follows:

$$TC = \frac{Q}{2}H + \frac{D}{Q}R$$

TC = total costs (in Rands)

Previous studies have shown that the traditional EOQ model is impractical due to the assumptions that are made in the model (Chuang and Chiang, 2016). Due to the firearm industry's volatile nature, the traditional EOQ model is not sufficient to address the problem because it assumes that the demand is static and deterministic.

### 5.5.2 Fixed Interval Model (Uncertain Demand)

Most organisations do not operate under the certain demand assumption, particularly the retail industry.

The image below depicts the fixed interval model. From the image, it can be concluded that the demand is not constant. In a fixed order quantity model, the orders are placed at a fixed interval, however the order quantity changes and is not fixed (Stevenson, 2014).

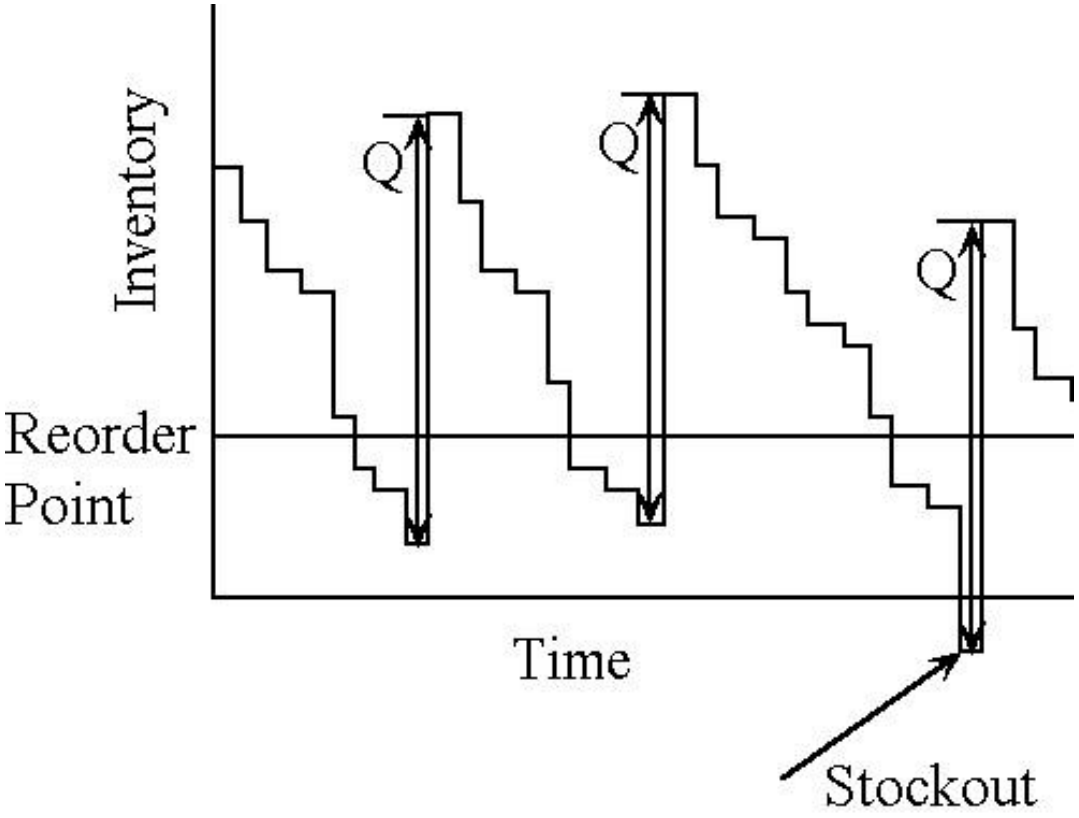



**Figure 7 Fixed Order Quantity Model (John J. Coyle, 2016)**

(Stevenson, 2014) states that the reasons why companies use the Fixed interval model are the following:

- The fixed interval model assumes that the demand is not constant, which is more realistic

for many companies.

- A supplier's policy may require the organisation to order at fixed intervals.
- Grouping the orders for items from the same supplier will result in cost saving. The organisation will save on ordering costs.

(John J Coyle, 2016) describes the reorder point as the on hand level of inventory that is required to satisfy demand during the lead time. With uncertainty of demand taken into consideration, the reorder must be calculated to include the safety stock that is needed. The reorder point will therefore be the average demand needed during lead time plus the safety stock.

According to(John J Coyle, 2016), the following assumptions are made for the FIQ model:

- Lead time is constant
- A constant cost that is independent of time
- Infinite planning horizon
- The demand has either a discrete distribution or a continuous distribution

In an FIQ model, an organisation has to determine a range of demand values during lead time and the probability associated with the demand value. The FIQ model will discrete distribution will be discussed in this literature review.

**FOQ Model for discrete distribution**

(John J Coyle, 2016) describes the FIQ Model with discrete distribution as a model that assumes that the demand (Demand = D) is uncertain, but ranges between two discrete values ($a < D < b$). The probability distribution of the demand ranging between a and b is known.

The orders in a FIQ model are placed on fixed intervals. This implies that there is a possibility of having stock outs or excess inventory.

The following notations are denoted for an FIQ model:

Q = quantity ordered

D= demand in units

H = inventory carrying cost

O = ordering cost

e = expected excess in units

g = expected shorts in units

k = stock out cost in rands per unit stocked out

G = gk = expected stock out cost per cycle

G $(\frac{D}{Q})$ = expected cost out per year

eH = expected carrying cost per year for excess inventory

The total costs are calculated as:

$TC = \frac{1}{2} QH + O\frac{D}{Q} + eH + G\frac{D}{Q}$

### 5.5.3 Dynamic Economic Lot Sizing (DEL) model

(Agra and Poss, 2018) propose another type of inventory model that can be used to solve inventory problems. The model considers the fact that the demand is uncertain and is more realistic. Three techniques can be used to solve the inventory problem with this model namely:

- Linear Programming
- Dynamic Programming
- Heuristics

### 5.5.4 Markov Decision Model (Stochastic demand)

(Mubiru, 2010)describes the markov decision model as a model that adopts the markov decision process approach. The markov chain represents the possible demand in different states. The decision of purchasing additional inventory is made using dynamic programming.

The following model development is described by (Mubiru, 2010).

**Model formulation**

The demand in each period is classified as either favourable or unfavourable, and we assume that the demand in a period is dependent on the demand of the preceding period. The transition probabilities from one demand state to another is described by a markov chain.

The demand is modelled as a markov chain.

$$Q^S = \begin{matrix} \\ F \\ U \end{matrix} \begin{matrix} \begin{matrix} F & U \end{matrix} \\ \begin{bmatrix} Q^S{}_{FF} & Q^S{}_{FU} \\ Q^S{}_{UF} & Q^S{}_{UU} \end{bmatrix} \end{matrix}$$

$Q_{ij}^S$ is the probability of a transition in demand from state i to state j.

The number of customers is denoted as:

$$N^S = \begin{matrix} \\ F \\ U \end{matrix} \begin{matrix} \begin{matrix} F & U \end{matrix} \\ \begin{bmatrix} N^S{}_{FF} & N^S{}_{FU} \\ N^S{}_{UF} & N^S{}_{UU} \end{bmatrix} \end{matrix}$$

The demand is denoted as:

$$D^S = \begin{matrix} \\ F \\ U \end{matrix} \begin{matrix} \begin{matrix} F & U \end{matrix} \\ \begin{bmatrix} D^S{}_{FF} & D^S{}_{FU} \\ D^S{}_{UF} & D^S{}_{UU} \end{bmatrix} \end{matrix}$$

The quantity of stock is denoted as:

$$Y^S = \begin{matrix} \\ F \\ U \end{matrix} \begin{matrix} \begin{matrix} F & U \end{matrix} \\ \begin{bmatrix} Y^S{}_{FF} & Y^S{}_{FU} \\ Y^S{}_{UF} & Y^S{}_{UU} \end{bmatrix} \end{matrix}$$

The cost is denoted as:

$$T^S = \begin{matrix} \\ F \\ U \end{matrix} \begin{matrix} \begin{matrix} F & U \end{matrix} \\ \begin{bmatrix} T^S{}_{FF} & T^S{}_{FU} \\ T^S{}_{UF} & T^S{}_{UU} \end{bmatrix} \end{matrix}$$

Where,

S = lot sizing policy where S=0 represents no additional stock being purchased and S = 1 represents stock being purchased.

U = The favourable condition

F = The unfavourable condition

The expected total future cost is denoted as $w_i^S$ = transpose of $[\, w_F^S, w_u^S]$ and the accumulated total cost at the end of period 1 is denoted by $a_i^S = \text{transpose of } [a_F^S\,, a_u^S]$.

The following dynamic programming model can be formulated in order to solve the problem:

Let $C_n(i)$ be the optimal total expected inventory cost accumulated during the periods n= 1, 2 ,3….., N

$$c_n\,(i) = \min_S\{\, Q^S{}_{iF}\ (T^S{}_{iF} + \ c_{n+1}(F)\ ), Q^S{}_{iU}\ (T^S{}_{iU} + \ c_{n+1}(U))\}\,, i \in \{F, U\}\,, n = 1,2, \ldots., N$$

$$w^s = Q^S([T^s])^T,\ S\ \in (0,1)$$

Where T represents the transpose of the matrix. The total optimal expected cost will therefore be:

$$c_n\,(i) = \min_S\{\, w^S{}_i\ + \ \left(Q^S{}_{iF}\ c_{n+1}(F)\ \right) + \ Q^S{}_{iU}\ \ c_{n+1}(U)\}\,, i \in \{F, U\}\,, n = 1,2, \ldots., N\text{-}1$$

$$c_N\,(i) = \min_S\{\, w^S{}_i\ \}\,, i \in \{F, U\}$$

$Q^S\,, T^S\ and\ p^s$ are therefore computed as:

$$Q^S{}_{ij} = \frac{N^S{}_{ij}}{N^S{}_{iF} + N^S{}_{iU}}\ ,\ \ i \in \{F, U\},\ S \in \{0,1\}$$

$$T^S{}_{ij} = \begin{cases} \left(c_p + c_h + c_s\right)\left(D^S{}_{ij} - Y^S{}_{ij}\right) & if\ D^S{}_{ij} > \ Y^S{}_{ij} \\ 0 & if\ D^S{}_{ij} \leq \ Y^S{}_{ij} \end{cases}$$

$$p^S{}_i = (D^S{}_{iF} - Y^S{}_{iF}) + \ (D^S{}_{iU} - Y^S{}_{iU}),\ i \in \{F, U\},\ S \in \{0,1\}$$

**The optimal strategy at time period 1**

When the demand is favourable during period 1, the optimal lot sizing and the inventory costs will be:

$$S = \begin{cases} 1\ if\ w^1{}_F\ < w^0{}_F \\ O\ if\ w^1{}_F\ \geq w^0{}_F \end{cases}$$

and,

$$c_1(F) = \begin{cases} {w^1}_F \ if\ S = 1 \\ {w^0}_F \ if\ S = 0 \end{cases}$$

When the demand is unfavourable, the optimal lot sizing policy and the inventory costs will be:

$$S = \begin{cases} 1 \ if\ {w^1}_U < {w^0}_U \\ O \ if\ {w^1}_U \geq {w^0}_U \end{cases}$$

and,

$$c_1(U) = \begin{cases} {w^1}_U \ if\ S = 1 \\ {w^0}_U \ if\ S = 0 \end{cases}$$

**The optimal strategy for time period 2**

The accumulated costs at the end of period 1 will be:

$$a^S{}_i = w^S{}_i + Q^S{}_{iF} \min\{ {w^1}_F, {w^0}_F \} + Q^S{}_{iU} \min\{ {w^1}_U, {w^0}_U \}$$
$$= w^S{}_i + Q^S{}_{iF} c_1(F) + Q^S{}_{iU} c_1(U)$$

This implies that during time period 2, when the demand is favourable, the optimal lot sizing policy will be:

$$S = \begin{cases} 1 & if\ {a^1}_F < {a^0}_F \\ O & if\ {a^1}_F \geq {a^0}_F \end{cases}$$

The corresponding inventory costs will be:

$$c_2(F) = \begin{cases} {a^1}_F \ if\ S = 1 \\ {a^0}_F \ if\ S = 0 \end{cases}$$

When the demand is unfavourable, the corresponding optimal lot sizing policy and inventory costs will be:

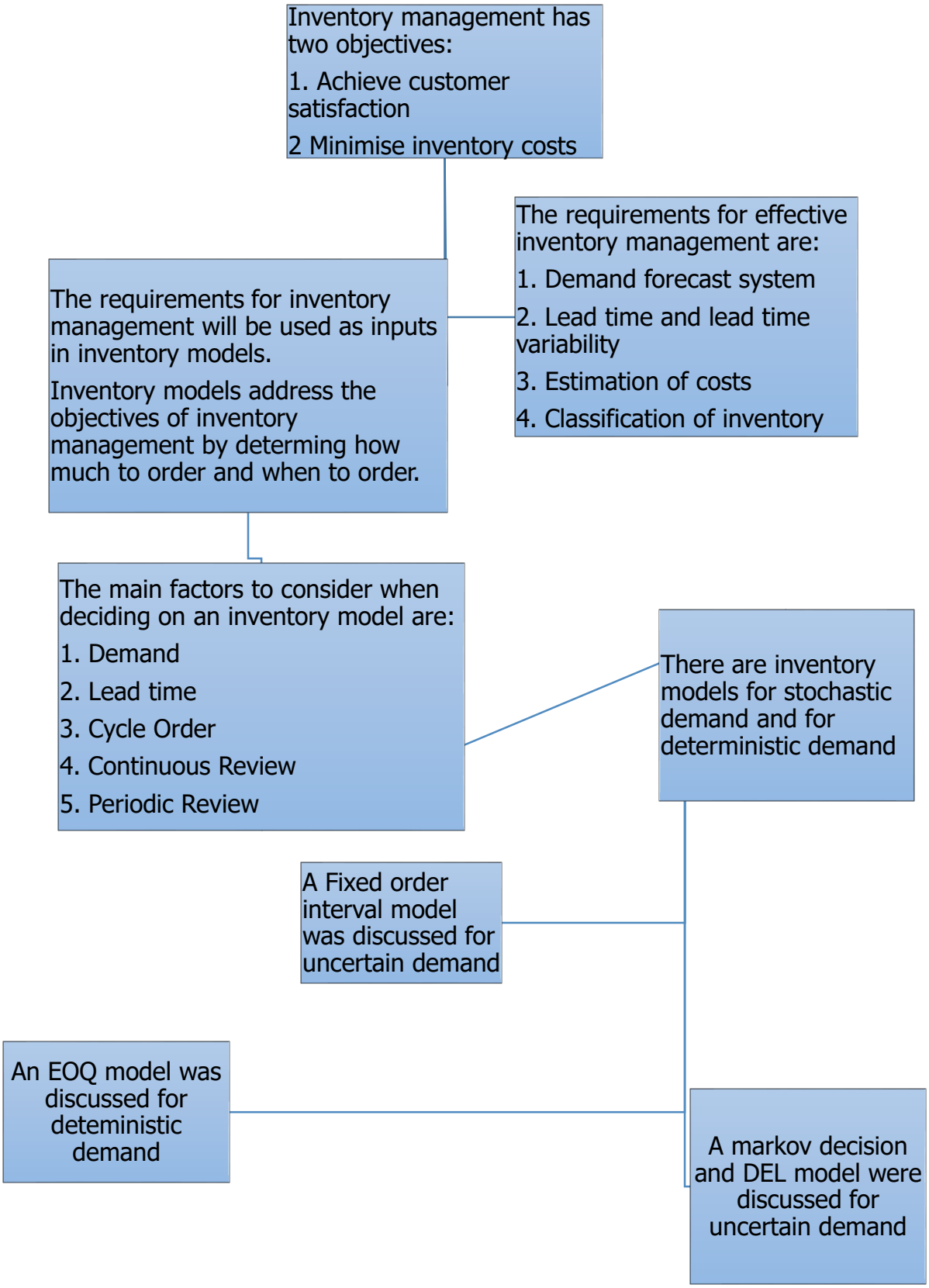
$$S = \begin{cases} 1 & if\ {a^1}_2 < {a^0}_2 \\ O & if\ {a^1}_2 \geq {a^0}_2 \end{cases}$$

and,

$$c_2(U) = \begin{cases} {a^1}_U \ if\ S = 1 \\ {a^0}_U \ if\ S = 0 \end{cases}$$

The model described by (Mubiru, 2010) considers a two period planning horizon (N = 2). The advantage of using this model is that it considers the fact that the demand is stochastic and it can be used for real life problems. The disadvantage of the model is that it only considers a two period planning horizon which makes it restricted.

## 5.6 Inventory management summary



## 5.7 Literature Review Summary

The literature review highlighted very important factors that need to be taken into consideration when solving an inventory problem. These factors provided a roadmap for solving the problem that the company is currently experiencing. The roadmap is highlighted in the figure below.

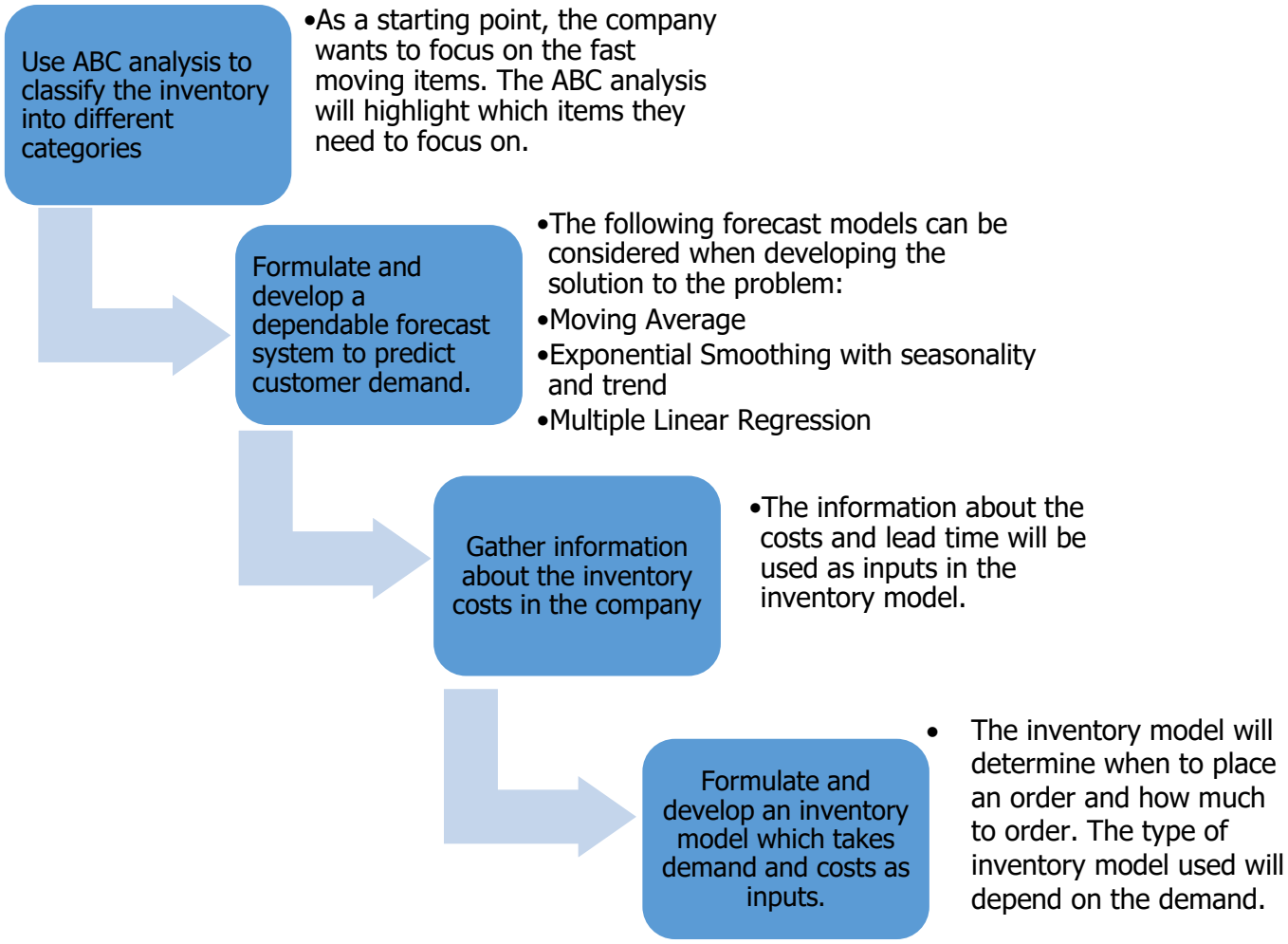



**Figure 8 Roadmap for solving problem deduced from literature review**

# 6. Project Techniques

The following Industrial Engineering techniques will be used to approach the problem:

- Inventory management as the main technique. The other tools that fall under inventory management that will be used are:
  - ABC analysis to classify the inventory
  - Cost Analysis
  - Demand Forecasting using exponential smoothing and multiple linear regression
  - Lot sizing using linear programming

# 7. Data analysis

The purpose of this section is to indicate what type of data is going to be used and how it is going to be used in the project.

## 7.1 Sales Data

The sales data is going to be used to firstly determine what trend the data follows and secondly to forecast the demand for the items. It is important to understand the data because it will help determine what type of demand we have, which will help in making decisions such as what type of forecast model to build.

An analysis was done on the sales for all the products sold in each month for 2015,2016 and 2017 to establish if the sales data has any trends or patterns that it follows.

The image below indicates the analysis on orders created per month for the years 2016 and 2017.

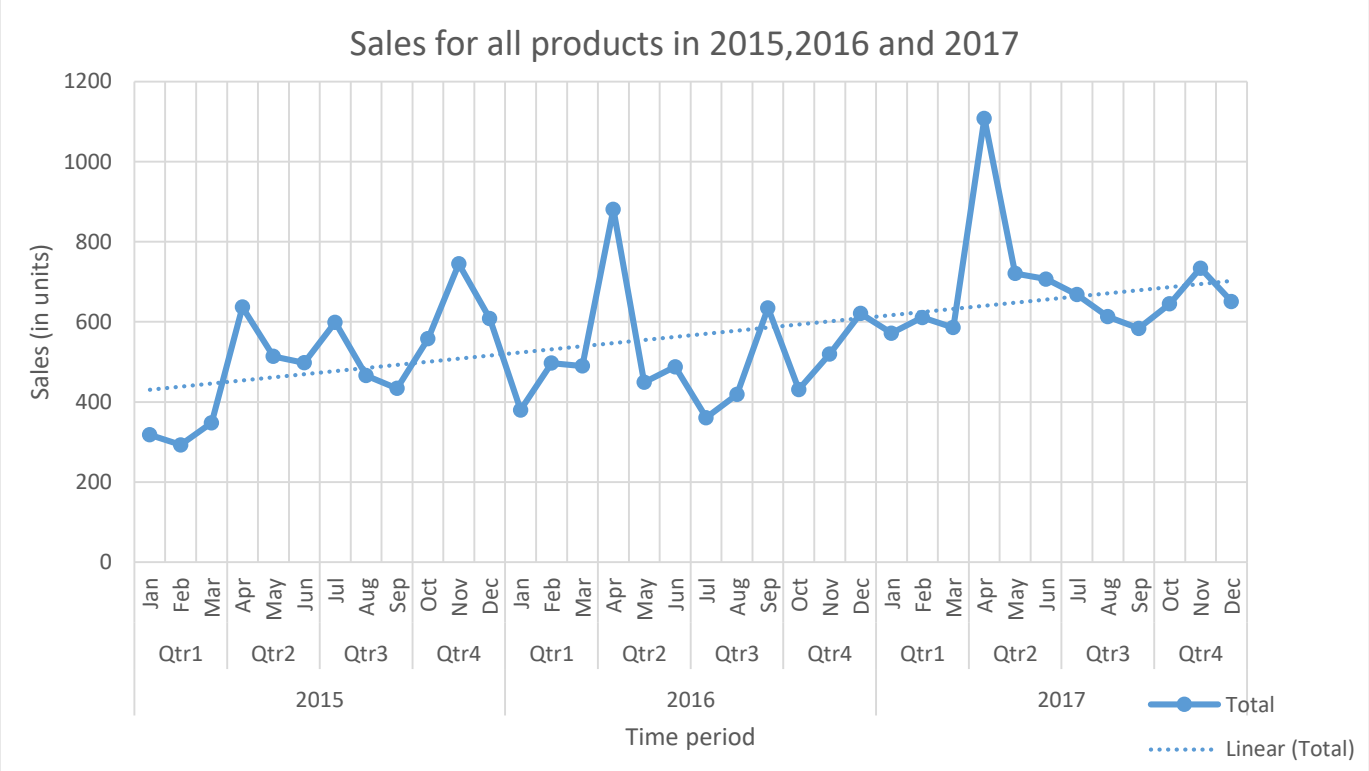



**Figure 9 Sales over three years**

The demand has peak periods and off peak periods, and it is increasing over time. This indicates that there is seasonality and trend in the data. The graph also indicates the demand is uncertain. This information is going to help determine what type of inventory model and forecast model is going to be selected to solve the problem.

## 7.2 Costs Data

Estimations for inventory costs are required in order to execute the project. The inventory costs will be used as inputs in the model.

# 8. Alternative Solutions to solving the problem

The aim of this project is to develop an inventory management process that the company can use to reduce their inventory costs while meeting the demand of the customers. A way of achieving this is to build a forecast model and an inventory model. The forecast model will predict the demand for a 12-month planning period and it will take into consideration the seasonality and the trend that exists in the demand. The inventory model will suggest optimal quantities and when to order the quantities in order to minimise the total inventory costs. In essence, the two models will work together; the demand predicted from the forecast model will be used as an input in the inventory model.

This section will focus on comparing two forecast models and selecting the best one, and also comparing two inventory models and selecting the best one. The best two models will then be the combined solution for this project.

It is important to note that an ABC analysis was performed in order to segment the inventory. The testing and validating of the models was based on selected A items, and the analysis will be used by the company to understand their inventory better and to start controlling their inventory based on the ABC segmentation. The ABC analysis can be found in appendix B.

## 8.1 Exponential Smoothing Vs. Multiple Linear Regression

As discussed in the paper, the project solution will consist of two models. The forecast model being the first part and the inventory model being the second part. The objective of the forecast model is to predict the demand as accurately as possible. It is important to note that a forecast model is merely a prediction and it can never be 100% accurate. The key in building forecast models is to minimise the error between the forecasted values and the actual values.

Exponential smoothing with seasonality and trend (also known as triple smoothing) and multiple linear regression were the two forecast models that were considered. This section of the report will discuss the model formulation of both the triple smoothing and multiple linear regression methods and which model was selected and why it was selected.

### 8.1.1 Exponential Smoothing model formulation

**Model Variables and Parameters**

The variables in the forecast model are what we are calculating. They are the unknown variables that the model will give back as outputs.

Let:

$L_t$ = The level at time $t$

$T_t$ = The trend at time $t$

$S_t$ = The seasonality at time $t$

$f_{t,r}$ = The forecasted demand at time $t, r$ time steps ahead

Parameters are values that are used in the model that do not change. The triple smoothing model has three parameters, namely the alpha ($\alpha$) , beta (β) and gamma (Y) constants. For the model in this project, the smoothing constants were determined using the solver in excel.

Let:

$\alpha$ = 0,229193
β = 0,024444
ϒ = 0,997839

**Equations used for the forecast model**

The equations used to determine the variables are detailed below:

$$L_t = \alpha\, x_t/s_t + (1-\alpha)(L_{t-1} + T_{t-1}) \quad (1)$$

$$T_t = \beta\,(L_t - L_{t-1}) + (1-\beta)(T_{t-1}) \quad (2)$$

$$S_t = \Upsilon\, X_t\,/L_t + (1-\Upsilon)(S_t) \quad (3)$$

$$f_{t,r} = (L_t + rT_t)(S_t) \quad (4)$$

**Forecast Model Explanation**

The sales data analysis exhibited trend and seasonality traits. In order to build a forecast model, the level, trend and seasonality have to be initialised. This means that we need the values of the aforementioned variables at time step zero.

The sales data was given for four years (2014 – 2017). The sales data for 2014 and 2015 were used to initialise the trend, level and the seasonality. The initialised values are used to calculate the level, trend and seasonality for time period 1. A forecast for time period t is calculated from the aforementioned variables, as seen in equation (4).

Once the model runs, the variables are updated for the time period being considered, using equation (1), (2) and (3) and used to forecast the demand in the time period that is being considered. The model inputs are the historic demand values for the products. The model gives back trend, seasonality, level and the forecasted demand as outputs.

### 8.1.2 Multiple Linear Regression Model Formulation

In multiple linear regression, we use multiple variables to predict the demand of the customers. The explanatory variables are the variables that will be used to predict the demand. In this project, the explanatory variables are the time period, which takes the trend into consideration and the seasonal variables.

**Model Variables and Parameters**

There is only one unknown variable, which is the demand.

Let:

$Y_i =$ The predicted demand in month $i$ where, $i = \{1,2,3,4,5,6,7,8,9,10,11,1,2\}$

The parameters in the model are dynamic and depend on the historic demand data. The parameters will be different for each product in the company. For the seasonality variables, there will be 12 seasonal variables for 12 months.

Let:

$\alpha_i =$ The coefficient for the seasonality in month $i$ where $i$ ={1,2,3,4,5,6,7,8,9,10,11,12}

$\beta =$ The coefficient for the slope (predicts the trend)

$\Upsilon =$ The intercept

**Model Inputs**

$X$ = The time period

$K_{pi} = \begin{cases} 1 \text{ if predicting for season p} \\ 0 \text{ if not predicting for season p} \end{cases}$ , where $p = \{1,2,3,4,5,6,7,8,9,10,11,12\}$

**Equation used for the model**

$$Y_i = \Upsilon + X\beta + K_{1i}\alpha_1 + K_{2i}\alpha_2 + K_{3i}\alpha_3 + K_{4i}\alpha_4 + K_{5i}\alpha_5 + K_{6i}\alpha_6 + K_{7i}\alpha_7 + K_{8i}\alpha_8 + K_{9i}\alpha_9 + K_{10i}\alpha_{10} + K_{11i}\alpha_{11} + K_{12i}\alpha_{12}$$

### 8.1.3 Results for Exponential smoothing and multiple linear regression

The models were built on MS excel and they were tested using three selected A items which are the company's fast selling items and bring in the most profit in the business. The comparison for both of the models will be discussed in this section.

The image below depicts the actual demand vs. the forecasted demand for item one using exponential smoothing over three years.

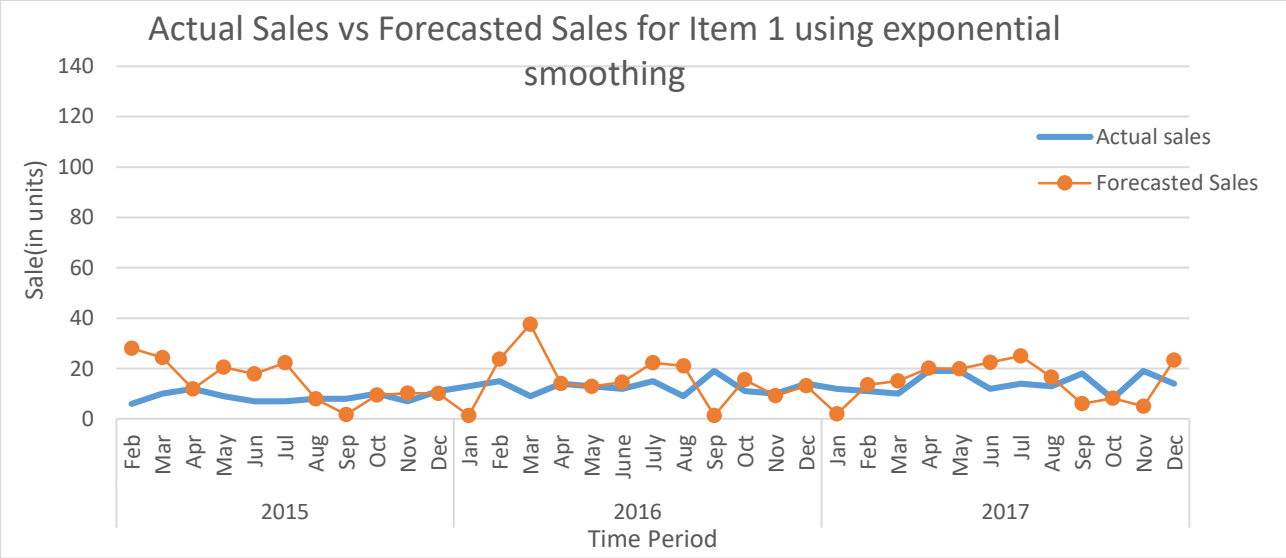



**Figure 10 Actual Sales vs. Forecasted Sales for item one using triple smoothing**

The image below depicts the actual demand vs. the forecasted sales for item 1 using multiple linear regression over three years.

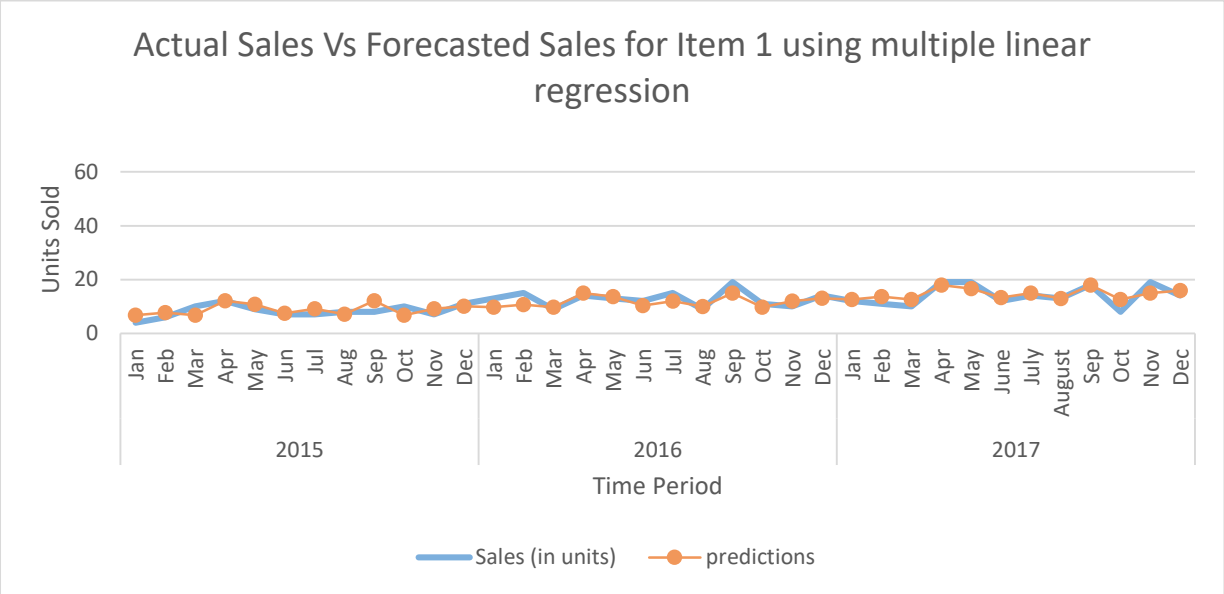



**Figure 11 Actual Sales vs. Forecasted Sales for item 1 using multiple linear regression**

The image below depicts the actual sales vs. the forecasted sales for item 2 using exponential smoothing over two years. The actual sales are the actual demand for item 2 and the forecasted sales are the predicted demand value using the triple smoothing model.

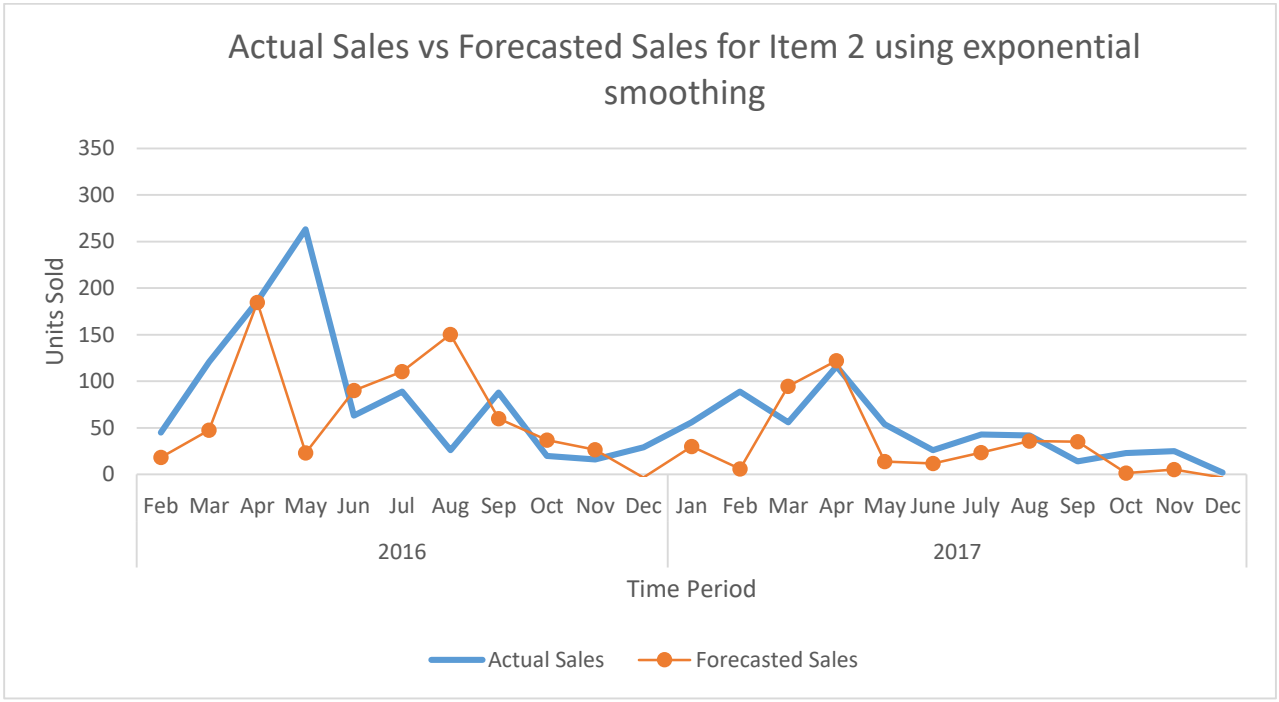



**Figure 12 Actual Sales vs. Forecasted Sales for item 2 using triple smoothing**

The image below depicts the actual sales vs. the forecasted sales for item 2 using multiple linear regression over two years.

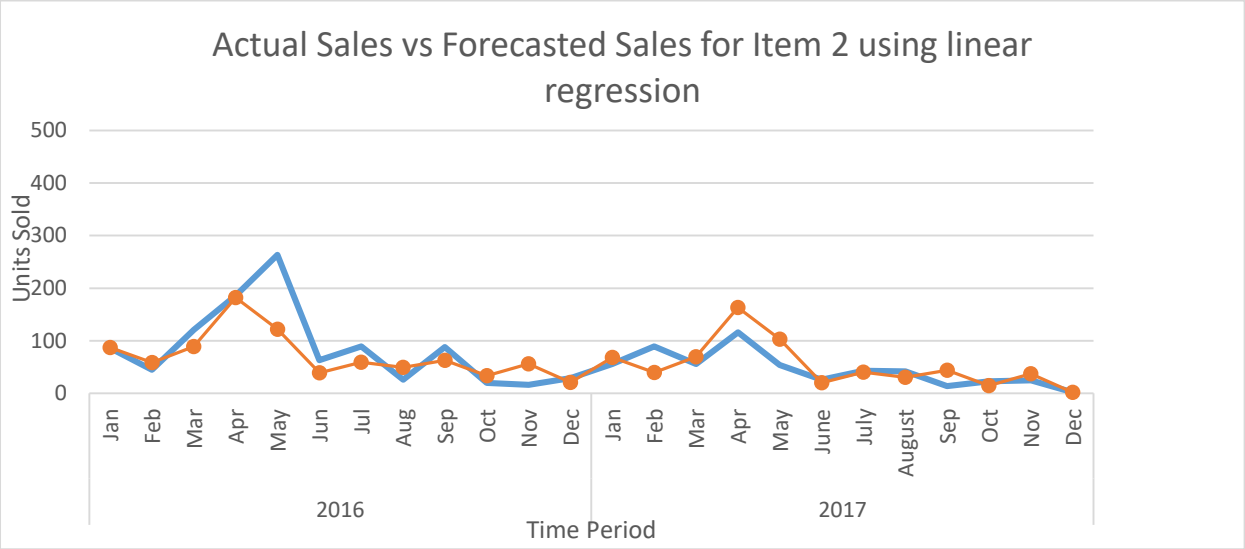



**Figure 13 Actual Sales vs. Forecasted Sales for item 2 using multiple linear regression**

The image below depicts the actual sales vs. the forecasted sales for item 3 using exponential smoothing over two years.

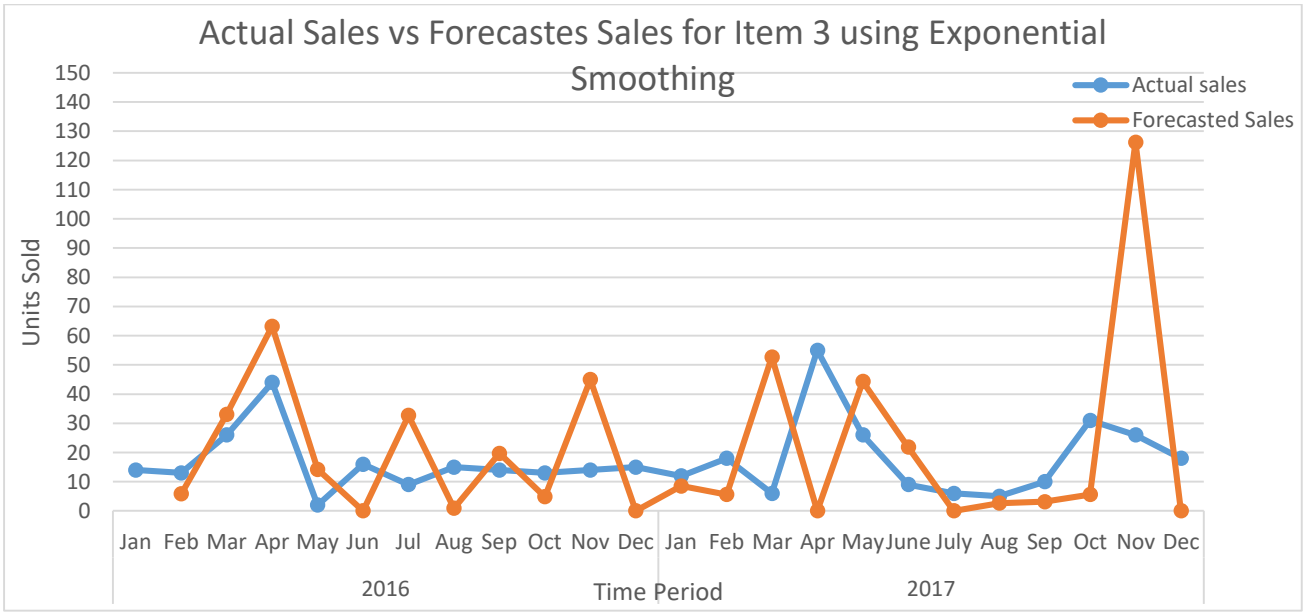



**Figure 14 Actual Sales vs. Forecasted Sales for item 3 using triple smoothing**

The image below depicts the actual sales vs. the forecasted sales. The actual sales are the actual demand for item 3 and the forecasted sales are the predicted demand value using the multiple linear regression model.

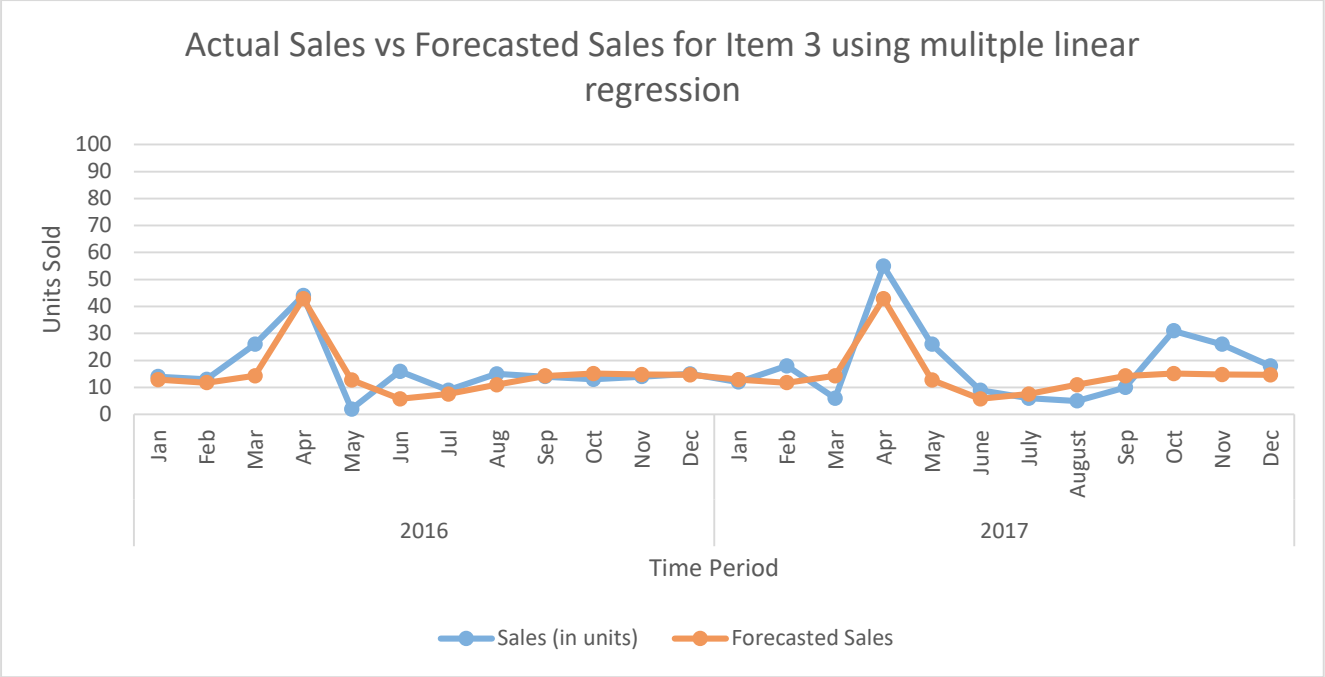



**Figure 15 Actual Sales vs. Forecasted Sales for item 3 using multiple linear regression**

### 8.1.4 Discussion of model comparison results and model selection

(John J. Coyle, 2016) states that the forecast error during any period is calculated as the actual value minus the forecasted value. There are different forecast error methods that can be used to compare the observed value and the predicted value. Three methods were used to analyse the forecast errors for the triple smoothing method and the multiple linear regression method, namely the mean squared error (MSE), the mean absolute deviation (MAD) and the mean absolute percentage error (MAPE).

The formulas for the error methods are listed below:

$$\text{MSE} = \frac{\sum {E_t}^2}{n}$$

$$\text{MAD} = \frac{\sum |E_t|}{n}$$

$$\text{MAPE} = \frac{100 \sum |E_t|/D_t}{n}$$

Where,

$E_t$ = The error in time period $t$

$D_t$ = The actual demand in time period $t$

$n$ = The number of periods

The three different methods were calculated for each model and each supplier.

The table below depicts the results of the forecast error methods for supplier one. It can be concluded from these results that multiple linear regression is the best method because it has the least error from all of the methods.

**Table 1 Item one forecast error results**

| **Item one** | | |
|---|---|---|
| **Forecast Error Method** | Exponential Smoothing | Multiple Linear Regression |
| **Mean Squared Error (MSE)** | 102,56 | 5,38 |
| **Mean Absolute Deviation (MAD)** | 7,43 | 1,93 |
| **Mean Absolute Percentage Error (MAPE)** | 72,52 | 18,95 |

The table below depicts the results of the forecast error methods for item two. It can be concluded from these results that multiple linear regression is the best method because it has the least error from all of the methods.

**Table 2 Item two forecast error results**

| **Item two** | | |
|---|---|---|
| **Forecast Error Method** | Exponential Smoothing | Multiple Linear Regression |
| **Mean Squared Error (MSE)** | 4136,14 | 1495,79 |
| **Mean Absolute Deviation (MAD)** | 39,27 | 25,97 |
| **Mean Absolute Percentage Error (MAPE)** | 88,52 | 53,83 |

The table below depicts the results of the forecast error methods for item three. It can be concluded from these results that multiple linear regression is the best method because it has the least error from all of the methods.

**Table 3 Item three forecast error results**

| **Item three** | | |
|---|---|---|
| **Forecast Error Method** | Exponential Smoothing | Multiple Linear Regression |
| **Mean Squared Error (MSE)** | 864,70 | 43,83 |
| **Mean Absolute Deviation (MAD)** | 20,30 | 5,30 |
| **Mean Absolute Percentage Error (MAPE)** | 106,74 | 65,93 |

In order to compare the two forecast models, three items were analysed using both models. The models forecasted the demand for each item and the results were compared against the observed

demand and depicted with line graphs. From the visual depiction of the results, it was clear that the multiple linear regression model was the better model.

For an accurate and fair decision to be made, three forecast error methods were used to analyse the errors of both models for all three items. All three methods indicated that the multiple linear regression model produces demand forecast values with the least error.

The model that was selected as a solution to the problem is the multiple linear regression model because of the aforementioned reasons.

## 8.2 Fixed Interval Order Quantity model vs. Dynamic Economic Lot (DEL) Sizing using linear programming

The sales data indicated that the demand is not certain. The literature review revealed that there are many inventory models that can be considered when there is uncertain demand. This section of the report focuses on reviewing two approaches that can be used to solve inventory management problems that deal specifically with uncertain demand. The two approaches that will be discussed are the DEL model using linear programming and the fixed interval order quantity model.

### 8.2.1 Fixed Interval Order Quantity Model

(Stevenson, 2014) states that the fixed interval order quantity model is used when the demand is variable. The orders are placed on fixed intervals, but the order size varies from cycle to cycle. This model is demand sensitive. The disadvantage of the model is that if you order on a fixed interval, there is a possibility that stock might run out because the order interval is fixed; a lot of carrying stock is needed.

The demand as seen in the sales graph is very dynamic. It follows a certain pattern every year but it is very erratic. Using the fixed interval order model will be a disadvantage because there is a high possibility of running out of stock during the cycle time. The order interval is fixed and leaves no room for creativity and moving the reorder points continuously based on the demand.

### 8.2.2 DEL model using linear programming

The DEL model is also used when dealing with uncertain demand as well. The difference with this model is that the order size and the reorder point are both dynamic. They change every cycle depending on what the demand is.

### 8.2.3 Inventory model selection

The model that will be used to solve the problem is the dynamic economic lot sizing (DEL) model using linear programming. The reasons as why the method was selected is listed below:

- The demand is uncertain.
- The demand follows a certain trend and seasonality. The seasonality can be seen through the sales analysis, where the data follows a certain pattern every 12 months.
- The (DEL) model is a dynamic model which is used when there is uncertain demand in the system. It will meet the objective of minimising total inventory costs, while making sure that demand is met in each month.

- The linear programming method is easy to build and implement using open office excel, which the client has access to.
- The order size and reorder point will be different every cycle, which will accommodate the dynamic demand.

## 8.3 Inventory model formulation

The objective of the inventory model is to find optimal order quantities that will minimise the total inventory costs. For this project, the total inventory costs are the ordering costs and the carrying costs.

Linear programming was used to formulate the inventory model.

### 8.3.1 Model Assumptions

- The model assumes that the demand is met in all the time periods, i.e. there are no shortages.
- There are no backorders.
- An order is only placed once all of the demand has been depleted.
- The planning period is 12 months.
- The order quantity is placed at the beginning of the month.
- The order quantity will be a summation of the demand in k periods.

### 8.3.2 Model Variables and parameters

**Variables**

Let:

$Y_i \triangleq \begin{cases} 1 \text{ if we place an order in month i} \\ 0 \text{ if we do not place an order in month i} \end{cases}$ ; The variable that determines if we place an order in month $i$, where $i$ = {1,2,…,12}

$x_i \triangleq$ The order quantity in month $i$, where $i$ = month {1,2,…,12}

**Parameters**

The parameters for the model are the carrying costs and the ordering costs. These are different for every supplier.

$s =$ ordering costs

$c =$ carrying costs

### 8.3.3 Model

**Explanation of objective function**

The objective function of the model is divided into two parts. The parts will be explained and derived in the next paragraph.

**Part A**

$\sum_{i=1}^{12} sY_i \longrightarrow$ This part describes the ordering costs. It is a summation over 12 time periods. If an order is place for month $i$, where $i$ = {1, 2,….,12}, the variable will be one and the cost will

be included in the summation. If an order is not placed, the variable will be zero and the ordering cost will therefore be excluded from the summation.

**Part B**

$c\ (12x_1 + 11x_2 + 10x_3 + 9x_4 + 8x_5 + 7x_6 + 6x_7 + 5x_8 + 4x_9 + 3x_{10} + 2x_{11} + x_{12}\ )$ ⟶

Part B was calculated using ending inventory denoted as *E*. The carrying costs are associated with inventory that is in stock. The ending inventory *E* at the end of each month was formulated as follows:

$E_i$ = Ending inventory at the end of month $i$ where $i$ = {1,2,3,..,12}

$D_i$ = Demand required in month $i$ where $i$ = {1,2,3,..,12}

Month 1: $E_1 = X_I - D_1$

Month 2: $E_2 = X_I + X_2 - D_1 - D_2$

Month 3: $E_3 = X_I + X_2 + X_3 - D_1 - D_2 - D_3$

Month 4: $E_4 = X_I + X_2 + X_3 + X_4 - D_1 - D_2 - D_3 - D_4$

Month 5: $E_5 = X_I + X_2 + X_3 + X_4 + X_5 - D_1 - D_2 - D_3 - D_4 - D_5$

Month 6: $E_6 = X_I + X_2 + X_3 + X_4 + X_5 + X_6 - D_1 - D_2 - D_3 - D_4 - D_5 - D_6$

Month 7: $E_7 = X_I + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 - D_1 - D_2 - D_3 - D_4 - D_5 - D_6 - D_7$

Month 8: $E_8 = X_I + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 - D_1 - D_2 - D_3 - D_4 - D_5 - D_6 - D_7 - D_8$

Month 9: $E_9 = X_I + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 - D_1 - D_2 - D_3 - D_4 - D_5 - D_6 - D_7 - D_8 - D_9$

Month 10: $E_{10} = X_I + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} - D_1 - D_2 - D_3 - D_4 - D_5 - D_6 - D_7 - D_8 - D_9 - D_{10}$

Month 11: $E_{11} = X_I + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} - D_1 - D_2 - D_3 - D_4 - D_5 - D_6 - D_7 - D_8 - D_9 - D_{10} - D_{11}$

Month 12: $E_{12} = X_I + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} - D_1 - D_2 - D_3 - D_4 - D_5 - D_6 - D_7 - D_8 - D_9 - D_{10} - D_{11} - D_{12}$

The summation of the ending inventory for all 12 months = $E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7 + E_8 + E_9 + E_{10} + E_{11} + E_{12}$

This summation will therefore be:

$12x_1 + 11x_2 + 10x_3 + 9x_4 + 8x_5 + 7x_6 + 6x_7 + 5x_8 + 4x_9 + 3x_{10} + 2x_{11} + x_{12}$ - $12D_1 - 11D_2 - 10D_3 - 9D_4 - 8D_5 - 7Dx_6 - 6D_7 - 5D_8 - 4D_9 - 3D + 2D_{11} - D_{12}$

The equation above represents the summation of the ending inventory for 12 months. The equation was used in the objective function to minimise the total carrying costs for 1 year. The demand $D_i$ was excluded in the objective function because it is a known variable.

**Objective Function**

Min $\sum_{i=1}^{12} sY_i + c\ (12x_1 + 11x_2 + 10x_3 + 9x_4 + 8x_5 + 7x_6 + 6x_7 + 5x_8 + 4x_9 + 3x_{10} + 2x_{11} + x_{12}\ )$

**Constraints**

$\sum_{n=1}^{i} X_n \geq \sum_{n=1}^{i} D_n$ for all $i = \{1,2,3,4,5,6,7,8,9,10,11,12\}$ (1)

(This constraint ensures that the demand is met every month for all months)

$X_i \leq MY_i$ for all $i = \{1,2,3,4,5,6,7,8,9,10,11,12\}$ (2)

(This constraint links the binary variable to the integer variable)

$Y_i$ = {0,1} (Binary Variable) for all $i = \{1,2,3,4,5,6,7,8,9,10,11,12\}$ (3)

$X_i$ = integer for all $i = \{1,2,3,4,5,6,7,8,9,10,11,12\}$ (4)

### 8.3.4 Safety Stock

(Stevenson, 2014) states that safety stock protects against stock outs. It is kept in storage to protect against any stock outs that many occur due to discrepancies in demand forecasts and problems during lead time.

The safety stock for this project will not affect the inventory model. It is calculated and ordered at the beginning of the year together with the first order of the year. The safety stock for each item will be different. It will remain in storage until it is needed to balance the inventory levels.

The safety stock is calculated as follows:

Safety stock = (maximum daily usage × maximum lead time) – (Average daily usage × average lead time)

# 9. Proposed Solution Implementation

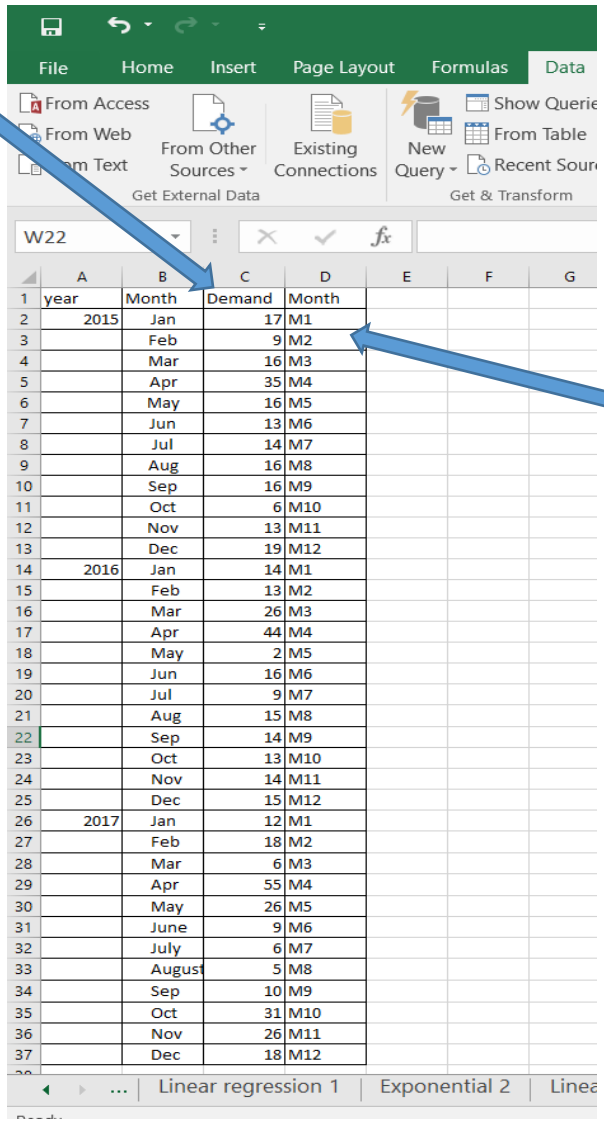
## 9.1 Model Implementation using item two's data

The aforementioned multiple linear regression model and the inventory model that were formulated form a combined solution for this project. The two models were built on MS Excel.

In order to illustrate how the combined model works and how it will be used in the company going forward, item two is going to be used as an example to plan for this years (2018) inventory. The model will produce results which will then be interpreted.

- Step 1: Part 1 is using the forecast model. Pull up the historic data for item two. The data was condensed to the year, month and demand for confidentiality reasons.

Past Sales over the last three years

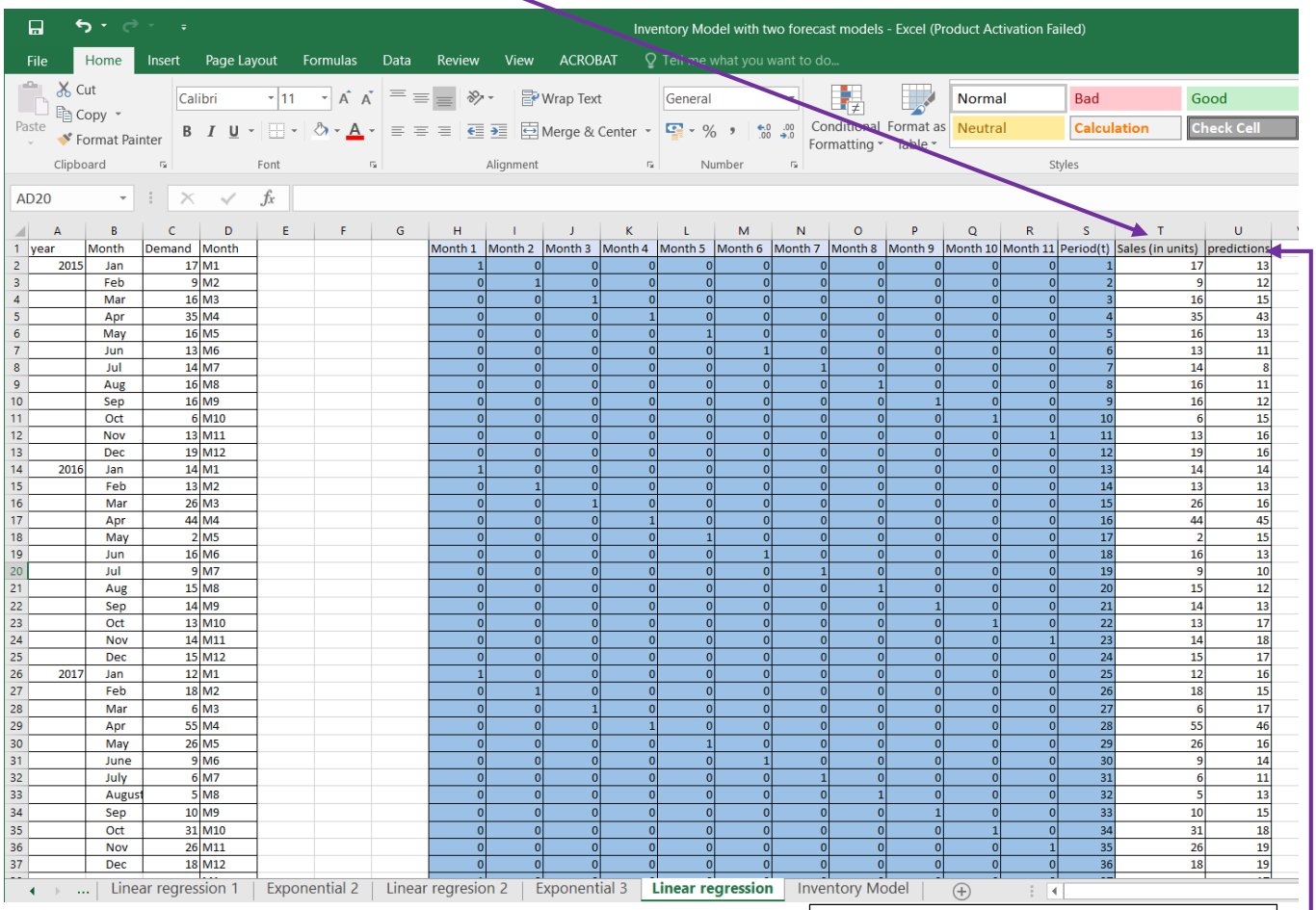



| | A | B | C | D |
|---|---|---|---|---|
| 1 | year | Month | Demand | Month |
| 2 | 2015 | Jan | 17 | M1 |
| 3 | | Feb | 9 | M2 |
| 4 | | Mar | 16 | M3 |
| 5 | | Apr | 35 | M4 |
| 6 | | May | 16 | M5 |
| 7 | | Jun | 13 | M6 |
| 8 | | Jul | 14 | M7 |
| 9 | | Aug | 16 | M8 |
| 10 | | Sep | 16 | M9 |
| 11 | | Oct | 6 | M10 |
| 12 | | Nov | 13 | M11 |
| 13 | | Dec | 19 | M12 |
| 14 | 2016 | Jan | 14 | M1 |
| 15 | | Feb | 13 | M2 |
| 16 | | Mar | 26 | M3 |
| 17 | | Apr | 44 | M4 |
| 18 | | May | 2 | M5 |
| 19 | | Jun | 16 | M6 |
| 20 | | Jul | 9 | M7 |
| 21 | | Aug | 15 | M8 |
| 22 | | Sep | 14 | M9 |
| 23 | | Oct | 13 | M10 |
| 24 | | Nov | 14 | M11 |
| 25 | | Dec | 15 | M12 |
| 26 | 2017 | Jan | 12 | M1 |
| 27 | | Feb | 18 | M2 |
| 28 | | Mar | 6 | M3 |
| 29 | | Apr | 55 | M4 |
| 30 | | May | 26 | M5 |
| 31 | | June | 9 | M6 |
| 32 | | July | 6 | M7 |
| 33 | | August | 5 | M8 |
| 34 | | Sep | 10 | M9 |
| 35 | | Oct | 31 | M10 |
| 36 | | Nov | 26 | M11 |
| 37 | | Dec | 18 | M12 |

This column was created because it was used for building the regression model

- Step 2: Copy and paste the demand in the correct column under Sales (in units). The built in model will automatically calculate the predictions for all the previous years.

Copy and Paste demand in the Sales (in units) column

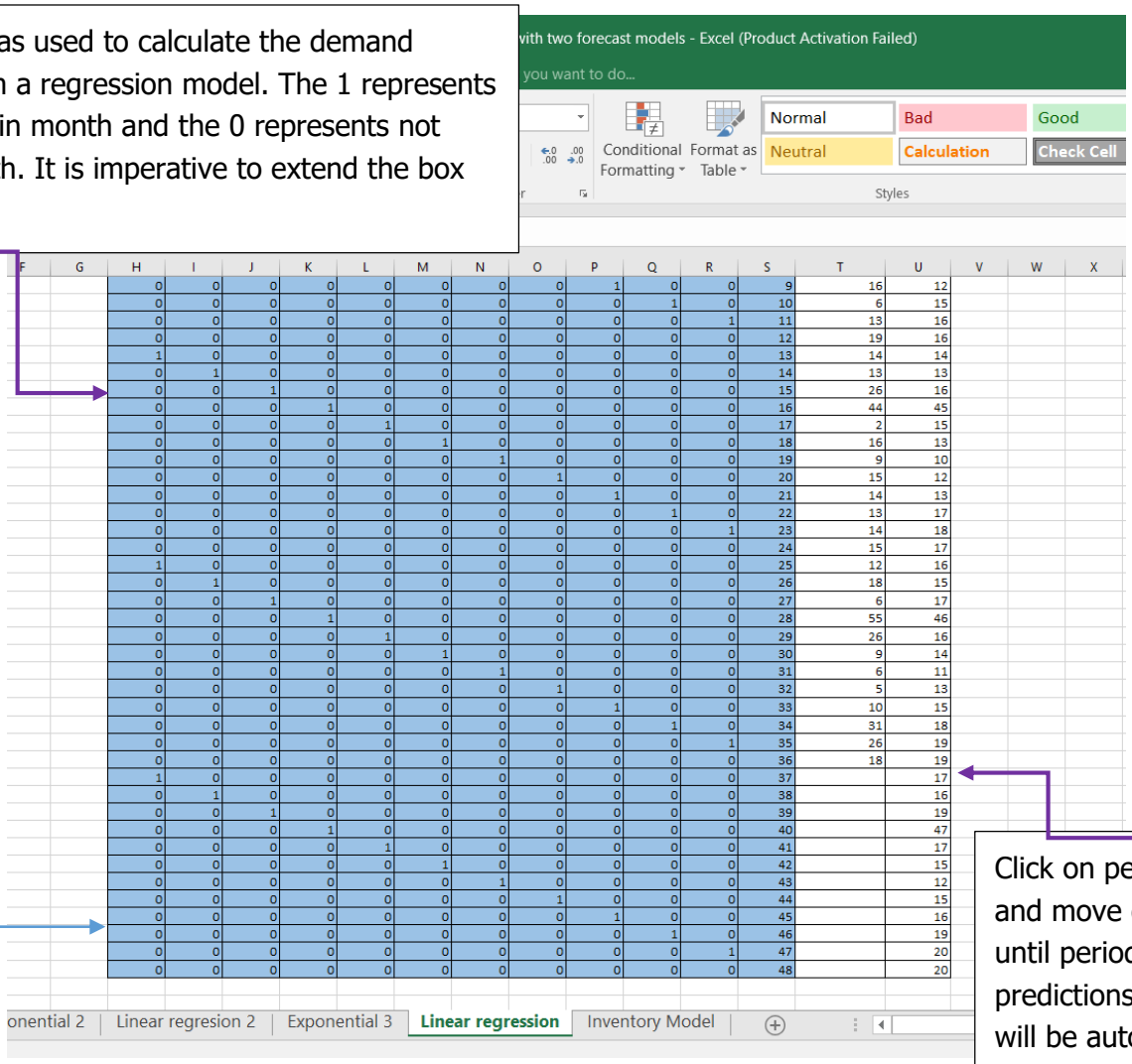



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | year | Month | Demand | Month | | | | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 | Month 7 | Month 8 | Month 9 | Month 10 | Month 11 | Period(t) | Sales (in units) | predictions |
| 2 | 2015 | Jan | 17 | M1 | | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 17 | 13 |
| 3 | | Feb | 9 | M2 | | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 12 |
| 4 | | Mar | 16 | M3 | | | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 16 | 15 |
| 5 | | Apr | 35 | M4 | | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 35 | 43 |
| 6 | | May | 16 | M5 | | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 16 | 13 |
| 7 | | Jun | 13 | M6 | | | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 6 | 13 | 11 |
| 8 | | Jul | 14 | M7 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 7 | 14 | 8 |
| 9 | | Aug | 16 | M8 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 | 16 | 11 |
| 10 | | Sep | 16 | M9 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 9 | 16 | 12 |
| 11 | | Oct | 6 | M10 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 10 | 6 | 15 |
| 12 | | Nov | 13 | M11 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 13 | 16 |
| 13 | | Dec | 19 | M12 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 19 | 16 |
| 14 | 2016 | Jan | 14 | M1 | | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 14 | 14 |
| 15 | | Feb | 13 | M2 | | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 13 | 13 |
| 16 | | Mar | 26 | M3 | | | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 26 | 16 |
| 17 | | Apr | 44 | M4 | | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 44 | 45 |
| 18 | | May | 2 | M5 | | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 2 | 15 |
| 19 | | Jun | 16 | M6 | | | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 18 | 16 | 13 |
| 20 | | Jul | 9 | M7 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 19 | 9 | 10 |
| 21 | | Aug | 15 | M8 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 20 | 15 | 12 |
| 22 | | Sep | 14 | M9 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 21 | 14 | 13 |
| 23 | | Oct | 13 | M10 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 22 | 13 | 17 |
| 24 | | Nov | 14 | M11 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 23 | 14 | 18 |
| 25 | | Dec | 15 | M12 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 15 | 17 |
| 26 | 2017 | Jan | 12 | M1 | | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 12 | 16 |
| 27 | | Feb | 18 | M2 | | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 18 | 15 |
| 28 | | Mar | 6 | M3 | | | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 6 | 17 |
| 29 | | Apr | 55 | M4 | | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 55 | 46 |
| 30 | | May | 26 | M5 | | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 26 | 16 |
| 31 | | June | 9 | M6 | | | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 30 | 9 | 14 |
| 32 | | July | 6 | M7 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 31 | 6 | 11 |
| 33 | | August | 5 | M8 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 32 | 5 | 13 |
| 34 | | Sep | 10 | M9 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 33 | 10 | 15 |
| 35 | | Oct | 31 | M10 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 34 | 31 | 18 |
| 36 | | Nov | 26 | M11 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 35 | 26 | 19 |
| 37 | | Dec | 18 | M12 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 18 | 19 |

Predictions are automatically calculated with built in formulas

❖ Step 3: Extend the column in blue for the next 12 months.

The blue box was used to calculate the demand predictions from a regression model. The 1 represents being in a certain month and the 0 represents not being in a month. It is imperative to extend the box




Click on period 37 and move down until period 48. The predictions for 2018 will be automatically calculated

❖ Step 4: Calculate the inventory costs for the item. For item two, the inventory costs are calculated below.

**Table 4 Ordering Costs for item two**

| **Ordering Cost** | **Amount (in rands)** |
|---|---|
| Cost to prepare order requisition | 500 |
| Cost to prepare and issue a payment to the supplier | 372 |
| Cost to ship order from supplier | 697 |
| Cost to clear a shipment through customs | 380 |
| **Total Costs** | 1949 |

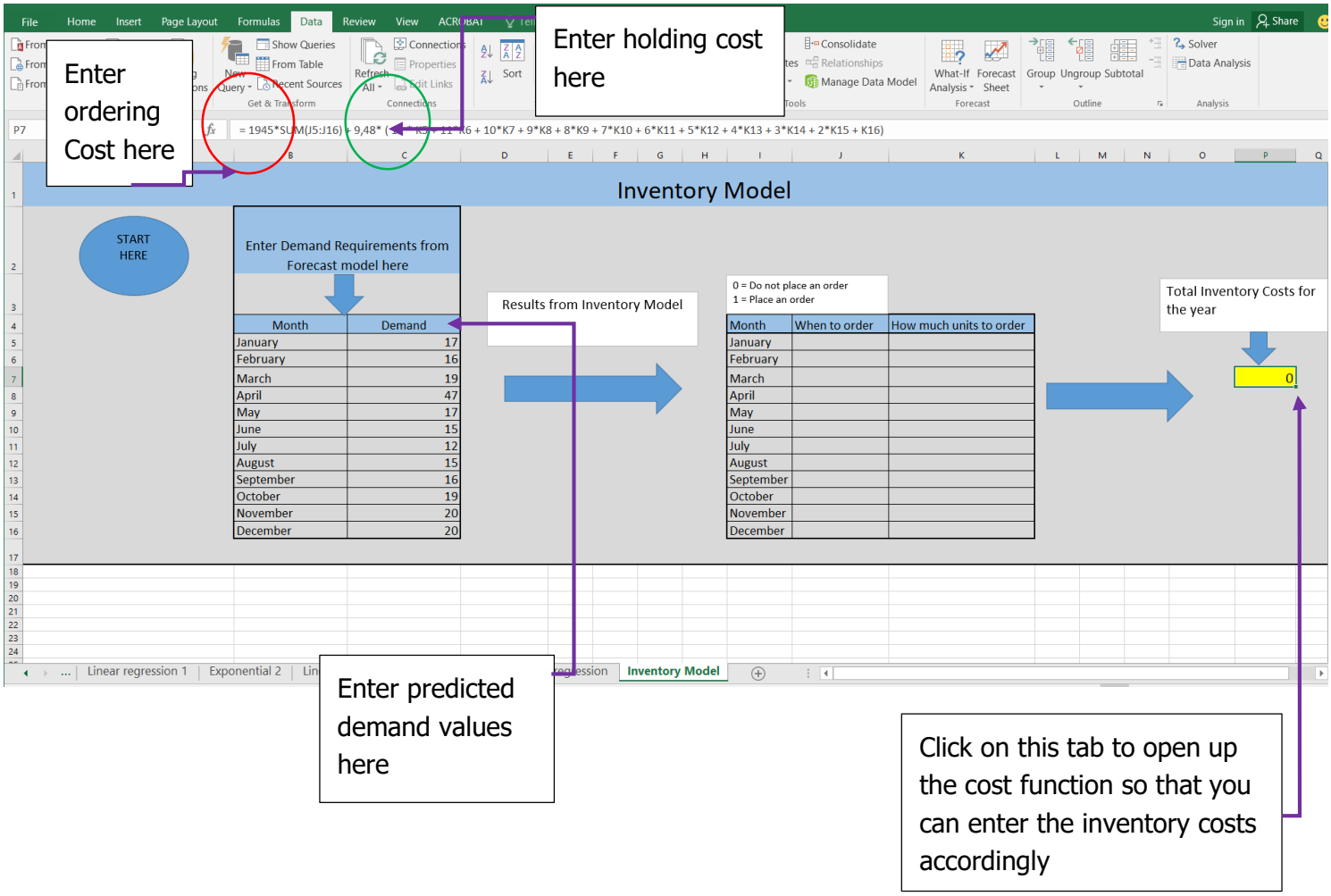
**Table 5 Holding Costs for item two**

| **Holding Cost** | **Percentage** |
|---|---|
| Insurance on the warehouse area | 0.06% of unit costs per year |
| Finance Cost | 18% of unit cost per year |
| Redundancy cost | 0.75% of unit cost per year |
| **Total** | 18,81% of unit cost per year |

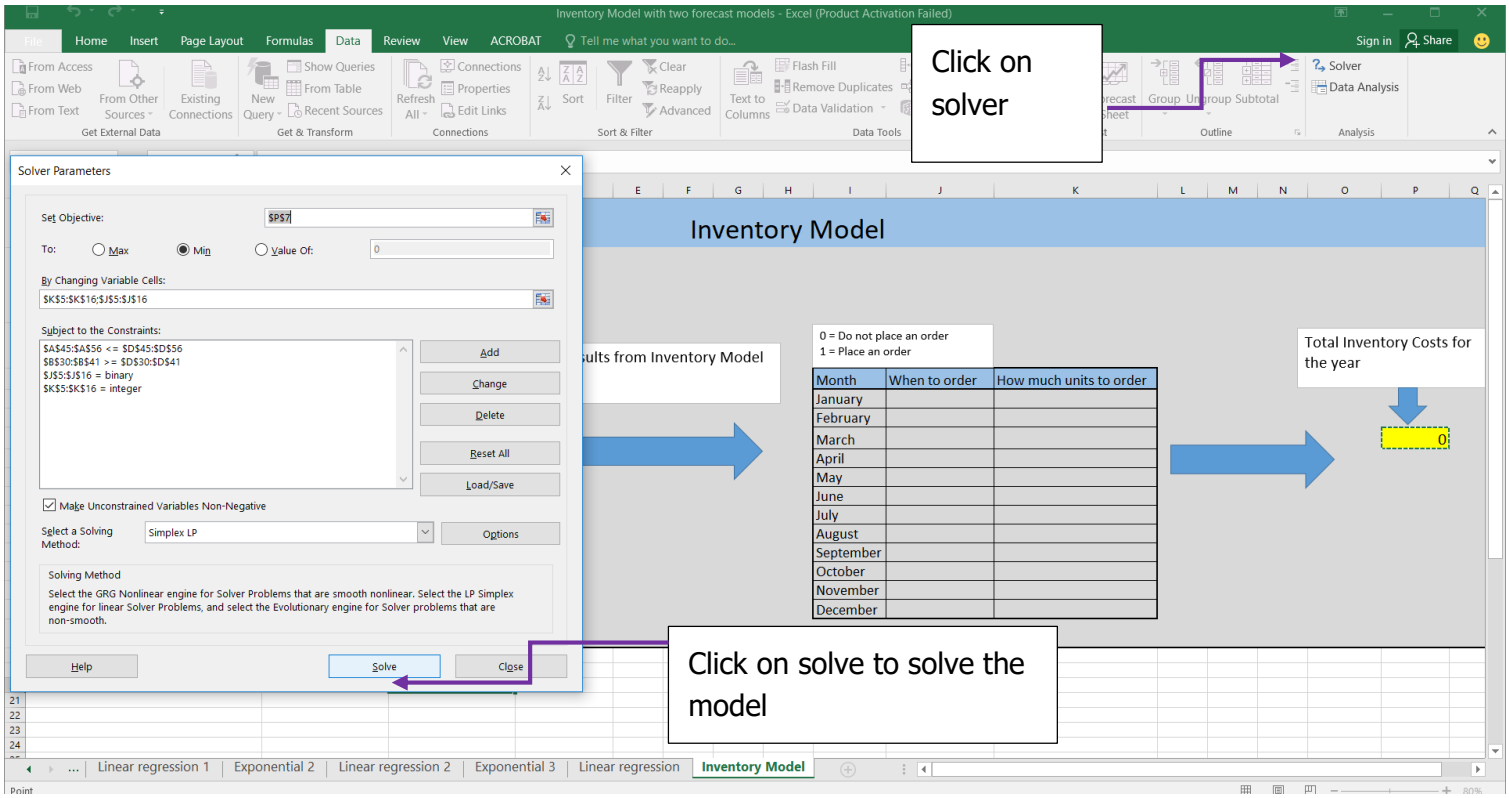
Unit cost = 626

Holding Cost per month = 18,81% * 626/12 = 9.48 per month

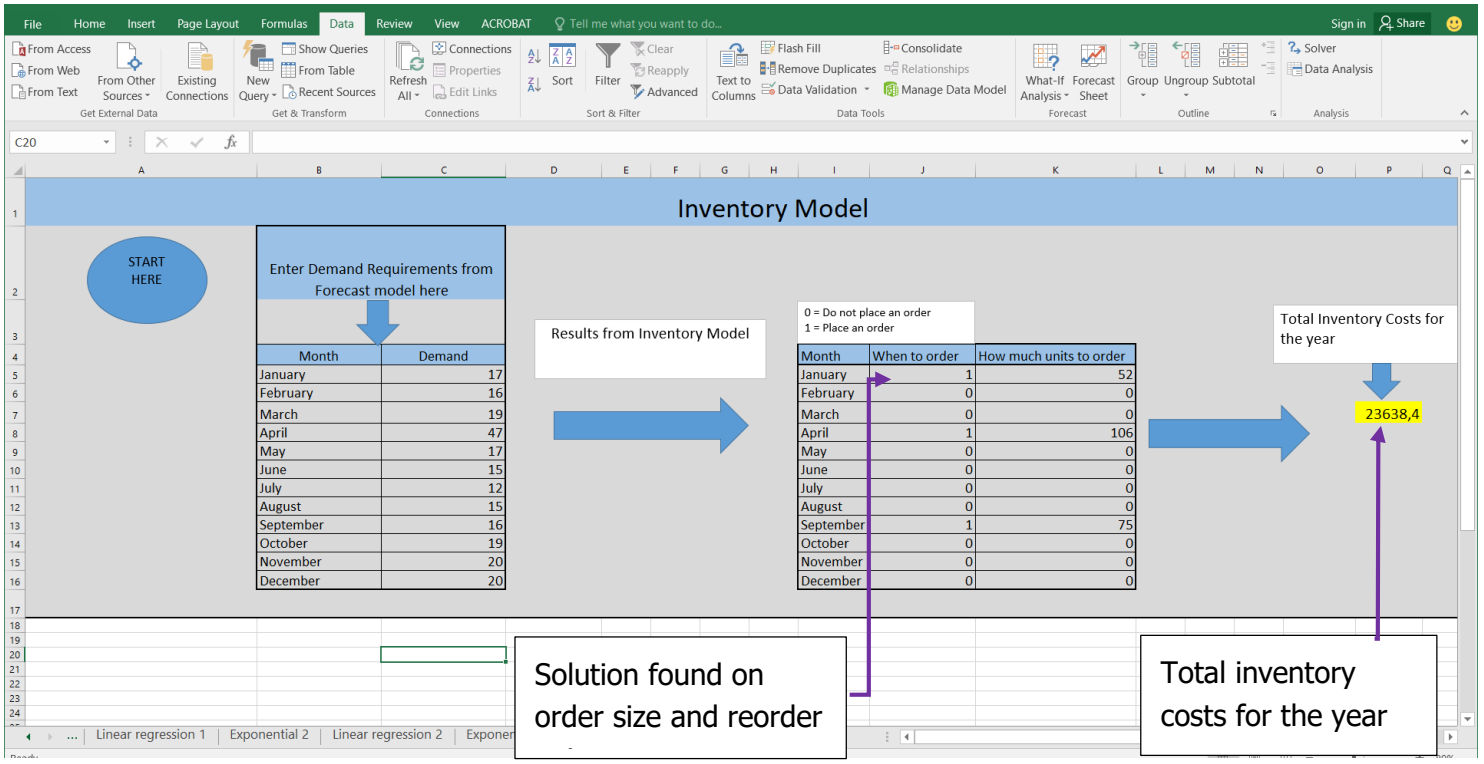
- Step 5: Click on the inventory model sheet and enter the forecasted demand values and the inventory costs accordingly.



- Step 5: The inventory model has been built in the excel document, it will automatically calculate the order size and reorder point for the forecasted demand in 2018. Click on data, go to solver and solve the model.




- Step 6: The model has found a solution, which needs to be interpreted.



## 9.2 Item two results interpretation

### 9.2.1 Forecast model results for item two

The table below contains the results from the forecast model. The model predicted the demand values for 2018.

**Table 6 Forecast Model results for item two**

| Month | Demand (in units) |
|---|---|
| January | 17 |
| February | 16 |
| March | 19 |
| April | 47 |
| May | 17 |
| June | 15 |
| July | 12 |
| August | 15 |
| September | 16 |
| October | 19 |
| November | 20 |
| December | 20 |

### 9.2.2 Inventory Model results for item two

The table below contains the results from the inventory model. The 1 implies that an order should be placed in that month and the 0 implies that no order will be placed in that month.

The results show that in order to minimise costs for 2018, 3 orders have to be placed in the year. An order of 52 units in January, an order of 106 units in April and an order of 75 units in September.

The order placed for January will be enough to satisfy the demand for January, February, and March.

The order placed for April will be enough to satisfy the demand for April, May, June, July, and August.

The order placed for September will be enough to satisfy the demand for September, October November, and December.

**Table 7 Inventory model results for item two**

| Month | When to order | How much units to order |
|---|---|---|
| January | 1 | 52 |
| February | 0 | 0 |
| March | 0 | 0 |
| April | 1 | 106 |
| May | 0 | 0 |
| June | 0 | 0 |
| July | 0 | 0 |
| August | 0 | 0 |
| September | 1 | 75 |
| October | 0 | 0 |
| November | 0 | 0 |
| December | 0 | 0 |

The total inventory costs incurred for 2018 using the model is R 23 638,40.

# 10. Model Validation

In order for the model to be useful, it should measure what it was intended to measure and support the intended uses and purposes. This section of the report illustrates using items from the company that both the forecast model and the inventory model achieve the intended uses and purposes; they do what they were designed to do.

## 10.1 Forecast Model Validation

The purpose of the model is to predict the demand for a time period of 12 months using historical data.

This model can be validated by comparing the actual sales in 2015, 2016 and 2017 with the model prediction values. If the error is low, then the model is good enough to be used for future predictions. Item four's data was used to compare the values.

**Table 8 Supplier 4's observed values vs. forecasted values**

| Year | Month | Observed Demand | Forecasted Demand | Error |
|---|---|---|---|---|
| **2015** | January | 4 | 7 | 3 |
| | February | 6 | 8 | 2 |
| | March | 10 | 7 | 3 |
| | April | 12 | 12 | 0 |
| | May | 9 | 11 | 2 |
| | June | 7 | 7 | 0 |
| | July | 7 | 9 | 2 |
| | August | 8 | 7 | 1 |
| | September | 8 | 12 | 4 |
| | October | 10 | 7 | 3 |
| | November | 7 | 9 | 2 |
| | December | 11 | 10 | 1 |
| **2016** | January | 13 | 10 | 3 |
| | February | 15 | 11 | 4 |
| | March | 9 | 10 | 1 |
| | April | 14 | 15 | 1 |
| | May | 13 | 14 | 1 |
| | June | 12 | 10 | 2 |
| | July | 15 | 12 | 3 |
| | August | 9 | 10 | 1 |
| | September | 19 | 15 | 4 |
| | October | 11 | 10 | 1 |
| | November | 10 | 12 | 2 |
| | December | 14 | 13 | 1 |
| **2017** | January | 12 | 13 | 1 |
| | February | 11 | 14 | 3 |
| | March | 10 | 13 | 3 |
| | April | 19 | 18 | 1 |
| | May | 19 | 17 | 2 |
| | June | 12 | 13 | 1 |
| | July | 14 | 15 | 1 |
| | August | 13 | 13 | 0 |
| | September | 18 | 18 | 0 |
| | October | 8 | 13 | 5 |
| | November | 19 | 15 | 4 |
| | December | 14 | 16 | 2 |

It can be concluded from the table that model is a good one because the error is low.

## 10.2 Inventory model Validation

The purpose of the inventory model is to give as an output the size of the optimal quantities and reorder points in order to minimise total inventory costs. For this project, the total inventory costs of last year (2017) for the 3 items that were compared earlier in the paper were analysed and calculated. In order for the model to be valid, the total inventory costs produced by the model should be significantly lower than the actual total inventory costs that were incurred last year.

The inventory model was validated using the following steps:

- Three items were used to validate the model.
- The actual total inventory costs for 2017 for each item were collected, analysed and calculated. These are the actual costs that were incurred in 2017 and were compared against the model results.
- The forecast model was used to predict the demand for 12 months for all three items in 2017.
- The demand values from the forecast model and the inventory costs were used as inputs in the inventory model.
- The optimal order quantities and reorder points were determined by the inventory model for each item for 2017.
- The results from the model for all three items were compared against the actual results from 2017

The table in the next page depicts the various costs of the three items that make up the holding costs and the ordering costs. The cost information in the table was used to calculate the total inventory costs for each item, which would subsequently be used to calculate both the actual total incurred costs for 2017 and also be used as inputs in the inventory model. The table also shows the actual number of orders placed for each item and the order size. The information about the actual order size and number of orders placed aided in calculating the actual costs that were incurred in 2017.

The table below depicts the various cost information and stock information for three selected items in the company.

**Table 9 Inventory Costs and actual order size of three items for 2017**

| | | Item 1 | Item 2 | Item 3 |
|---|---|---|---|---|
| **Ordering Costs** | | | | |
| | Costs to prepare order requisition | 2000 | 1000 | 250 |
| | Cost to prepare and issue a payment to the supplier | 372 | 0 | 0 |
| | Cost to ship order from supplier | 6250 | 0 | 180 |
| | Cost to clear a shipment through customs | 1950 | 0 | 0 |
| **Holding Costs** | | | | |
| | Insurance on the warehouse area | 0.6% per year | 0.6% per year | 0.6% per year |
| | Finance cost (for holding costs) | 18% per year | 18% per year | 18% per year |
| | Redundancy cost | 0.5% per year | 0.25% per year | 0.75% per year |
| **Number of orders placed in 2017 by company** | | 1 | 11 | 10 |
| **Actual order size in 2017** | | 453 | 20 or 30 | 25 or 30 |

The table below depicts the calculated inventory costs derived from the table above.

**Table 10 Inventory Costs per item**

| | Item 1 | Item 2 | Item 3 |
|---|---|---|---|
| **Holding Cost per item (%)** | 19.1 | 18.85 | 19.35 |
| **Unit Cost per item (R)** | 47 | 295 | 50 |
| **Holding cost per item (R)** | 0.75 | 4.63 | 0.81 |
| **Ordering cost per item (R)** | 10572 | 1000 | 430 |

The actual costs that were incurred for each item were calculated and compared against the results from the model. The following table depicts the model results against the actual results.

**Table 11 Model Results against Actual Results**

| | | Item 1 | Item 2 | Item 3 |
|---|---|---|---|---|
| | Model Results | | | |
| **Stock Information** | Reorder Points (in months) and order size (in units) | January<br>313 units | January 48 units<br>April 100 units<br>September 71 units | January 83 units<br>June 160 units |
| | Total units needed for the year 2017 based on demand | 348 | 222 | 246 |
| | Safety Stock calculated for 2017 (acts as a buffer) | 53 | 14 | 30 |
| | Amount of Safety Stock Needed to meet demand | 35 | 3 | 3 |
| **Cost Information** | Total Holding Costs and Ordering Costs | 11870.28 | 4347.3 | 1372.7 |
| | Safety Stock Costs | 37.28 | 70.64 | 24.56 |
| | Total Costs | 11907.56 | 4417.94 | 1397.26 |
| | | | | |
| | Actual Results | | | |
| **Stock Information** | Reorder Points (in months) and order size (in units) | January 453 units | January – February 20 units<br>March-June 30 units<br>July – November 20 units | January-February 30 units<br>March-October 25 units |
| | | | | |
| **Cost Information** | Total Carrying Costs | 1894.5 | 2074.24 | 230.04 |
| | Total ordering costs | 10572 | 11000 | 4300 |
| | Total Costs | 12466.50 | 13074.24 | 4530.04 |
| **Cost Saving** | | **558.94** | **8656.30** | **3132.78** |

The table above shows that the model produces results that minimise the total inventory costs; there is a significant cost saving for each item when the model is used. This validates that the model is doing what it was designed to do.

The safety stock calculations for the model results section and the calculations for the carrying costs and the ordering costs in the actual results section can be found in appendix C.

# 11. Conclusion

The aim of the project was to establish an inventory management process that the company could use to balance their inventory levels while minimising the total inventory costs.

To achieve an adequate stock process, a forecast model and an inventory model were developed and built on excel. An ABC analysis was developed as the first step to solving the problem. The ABC analysis was performed so that the inventory could be segmented into three different groups depending on how much profit the products generate. The purpose of the ABC analysis in this project was to highlight the products that the company should focus on as an initial step to improving their stock process.

Two alternatives were considered for the forecast model, namely the multiple linear regression model and the exponential smoothing model. The models were both built on excel and tested using three A items (items that generate the most income in the company) from the company. For both models, the demand for 24 months was forecasted for each of the three items and then compared against the actual demand for the 24 months. The graphs of the actual demand and the forecasted demand for all three items showed that the multiple linear regression model produced demand results that had the least error.

To verify that the multiple linear regression does indeed produce results with the least error, the error values for both models were analysed using the mean squared error, the mean absolute deviation and the mean absolute percentage error techniques. This analysis showed that the multiple linear regression model produces results with the least error, and thus the model was selected as the forecast model that the company should use to forecast the demand.

An inventory model using linear programming was developed to minimise the total inventory costs. The model has three inputs; the forecasted demand from the multiple linear regression model, the holding costs and the ordering costs. The forecast model is not 100% accurate, so to account for that safety stock is used as a buffer.

The inventory model and the forecast model form a combined solution for the problem. The combined solution ensures that the demand with the lowest error is predicted, which implies that the trend and seasonality that exists in the demand will be taken into consideration. It will also ensures that the total inventory costs will be minimised. The combined solution will thus meet the customer demand while minimising the inventory costs.

## References

CHUANG, C.-H. & CHIANG, C.-Y. 2016. Dynamic and stochastic behavior of coefficient of demand uncertainty incorporated with EOQ variables: An application in finished-goods inventory from General Motors' dealerships. *International Journal of Production Economics,* 172**,** 95-109.

FARAHANI, R. Z., REZAPOUR, S. & KARDAR, L. 10.2 The Role of Distribution Centers and Warehouses in Logistics. *Logistics Operations and Management - Concepts and Models.* Elsevier.

GULATI, R. 5.3.1 Inventory Classifications. *Maintenance and Reliability Best Practices (2nd Edition).* Industrial Press.

JOHN J COYLE, C. J. L. J., ROBERT A NOVACK, BRIAN J GIBSON 2016. Supply Chain Management, A Logistics Perspective. Cengage Learning.

JOHN J. COYLE, C. J. L. J., ROBERT A. NOVACK, BRIAN J. GIBSON 2016. Supply Chain Management, A Logistics Perspective. Cengage Learning.

MADDAH, B. & NOUEIHED, N. 2017. EOQ holds under stochastic demand, a technical note. *Applied Mathematical Modelling,* 45**,** 205-208.

MUBIRU, P. K. 2010. A Markov decision model for optimising economic production lot size under stochastic demand. *ORiON,* vol. 26, no. 1 . pp. 45-52.

NAYAK, R. & PADHYE, R. 4.6.2 Average Days of Inventory in Hand. *Garment Manufacturing Technology.* Elsevier.

SALVENDY, G. 77.1.2.2 Evaluating the Cost of an Inventory Policy. *Handbook of Industrial Engineering - Technology and Operations Management (3rd Edition).* John Wiley & Sons.

SAMAK-KULKARNI, S. M. & RAJHANS, N. R. 2013. Determination of Optimum Inventory Model for Minimizing Total Inventory Cost. *Procedia Engineering,* 51**,** 803-809.

STEVENSON, W. J. 2014. Operations Management, Twelfth Edition, Global Edition. McGraw-Hill Education.

YADAV, S. R. & MALIK, A. K. 21.2 Inventory. *Operations Research.* Oxford University Press.

Agostinho Agra, Michael Poss, Micael Santos 2018. *Optimizing make-to-stock policies through a robust lot-sizing model*. International Journal of Production Economics,Volume 200,Pages 302-310,ISSN 0925-5273

## Appendix A

The appendix consists of the mentorship form.

**Department of Industrial & Systems Engineering**
**University of Pretoria**

**Final Year Project Mentorship Form**
**2018**

**Introduction**

An industry mentor is the key contact person within a company for a final year project student. The mentor should be the person that could provide the best guidance on the project to the student and is most likely to gain from the success of the project.

The project mentor has the following important responsibilities:

1. To select a suitable student/candidate to conduct the project.
2. To confirm his/her role as project mentor, duly authorised by the company by signing this **Project Mentor Form**. Multiple mentors can be appointed, but is not advised.
3. To ensure that the **Project Definition** adequately describes the project.
4. To review and approve the **Project Proposal**, ensuring that it clearly defines the problem to be investigated by the student and that the project aim, scope, deliverables and approach is acceptable.
5. To review and approve all subsequent project reports, particularly the **Final Project Report** at the end of the second semester, thereby ensuring that information is accurate and the solution addresses the problems and/or design requirements of the defined project.
6. Ensure that sensitive confidential information or intellectual property of the company is not disclosed in the document and/or that the necessary arrangements are made with the Department regarding the handling of the reports.

**Project Mentor Details**

| | |
|---|---|
| Company: | Jizni CZ Accessories |
| Project Description: | Stock optimisation for an online business |
| Student Name: | Palesa Maringa |
| Student number: | 14069815 |
| Student Signature: | Pmaringa |
| **Mentor Name:** | Marius van Bijon |
| **Designation:** | Owner. |
| **E-mail:** | admin@jizni.co.za. |
| **Tel No:** | |
| **Cell No:** | 083 304 0940 |
| **Fax No:** | |
| **Mentor Signature:** |  |

## Appendix B

The appendix contains the ABC analysis that was performed for the company. The ABC analysis will help the company to control the items differently based on the category.

| Product Name | Quantity Sold | Total Sales (Annual Consumption) | Cumulative Consumption (ZAR) | Cumulative Consumption (%) | ABC category |
|---|---|---|---|---|---|
| Shockbottle case gauge | 58 | 79407 | 79407 | 3.5399 | A |
| Double Alpha aluminium grips | 58 | 58000 | 137407 | 6.1255 | A |
| CZ Competition hammer | 37 | 57664 | 195071 | 8.6961 | A |
| CZ P-07 magazine, 9mmP 15 round | 190 | 44811 | 239882 | 10.6938 | A |
| Black Mamba Full Cover (P-07) | 40 | 39000 | 278882 | 12.4323 | A |
| ET Pre B disconnector | 74 | 38155 | 317037 | 14.1333 | A |
| CAA Roni CZ7 (P-07 Gen 2 / P-09) | 4 | 36520 | 353557 | 15.7613 | A |
| CZC Extended firing pin (Shadow) | 86 | 31650 | 385207 | 17.1722 | A |
| Design Tech (med) (P-07 Gen 2) | 51 | 30510 | 415717 | 18.5323 | A |
| CR Speed EDC belt | 113 | 26985 | 442702 | 19.7353 | A |
| CGW Short Reset Kit (P-07/P-09) | 17 | 26605 | 469307 | 20.9213 | A |
| CZ Official Baseball Cap | 98 | 25536 | 494843 | 22.0597 | A |
| Design Tech (small) (P-07/09) | 45 | 25425 | 520268 | 23.1931 | A |
| CZ tritium night sights (P07/P09) | 21 | 24654 | 544922 | 24.2922 | A |
| CAA Roni CZ7 for P-07 Duty | 4 | 24348 | 569270 | 25.3776 | A |
| Inforce APL Pistol Light | 11 | 23914 | 593184 | 26.4437 | A |
| CZ P-09 magazine, 9mmP 19 round | 50 | 23661 | 616845 | 27.4985 | A |
| DPM recoil reduction system (P-07) | 27 | 23247 | 640092 | 28.5348 | A |
| CZ Custom Aluminium grips, grip tape (Shadow) | 14 | 23128 | 663220 | 29.5658 | A |
| Fiber optic rod CZC | 560 | 22750 | 685970 | 30.5800 | A |
| CZC Fiber optic front sight, 1mm (P07/P09) | 29 | 21431 | 707401 | 31.5354 | A |
| CZ Aluminium grips, Thin (Shadow) | 15 | 20692 | 728093 | 32.4578 | A |
| CZ rubber grips | 26 | 20650 | 748743 | 33.3784 | A |
| CZ Fiber optic front sight, 1mm (Shadow) | 43 | 20000 | 768743 | 34.2700 | A |
| IMI double mag pouch (P-07/09) | 46 | 19194 | 787937 | 35.1256 | A |
| DPM recoil system (SP-01 / TS Orange) | 21 | 19140 | 807077 | 35.9789 | A |
| CZ magazine, 9mmP 18 round | 80 | 18585 | 825662 | 36.8074 | A |
| Design Tech (med) (P-07 Duty) | 52 | 18480 | 844142 | 37.6312 | A |
| Sightron SIII 10-50x60 FCH | 1 | 17609 | 861751 | 38.4162 | A |
| Black Mamba (P-07) | 21 | 17157 | 878908 | 39.1810 | A |
| Sightron SIII 10-50x60 T/D | 2 | 16957 | 895865 | 39.9370 | A |
| Comp-Tac International (SP-01) | 15 | 16624 | 912489 | 40.6781 | A |
| CZ Brass grips, checkered (Shadow) | 7 | 15218 | 927707 | 41.3565 | A |
| DAA Magnetic Racer (Shadow) | 8 | 14608 | 942315 | 42.0077 | A |
| CZ magazine, 9mmP 16 round | 58 | 14430 | 956745 | 42.6510 | A |
| CZ Adjustable rear sight (Shadow) | 10 | 14130 | 970875 | 43.2809 | A |
| Range shirt | 38 | 14042 | 984917 | 43.9068 | A |
| CZC Recoil spring (Shadow) | 161 | 13806 | 998723 | 44.5223 | A |
| CR Speed World Shoot Model II | 9 | 13581 | 1012304 | 45.1277 | A |
| CZ Fiber optic front sight, 1.5mm (Shadow) | 26 | 13500 | 1025804 | 45.7296 | A |
| 02, Slide stop (CZ 75 B) | 31 | 13398 | 1039202 | 46.3268 | A |
| DAA PDR Pro (Shadow) | 11 | 13156 | 1052358 | 46.9133 | A |
| Fobus Paddle Evolution (P-07) | 30 | 12796 | 1065154 | 47.4837 | A |
| Sticky Holster (P-07) | 21 | 12789 | 1077943 | 48.0539 | A |
| Narrow 1mm fiber optic front sight (CZ 75 series | 20 | 12176 | 1090119 | 48.5967 | A |
| 1.5mm Fiber optic sights set - target (P07/P09) | 11 | 11957 | 1102076 | 49.1297 | A |
| CZ Stainless steel guide rod (Shadow) | 36 | 11840 | 1113916 | 49.6575 | A |
| CZ Aluminium grips, short (Shadow) | 7 | 11564 | 1125480 | 50.1730 | A |
| MaxTuck (P-07) | 16 | 11472 | 1136952 | 50.6844 | A |
| Kiddies range bag | 26 | 11300 | 1148252 | 51.1882 | A |
| Ross Leather IWB 16 (P-07) | 30 | 11100 | 1159352 | 51.6830 | A |
| CZC tritium front sight (P-07/P-09) | 10 | 11090 | 1170442 | 52.1774 | A |
| Mec Gar magazine, 19 round (CZ) | 40 | 11084 | 1181526 | 52.6715 | A |
| Black Mamba Full Cover (Shadow) | 11 | 11000 | 1192526 | 53.1619 | A |
| CZ flat safety set (SP-01) | 9 | 10960 | 1203486 | 53.6505 | A |
| 02, Slide stop (SP-01) | 23 | 10860 | 1214346 | 54.1346 | A |
| Competition hammer, wide | 6 | 10302 | 1224648 | 54.5939 | A |
| Appendix 2.1 (P-07) | 12 | 9912 | 1234560 | 55.0357 | A |
| Design Tech double mag pouch (P-07/09) | 27 | 9828 | 1244388 | 55.4739 | A |
| 1.5mm Fiber optic sights set - defender (P07/P0 | 9 | 9783 | 1254171 | 55.9100 | A |
| 24, 25, Sight set, standard metal (P-07 Gen 2) | 15 | 9780 | 1263951 | 56.3460 | A |
| Ross dress belt, 1.5 inch, black | 23 | 9384 | 1273335 | 56.7643 | A |

| | | | | | |
|---|---|---|---|---|---|
| CZ Team shirt | 10 | 9130 | 1282465 | 57.1713 | A |
| Hera Arms Triarii (Shadow) | 1 | 9130 | 1291595 | 57.5783 | A |
| Hogue Rubber Grips (CZ 75) | 22 | 9086 | 1300681 | 57.9834 | A |
| CZC Hammer spring (CZ) | 165 | 8820 | 1309501 | 58.3765 | A |
| IMI double mag pouch (CZ 75) | 24 | 8683 | 1318184 | 58.7636 | A |
| DPM recoil system (Glock Gen 3) | 10 | 8610 | 1326794 | 59.1475 | A |
| CZ Custom Alu grips, thick, grip tape (Shadow) | 5 | 8260 | 1335054 | 59.5157 | A |
| Viridian C5L light laser, green | 2 | 8260 | 1343314 | 59.8839 | A |
| TekMat cleaning mat (other handguns) | 62 | 8178 | 1351492 | 60.2485 | A |
| Black Mamba (CZ 75 B) | 10 | 8170 | 1359662 | 60.6127 | A |
| Black Mamba (P-09) | 8 | 8170 | 1367832 | 60.9769 | A |
| CZ Aluminium plus 2 shoe (P-07) | 20 | 8088 | 1375920 | 61.3375 | A |
| CZ Custom magazine well IDPA (CZ75) | 5 | 8045 | 1383965 | 61.6961 | A |
| Sight pusher | 4 | 7912 | 1391877 | 62.0488 | A |
| TekMat cleaning mat (CZ75) | 47 | 7830 | 1399707 | 62.3979 | A |
| DPM recoil reduction system (CZ 75) | 9 | 7749 | 1407456 | 62.7433 | A |
| CR Speed High Torque belt | 22 | 7497 | 1414953 | 63.0775 | A |
| Mamba single mag carrier (P-07/Glock) | 20 | 7434 | 1422387 | 63.4089 | A |
| Ross dress belt, 1.5 inch, tan | 18 | 7429 | 1429816 | 63.7401 | A |
| Mec Gar magazine, 17 round (CZ) | 26 | 7345 | 1437161 | 64.0675 | A |
| DPM recoil reduction system (P-09) | 6 | 7302 | 1444463 | 64.3931 | A |
| Peltor Sport Tac | 3 | 7173 | 1451636 | 64.7128 | A |
| Peltor Bull's Eye I | 17 | 7170 | 1458806 | 65.0325 | A |
| Coco bolo grips, part checker (CZ75) | 5 | 7044 | 1465850 | 65.3465 | A |
| CZ Adjustable rear sight (TS) | 5 | 6740 | 1472590 | 65.6469 | A |
| DPM recoil system (TS) | 9 | 6699 | 1479289 | 65.9456 | A |
| CR Speed Versa-Pouch | 61 | 6693 | 1485982 | 66.2439 | A |
| CZ Magazine well (Shadow) | 4 | 6608 | 1492590 | 66.5385 | A |
| Hogue Powerspeed Carry holster (P-09) | 8 | 6534 | 1499124 | 66.8298 | A |
| Meprolight night sights (CZ 75B) | 5 | 6305 | 1505429 | 67.1109 | A |
| Ross Leather IWB 15 (P-07) | 20 | 6226 | 1511655 | 67.3884 | A |
| Blade Tech OWB Holster (CZ 97B) | 6 | 6210 | 1517865 | 67.6653 | A |
| VZ Grips Tactical Diamonds | 6 | 6132 | 1523997 | 67.9386 | A |
| DAA Racer | 12 | 6090 | 1530087 | 68.2101 | A |
| Black Mamba Full Cover (CZ 75 B) | 6 | 6000 | 1536087 | 68.4776 | A |
| Ross Leather OWB 12 (P-07) | 16 | 5920 | 1542007 | 68.7415 | A |
| Ross Leather OWB 5 (P-07) | 16 | 5920 | 1547927 | 69.0054 | A |
| CZC TAC rear sight (P07/P09) | 6 | 5742 | 1553669 | 69.2614 | A |
| Hi Viz front sight | 10 | 5610 | 1559279 | 69.5115 | A |
| 1mm Fiber optic sights set - defender (P07/P09) | 5 | 5435 | 1581162 | 70.4870 | A |
| CGW Pro-package (P-01) | 1 | 5435 | 1586597 | 70.7293 | A |
| K-mag 32 round magazine (CZ 75) | 15 | 5360 | 1591957 | 70.9682 | A |
| CGW reduced spring kit - Carry (P-07 P-09) | 9 | 5283 | 1597240 | 71.2037 | A |
| Blade Tech OWB Holster (SP-01) | 12 | 5220 | 1602460 | 71.4364 | A |
| CZ Custom Comp rear HAJO (Shadow) | 3 | 5217 | 1607677 | 71.6690 | A |
| Blade Tech OWB Holster (P-09) | 6 | 5166 | 1612843 | 71.8993 | A |
| Competition hammer, low | 3 | 5151 | 1617994 | 72.1289 | A |
| Competition hammer, wide low | 3 | 5151 | 1623145 | 72.3586 | A |
| Redfield Counterstrike | 2 | 5130 | 1628275 | 72.5872 | A |
| VZ Grips Tactical Diamonds (Compact) | 5 | 5110 | 1633385 | 72.8150 | A |
| CZC H-TAC tritium rear sight (P-07/P-09) | 3 | 5088 | 1638473 | 73.0419 | A |
| CZ Custom FO Tactical rear sight (Shadow) | 4 | 5044 | 1643517 | 73.2667 | A |
| 11, Sear (Shadow) | 11 | 5000 | 1648517 | 73.4896 | A |
| Appendix 2.1 (Glock) | 6 | 4956 | 1653473 | 73.7106 | A |
| CZ magazine, 9mmP 26 round | 3 | 4956 | 1658429 | 73.9315 | A |
| Black Mamba (Glock) | 6 | 4902 | 1663331 | 74.1500 | A |
| CZ Custom magazine well IPSC (TS) | 3 | 4827 | 1668158 | 74.3652 | A |
| Extended safety, IPSC (TS) | 3 | 4827 | 1672985 | 74.5804 | A |
| 16, Hammer (Shadow) | 5 | 4785 | 1677770 | 74.7937 | A |
| Rubber magazine base (CZ 75) | 50 | 4704 | 1682474 | 75.0034 | A |
| CGW reduced spring kit - Comp (P-07 P-09) | 7 | 4696 | 1687170 | 75.2127 | A |
| Appendix 2.0 (P-07) | 9 | 4653 | 1691823 | 75.4202 | A |
| Ross Leather Shoulder 42A (P-07) | 2 | 4644 | 1696467 | 75.6272 | A |
| CZ magazine, 9mmP (Pre B) | 7 | 4566 | 1701033 | 75.8307 | A |
| 29, Safety LH (SP-01) | 5 | 4565 | 1705598 | 76.0342 | A |
| CZ Tritium night sight set (Shadow) | 2 | 4478 | 1710076 | 76.2339 | A |
| CZ 83 magazine, 9mmK 12 round | 8 | 4410 | 1714486 | 76.4305 | A |
| Hogue Powerspeed Carry holster (P-07) | 6 | 4356 | 1718842 | 76.6247 | A |
| Pachmayr Tactical rubber sleeve (CZ 75) | 25 | 4350 | 1723192 | 76.8186 | A |
| Sidewinder Pro (P-09) | 4 | 4348 | 1727540 | 77.0124 | A |
| BaseMax (P-07) | 8 | 4344 | 1731884 | 77.2061 | A |
| Hi Viz rear sight | 6 | 4278 | 1736162 | 77.3968 | A |

| | | | | | |
|---|---|---|---|---|---|
| TekMat cleaning mat (long gun) | 14 | 4176 | 1740338 | 77.5829 | A |
| Comp-Tac International (CZ 75B) | 5 | 4156 | 1744494 | 77.7682 | A |
| 05, Trigger (CZ 85 COMBAT) | 5 | 4130 | 1748624 | 77.9523 | A |
| VZ Grips Diamond Backs | 4 | 4088 | 1752712 | 78.1346 | A |
| Black Mamba (CZ 83) | 5 | 4085 | 1756797 | 78.3167 | A |
| A-Zoom snap caps (5 pack) | 19 | 4063 | 1760860 | 78.4978 | A |
| Cat laser | 3 | 4044 | 1764904 | 78.6781 | A |
| Mamba double mag carrier (CZ-75) | 6 | 4044 | 1768948 | 78.8583 | A |
| DAA Golden 20 Pocket Gauge | 5 | 4020 | 1772968 | 79.0376 | A |
| Black Mamba FC (CZ 75 D / P-01) | 4 | 4000 | 1776968 | 79.2159 | A |
| Black Mamba Full Cover (P-09) | 4 | 4000 | 1780968 | 79.3942 | A |
| Shotmaxx timer | 2 | 3914 | 1784882 | 79.5687 | A |
| DAA PDR Pro IDPA | 4 | 3912 | 1788794 | 79.7431 | A |
| CZC H-TAC rear sight (P07/P09) | 4 | 3828 | 1792622 | 79.9137 | A |
| CGW Stainless steel guide rod (P-07) | 6 | 3801 | 1796423 | 80.0832 | A |
| Black Mamba APL (P-07) | 4 | 3792 | 1800215 | 80.2522 | A |
| CZ rubber grips (Compact) | 5 | 3780 | 1803995 | 80.4207 | A |
| Fiber optic rear sight (Shadow) | 6 | 3780 | 1807775 | 80.5892 | B |
| 50, Extractor (CZ 75 B) | 19 | 3724 | 1811499 | 80.7552 | B |
| 45, Shadow front sight | 9 | 3717 | 1815216 | 80.9209 | B |
| CZC mag spring & follower kit 10 | 24 | 3700 | 1818916 | 81.0859 | B |
| Inforce WML Rifle Light | 2 | 3566 | 1822482 | 81.2448 | B |
| CGW reduced power trigger return spring | 38 | 3496 | 1825978 | 81.4007 | B |
| Lee Factory Crimp Die | 10 | 3480 | 1829458 | 81.5558 | B |
| CZ Custom Tactical rear HAJO (Shadow) | 2 | 3478 | 1832936 | 81.7109 | B |
| 27, Main spring plug, flat (P-07) | 17 | 3472 | 1836408 | 81.8657 | B |
| 41, Firing Pin Spring (Rami) | 62 | 3430 | 1839838 | 82.0186 | B |
| CZC TAC tritium rear sight (P-07/P-09) | 2 | 3392 | 1843230 | 82.1698 | B |
| CZ Buffer set (Shadow) | 53 | 3379 | 1846609 | 82.3204 | B |
| Mamba double mag carrier (P-07/Glock) | 5 | 3370 | 1849979 | 82.4706 | B |
| CZ 75 TS magazine, 17 round, 40S&W | 11 | 3346 | 1853325 | 82.6198 | B |
| Wolff Recoil spring (Shadow) | 19 | 3306 | 1856631 | 82.7672 | B |
| CZ Magazine well (TS) | 2 | 3304 | 1859935 | 82.9145 | B |
| Magazine spring, Wolff +5% (CZ 75) | 73 | 3270 | 1863205 | 83.0602 | B |
| Black Mamba (Other brands) | 4 | 3268 | 1866473 | 83.2059 | B |
| 1mm Fiber optic sights set - target (P07/P09) | 3 | 3261 | 1869734 | 83.3513 | B |
| Sticky Mag Pouch | 13 | 3260 | 1872994 | 83.4966 | B |
| CZC Extended safety (SP-01) | 2 | 3218 | 1876212 | 83.6401 | B |
| Fobus Paddle Holster (CZ 75 B) | 7 | 3199 | 1879411 | 83.7827 | B |
| CZ Custom grip screws hex | 17 | 3195 | 1882606 | 83.9251 | B |
| CZ Fiber optic rear sight (CZ75B) | 5 | 3150 | 1885756 | 84.0656 | B |
| CZ Aluminium +1 Shoe (TS) | 12 | 3132 | 1888888 | 84.2052 | B |
| Ross dress belt, 1.25 inch, black | 8 | 3128 | 1892016 | 84.3446 | B |
| 08, Trigger spring (CZ75) | 86 | 3050 | 1895066 | 84.4806 | B |
| CZ Serrated front sight (P07/P09) | 10 | 3040 | 1898106 | 84.6161 | B |
| 16, Hammer (CZ 75B) | 8 | 3019 | 1901125 | 84.7507 | B |
| Nextorch WL10X | 6 | 3000 | 1904125 | 84.8844 | B |
| UpLula | 7 | 3000 | 1907125 | 85.0182 | B |
| CZC Aluminium Mag Base (CZ 75) | 19 | 2960 | 1910085 | 85.1501 | B |
| Ross Leather OWB 5 (CZ 75) | 8 | 2960 | 1913045 | 85.2821 | B |
| CZ Plus 2 shoe (P-07 / P-09) | 57 | 2958 | 1916003 | 85.4139 | B |
| K-mag 23 round magazine (CZ 75) | 8 | 2890 | 1918893 | 85.5428 | B |
| CZ Custom H-TAC rear sight (CZ 75 B) | 3 | 2871 | 1921764 | 85.6708 | B |
| Everyday shirt | 8 | 2784 | 1924548 | 85.7949 | B |
| Extended safety, IPSC (SP-01) | 2 | 2756 | 1927304 | 85.9177 | B |
| DAA Magnetic pouch | 8 | 2742 | 1930046 | 86.0400 | B |
| CZ 97 B magazine, 10 round | 9 | 2715 | 1932761 | 86.1610 | B |
| Sidewinder (P-07) | 4 | 2696 | 1935457 | 86.2812 | B |
| 10, Ejector (CZ 75) | 3 | 2610 | 1938067 | 86.3975 | B |
| Blade Tech OWB Holster (P-07) | 6 | 2610 | 1940677 | 86.5139 | B |
| DAA PDR Belt-Ride | 6 | 2610 | 1943287 | 86.6302 | B |
| DPM recoil reduction system (CZ Compact) | 3 | 2583 | 1945870 | 86.7454 | B |
| Single action trigger, flat aluminium, adjustable | 4 | 2544 | 1948414 | 86.8588 | B |
| CZC Extended firing pin (CZ75-B) | 5 | 2532 | 1950946 | 86.9717 | B |
| CZ Custom FO Competition rear sight (Shadow) | 2 | 2522 | 1953468 | 87.0841 | B |
| Meprolight night sights (P-01) | 2 | 2522 | 1955990 | 87.1965 | B |
| DAA Deluxe magnetic pouch | 6 | 2500 | 1958490 | 87.3080 | B |
| Extended +4 magazine base (P-07) | 5 | 2412 | 1960902 | 87.4155 | B |
| Viridian C5L-R light laser, red | 1 | 2391 | 1963293 | 87.5221 | B |
| 53, Rear sight (Shadow) | 3 | 2384 | 1965677 | 87.6284 | B |
| Competition hammer (Decocker) | 2 | 2348 | 1968025 | 87.7330 | B |

| | | | | | |
|---|---|---|---|---|---|
| Competition hammer (P-07/P-09) | 1 | 2348 | 1970373 | 87.8377 | B |
| CZ Defender rear sight (P07/P09) | 4 | 2348 | 1972721 | 87.9424 | B |
| Black Mamba C5 (Glock) | 2 | 2304 | 1975025 | 88.0451 | B |
| Black Mamba CE C5 (Other brands) | 2 | 2304 | 1977329 | 88.1478 | B |
| 22,23,48 Decocking lever set (P-07/P-09) | 6 | 2220 | 1979549 | 88.2468 | B |
| Ross Leather Cross Draw 11 (P-07) | 6 | 2220 | 1981769 | 88.3457 | B |
| Ross Leather OWB 12 (P-09) | 8 | 2220 | 1983989 | 88.4447 | B |
| CZ Recoil buffer (Shadow) | 68 | 2210 | 1986199 | 88.5432 | B |
| Hi Viz sight set | 3 | 2200 | 1988399 | 88.6413 | B |
| Ross Leather OWB 23 (CZ 75) | 6 | 2190 | 1990589 | 88.7389 | B |
| Ross Leather OWB 23 (P-07) | 6 | 2190 | 1992779 | 88.8366 | B |
| Mec Gar magazine, 14 round (CZ) | 8 | 2175 | 1994954 | 88.9335 | B |
| Sidewinder Pro (P-07) | 2 | 2174 | 1997128 | 89.0304 | B |
| BaseMax (CZ 75 B) | 4 | 2172 | 1999300 | 89.1273 | B |
| CGW Stainless steel guide rod (P-09) | 4 | 2172 | 2001472 | 89.2241 | B |
| CZ Single action trigger, Tactical Sport | 4 | 2172 | 2003644 | 89.3209 | B |
| Lee Bulge Buster Kit | 7 | 2128 | 2005772 | 89.4158 | B |
| 54, Firing pin (CZ 75B) | 12 | 2088 | 2007860 | 89.5089 | B |
| 64, Safety RH (SP-01) | 3 | 2088 | 2009948 | 89.6019 | B |
| Design Tech single mag pouch (P-07/09) | 17 | 2088 | 2012036 | 89.6950 | B |
| Comp-Tac International (CZ 75 D / P-01) | 2 | 2078 | 2014114 | 89.7877 | B |
| Blade Tech OWB Holster (CZ 75B) | 2 | 2070 | 2016184 | 89.8799 | B |
| Appendix 2.0 (Glock) | 4 | 2068 | 2018252 | 89.9721 | B |
| CR Speed Model 2000 | 2 | 2060 | 2020312 | 90.0640 | B |
| VZ Grips Frag (Compact) | 2 | 2044 | 2022356 | 90.1551 | B |
| K-mag 17 round magazine (CZ 75) | 9 | 2034 | 2024390 | 90.2458 | B |
| CAA Single point sling | 3 | 2022 | 2026412 | 90.3359 | B |
| DPM recoil reduction system (CZ 97) | 2 | 2000 | 2028412 | 90.4250 | B |
| Gen 2 trigger with CGW overtravel stop (P-07 / P- | 2 | 2000 | 2030412 | 90.5142 | B |
| Double Alpha magazine brush | 13 | 1980 | 2032392 | 90.6025 | B |
| 29, Safety LH (Shadow) | 2 | 1914 | 2034306 | 90.6878 | B |
| CZ Custom Competition rear sight (Shadow) | 2 | 1914 | 2036220 | 90.7731 | B |
| CZ Recoil spring, reduced (P-07) | 11 | 1914 | 2038134 | 90.8584 | B |
| Gen 2 hammer assembly (P-07) | 4 | 1912 | 2040046 | 90.9437 | B |
| Black Mamba APL (Glock) | 2 | 1896 | 2041942 | 91.0282 | B |
| DAA magnet for CR Versa pouch | 3 | 1866 | 2043808 | 91.1114 | B |
| Fobus Paddle Holster (CZ 75 D / P-01) | 4 | 1828 | 2045636 | 91.1929 | B |
| Sticky Holster (CZ 75) | 3 | 1827 | 2047463 | 91.2743 | B |
| DAA Race Master pouch & Magnet | 2 | 1826 | 2049289 | 91.3557 | B |
| Sightron SIII Sunshade | 3 | 1826 | 2051115 | 91.4371 | B |
| 65, Slide stop RH (CZ 85) | 3 | 1788 | 2052903 | 91.5168 | B |
| 54/37, Firing pin (Shadow) | 13 | 1764 | 2054667 | 91.5955 | B |
| CZ Defender rear sight (Shadow) | 2 | 1761 | 2056428 | 91.6740 | B |
| 07, Trigger bar (CZ75) | 2 | 1740 | 2058168 | 91.7515 | B |
| CAA Flip-up sight set | 1 | 1739 | 2059907 | 91.8291 | B |
| Viridian CTL light | 1 | 1739 | 2061646 | 91.9066 | B |
| Blade Tech OWB Holster (TS) | 2 | 1722 | 2063368 | 91.9834 | B |
| DPM recoil system (M&P) | 2 | 1722 | 2065090 | 92.0601 | B |
| Folding knuckle for Triarii | 1 | 1696 | 2066786 | 92.1357 | B |
| Pocket knife (P-07) | 1 | 1696 | 2068482 | 92.2113 | B |
| CZC mag spring (10 coils) | 23 | 1672 | 2070154 | 92.2859 | B |
| CZ Custom Aluminium grips, checkered (Compac | 1 | 1652 | 2071806 | 92.3595 | B |
| CZ Custom Medium Alu grips, grip tape (TS) | 1 | 1652 | 2073458 | 92.4332 | B |
| CZ Custom Short alu grips, grip tape (Shadow) | 1 | 1652 | 2075110 | 92.5068 | B |
| DAA Golden Multi Gauge | 4 | 1652 | 2076762 | 92.5805 | B |
| Mamba single mag carrier (CZ-75) | 4 | 1652 | 2078414 | 92.6541 | B |
| Black Mamba (Shadow) | 2 | 1634 | 2080048 | 92.7269 | B |
| CZ Custom Shadow II rear sight (Shadow) | 2 | 1629 | 2081677 | 92.7996 | B |
| CZ Single action trigger, straight | 3 | 1629 | 2083306 | 92.8722 | B |
| CZ aluminium grips, checkered (Compact) | 1 | 1565 | 2084871 | 92.9419 | B |
| 11, Sear (CZ 75 B) | 4 | 1564 | 2086435 | 93.0117 | B |
| VZ Grips special order ($75) | 2 | 1556 | 2087991 | 93.0810 | B |
| Special Order: Ross Leather | 2 | 1548 | 2089539 | 93.1500 | B |
| CGW extended magazine release (P-07/P-09) | 3 | 1522 | 2091061 | 93.2179 | B |
| CZ magazine, 9mmP 16 round extended (75D Cor | 3 | 1522 | 2092583 | 93.2857 | B |
| IMI Polymer flip-up sight set | 1 | 1522 | 2094105 | 93.3536 | B |
| Lyman Brass Tapper | 4 | 1480 | 2095585 | 93.4196 | B |
| Ross Leather IWB 16 (CZ 83) | 4 | 1480 | 2097065 | 93.4855 | B |
| Ross Leather OWB 12 (CZ 75) | 4 | 1480 | 2098545 | 93.5515 | B |
| Ross Leather OWB 5 (Shadow) | 4 | 1480 | 2100025 | 93.6175 | B |
| Ross Leather OWB 7 (P-07) | 4 | 1480 | 2101505 | 93.6835 | B |

| | | | | | |
|---|---|---|---|---|---|
| DPM recoil system (1911/2011 Bull Barrel) | 1 | 1457 | 2102962 | 93.7484 | B |
| Hogue brushed aluminium grips (CZ 75) | 1 | 1457 | 2104419 | 93.8134 | B |
| Hogue matt aluminium grips (CZ 75) | 1 | 1457 | 2105876 | 93.8783 | B |
| 28, Grip Screws (CZ 75 B) | 15 | 1456 | 2107332 | 93.9432 | B |
| Hogue Powerspeed Carry holster (SP-01) | 2 | 1452 | 2108784 | 94.0080 | B |
| MaxTuck (CZ 75 B) | 2 | 1434 | 2110218 | 94.0719 | B |
| 48, 49, CZ 83 plastic grips | 5 | 1415 | 2111633 | 94.1350 | B |
| MTM 100 round ammo box | 65 | 1400 | 2113033 | 94.1974 | B |
| Hogue Handall universal grip sleeve | 9 | 1392 | 2114425 | 94.2594 | B |
| VZ Grips special order ($65) | 2 | 1348 | 2115773 | 94.3195 | B |
| Comp-Tac Single Mag Pouch (CZ75) | 3 | 1330 | 2117103 | 94.3788 | B |
| DPM recoil system (1911/2011) | 1 | 1326 | 2118429 | 94.4379 | B |
| 17, Extractor (P-07/P-09) | 3 | 1305 | 2119734 | 94.4961 | B |
| CZ magazine, 9mmP 14 round | 4 | 1305 | 2121039 | 94.5543 | B |
| 02, Slide stop (TS .40S&W) | 2 | 1304 | 2122343 | 94.6124 | B |
| 16, Narrowed Shadow hammer (CZ 75 B) | 2 | 1296 | 2123639 | 94.6702 | B |
| CZ Custom trigger pin | 10 | 1288 | 2124927 | 94.7276 | B |
| DPM recoil system (Czechmate) | 1 | 1283 | 2126210 | 94.7848 | B |
| Hogue Grim Reaper grips (CZ 75) | 1 | 1283 | 2127493 | 94.8420 | B |
| DAA Racer magazine pouch | 12 | 1266 | 2128759 | 94.8984 | B |
| CZ Magazine assembly (CZ200) | 1 | 1239 | 2129998 | 94.9537 | B |
| Sticky Holster (P-09) | 2 | 1218 | 2131216 | 95.0080 | B |
| Magazine spring, Wolff +10% (CZ 75) | 42 | 1199 | 2132415 | 95.0614 | C |
| CZ Adjustable rear sight (CZ 75 B) | 1 | 1196 | 2133611 | 95.1147 | C |
| Sidewinder (CZ 75 D / P-01) | 0 | 1192 | 2134803 | 95.1679 | C |
| CZ Defender rear sight (CZ75B) | 2 | 1174 | 2135977 | 95.2202 | C |
| CZ Target rear sight (P07/P09) | 2 | 1174 | 2137151 | 95.2726 | C |
| CZ 75 TS magazine, 20 round, 9mmP | 2 | 1130 | 2138281 | 95.3229 | C |
| CZ Single action trigger, smaller hands | 2 | 1086 | 2139367 | 95.3713 | C |
| Stainless steel magazine brake | 5 | 1085 | 2140452 | 95.4197 | C |
| Lyman Digital Trigger Pull Gauge | 1 | 1065 | 2141517 | 95.4672 | C |
| 41, Recoil spring (CZ 75 B) | 43 | 1050 | 2142567 | 95.5140 | C |
| 2mm Parallel punch | 26 | 1032 | 2143599 | 95.5600 | C |
| VZ Grips Frag | 1 | 1022 | 2144621 | 95.6056 | C |
| Progrip Lotion | 8 | 1020 | 2145641 | 95.6510 | C |
| 1.5mm Fiber optic front sight (P07/P09) | 2 | 1000 | 2146641 | 95.6956 | C |
| 1mm Fiber optic front sight (P07) | 2 | 1000 | 2147641 | 95.7402 | C |
| Black Mamba Full Cover (CZ 75 Compact) | 1 | 1000 | 2148641 | 95.7848 | C |
| CR Versa Hanger kit | 2 | 1000 | 2149641 | 95.8293 | C |
| SportEAR XT4 Hearing protector | 1 | 996 | 2150637 | 95.8737 | C |
| 21, Hammer spring (CZ 75B) | 16 | 962 | 2151599 | 95.9166 | C |
| CZ Custom Competition rear sight (CZ 75 B) | 1 | 957 | 2152556 | 95.9593 | C |
| CZ Custom Tactical rear sight (CZ 75 B) | 1 | 957 | 2153513 | 96.0020 | C |
| CZ magazine, 9mmP 16 round (Compact) | 2 | 956 | 2154469 | 96.0446 | C |
| Black Mamba APL (Other brands) | 1 | 948 | 2155417 | 96.0868 | C |
| Black Mamba APL (P-09) | 1 | 948 | 2156365 | 96.1291 | C |
| Stainless steel guide rod (SP-01) | 2 | 914 | 2157279 | 96.1698 | C |
| 55/38, Firing pin spring (CZ 75B) | 34 | 910 | 2158189 | 96.2104 | C |
| 64, Detent plunger RHS | 5 | 870 | 2159059 | 96.2492 | C |
| CZ P-07 magazine, .40S&W 12 round | 3 | 870 | 2159929 | 96.2880 | C |
| 34, Trigger bar spring (CZ 75 B) | 26 | 864 | 2160793 | 96.3265 | C |
| GG&G rail adaptor for H&K USP | 1 | 861 | 2161654 | 96.3649 | C |
| 52, Extractor spring, Wolff +25% (CZ 75) | 22 | 854 | 2162508 | 96.4029 | C |
| CAA quick release swing swivel | 6 | 850 | 2163358 | 96.4408 | C |
| Metal front sight with dot (P07) | 3 | 849 | 2164207 | 96.4787 | C |
| CZ 100 magazine, 9mm 10 round (CZ100) | 1 | 848 | 2165055 | 96.5165 | C |
| Appendix 2.1 (CZ 75B) | 1 | 826 | 2165881 | 96.5533 | C |
| CZC Bench Block | 1 | 826 | 2166707 | 96.5901 | C |
| 3mm Parallel punch | 20 | 817 | 2167524 | 96.6266 | C |
| Extended magazine base (P-09) | 1 | 804 | 2168328 | 96.6624 | C |
| Design Tech V2 Paddle | 7 | 791 | 2169119 | 96.6977 | C |
| DAA Racer Hanger Assembly | 1 | 783 | 2169902 | 96.7326 | C |
| 11, Sear (Pre B) | 2 | 782 | 2170684 | 96.7674 | C |
| Ross dress belt, 1.25 inch, tan | 2 | 782 | 2171466 | 96.8023 | C |
| 10, Ejector (TS) | 1 | 761 | 2172227 | 96.8362 | C |
| Dummy training gun | 1 | 761 | 2172988 | 96.8701 | C |
| Wide 1.5mm fiber optic front sight (CZ 75 series) | 1 | 761 | 2173749 | 96.9041 | C |
| Wide 1mm fiber optic front sight (CZ 75 series) | 1 | 761 | 2174510 | 96.9380 | C |
| Double Alpha grip tape | 13 | 747 | 2175257 | 96.9713 | C |
| 20, 21, Safety lever set (P-07/P-09) | 2 | 740 | 2175997 | 97.0043 | C |
| 53, Rear sight (CZ 75B) | 2 | 740 | 2176737 | 97.0373 | C |
| Ross Leather Ankle 13 (CZ 83) | 2 | 740 | 2177477 | 97.0703 | C |
| Ross Leather Ankle 13 (P-07) | 2 | 740 | 2178217 | 97.1032 | C |

| | | | | | |
|---|---|---|---|---|---|
| Ross Leather IWB 16 (CZ 75) | 0 | 740 | 2178957 | 97.1362 | C |
| Ross Leather IWB 16 (P-09) | 2 | 740 | 2179697 | 97.1692 | C |
| Ross Leather IWB MV1 (Compact) | 2 | 740 | 2180437 | 97.2022 | C |
| Ross Leather OWB 12 (CZ83) | 2 | 740 | 2181177 | 97.2352 | C |
| Ross Leather OWB 12 (Shadow) | 2 | 740 | 2181917 | 97.2682 | C |
| Ross Leather OWB 5 (CZ 83) | 2 | 740 | 2182657 | 97.3012 | C |
| Ross Leather OWB 5 (P-01) | 2 | 740 | 2183397 | 97.3342 | C |
| Ross Leather OWB 5 (P-09) | 2 | 740 | 2184137 | 97.3672 | C |
| DAA Racer magazine pouch with magnet | 1 | 726 | 2184863 | 97.3995 | C |
| SportEAR XT2 Hearing protector | 1 | 709 | 2185572 | 97.4311 | C |
| Red Dot Mount with racker (Shadow) | 1 | 704 | 2186276 | 97.4625 | C |
| 40, Magazine follower (CZ 75) | 26 | 700 | 2186976 | 97.4937 | C |
| 02, Slide stop (CZ 85) | 1 | 696 | 2187672 | 97.5247 | C |
| 39, Recoil spring assembly (P-07) | 4 | 696 | 2188368 | 97.5558 | C |
| 45, Plain front sight (TS) | 5 | 680 | 2189048 | 97.5861 | C |
| 32, Magazine catch, D-type (Shadow) | 2 | 678 | 2189726 | 97.6163 | C |
| 66/39, Firing pin stop (Shadow) | 7 | 678 | 2190404 | 97.6465 | C |
| Old Faithful IWB holster (CZ 75) | 1 | 674 | 2191078 | 97.6766 | C |
| Sidewinder (CZ 83) | 1 | 674 | 2191752 | 97.7066 | C |
| Sidewinder Zero (CZ 75 B) | 1 | 674 | 2192426 | 97.7367 | C |
| Sidewinder Zero (P-07) | 1 | 674 | 2193100 | 97.7667 | C |
| 51, Extractor pin | 15 | 672 | 2193772 | 97.7967 | C |
| Talon grips - Grip Tape (P-09) | 2 | 660 | 2194432 | 97.8261 | C |
| Talon grips - Rubber (P-07) | 2 | 660 | 2195092 | 97.8555 | C |
| 02, Slide stop (TS 9mm) | 1 | 652 | 2195744 | 97.8846 | C |
| Mec Gar +2 shoe | 3 | 652 | 2196396 | 97.9136 | C |
| 38, Guide rod (P-07 Duty) | 10 | 650 | 2197046 | 97.9426 | C |
| 09, Pin number 9 (CZ 75 B) | 29 | 645 | 2197691 | 97.9714 | C |
| SportEAR XP3 Ear plugs | 3 | 644 | 2198335 | 98.0001 | C |
| 3GM (Three Grand Masters) | 1 | 639 | 2198974 | 98.0286 | C |
| 3GM2 (Three Grand Masters 2) | 1 | 639 | 2199613 | 98.0571 | C |
| 05, Trigger (Shadow) | 2 | 630 | 2200243 | 98.0851 | C |
| 12, Sear spring (CZ 75 B) | 23 | 630 | 2200873 | 98.1132 | C |
| CZ 75 Spares Kit 1 (SP-01) | 1 | 630 | 2201503 | 98.1413 | C |
| CZ Fiber optic rear sight - defender (P07/P09) | 1 | 630 | 2202133 | 98.1694 | C |
| 39, CZ Magazine spring, 18 round SP-01 magazine | 25 | 624 | 2202757 | 98.1972 | C |
| 22, Main spring plug (CZ 75) | 2 | 618 | 2203375 | 98.2248 | C |
| 49, Trigger bar spring (P-07/P-09) | 15 | 610 | 2203985 | 98.2520 | C |
| 02, Slide stop (CZ 97 B) | 1 | 609 | 2204594 | 98.2791 | C |
| Sticky Dual Mag Pouch | 1 | 609 | 2205203 | 98.3063 | C |
| 37, Magazine Base, plastic (SP-01) | 27 | 602 | 2205805 | 98.3331 | C |
| Ross Leather OWB 7 (CZ 97 | 2 | 600 | 2206405 | 98.3598 | C |
| Talon grips - Rubber (P-09) | 2 | 600 | 2207005 | 98.3866 | C |
| Travel mount (Sticky holster) | 1 | 596 | 2207601 | 98.4132 | C |
| 02, Slide stop (Shadow 2 / P-01) | 1 | 587 | 2208188 | 98.4393 | C |
| Hogue grip screws (CZ) | 7 | 576 | 2208764 | 98.4650 | C |
| DPM replacement spring set (SP-01) | 3 | 573 | 2209337 | 98.4905 | C |
| Hogue Powerspeed Carry holster (CZ 75B) | 1 | 565 | 2209902 | 98.5157 | C |
| 46, Front sight pin (CZ 75B) | 35 | 550 | 2210452 | 98.5403 | C |
| Courier delivery | 7 | 546 | 2210998 | 98.5646 | C |
| Single action trigger, target | 1 | 543 | 2211541 | 98.5888 | C |
| Stainless steel guide rod (Compact) | 1 | 543 | 2212084 | 98.6130 | C |
| K-mag 23 round magazine (CZ 100) | 1 | 530 | 2212614 | 98.6366 | C |
| Ross Leather OWB 7 (CZ 75) | 6 | 522 | 2213136 | 98.6599 | C |
| Stainless steel guide rod (CZ 75) | 1 | 522 | 2213658 | 98.6832 | C |
| Venture Gear Drone | 1 | 522 | 2214180 | 98.7064 | C |
| 20, Main spring strut (CZ 75) | 4 | 520 | 2214700 | 98.7296 | C |
| CZ Custom solid firing pin retaining pin (CZ 75B) | 5 | 520 | 2215220 | 98.7528 | C |
| 52, Extractor spring (SP-01) | 14 | 516 | 2215736 | 98.7758 | C |
| Performance shirt | 1 | 513 | 2216249 | 98.7987 | C |
| DR Performance Practice Deck 1.0 | 2 | 504 | 2216753 | 98.8211 | C |
| 04, Slide stop (P-07/P-09) | 1 | 500 | 2217253 | 98.8434 | C |
| 37, Magazine Base, metal (CZ 75) | 9 | 500 | 2217753 | 98.8657 | C |
| 41, Slide stop (CZ 83) | 1 | 500 | 2218253 | 98.8880 | C |
| Design Tech V2 Belt attachment | 8 | 500 | 2218753 | 98.9103 | C |
| Pin for CZ Custom mag well (CZ75) | 1 | 500 | 2219253 | 98.9326 | C |
| Practical Shooting Beyond Fundamentals | 1 | 500 | 2219753 | 98.9549 | C |
| CZC mag spring & follower kit 13 | 4 | 496 | 2220249 | 98.9770 | C |
| Peltor Optime III | 1 | 487 | 2220736 | 98.9987 | C |
| Old Faithful IWB (new design) (P-07 / P-09) | 1 | 474 | 2221210 | 99.0198 | C |
| 31, Detent plunger spring | 20 | 468 | 2221678 | 99.0407 | C |
| 29, Safety (Pre B) | 1 | 465 | 2222143 | 99.0614 | C |

| | | | | | |
|---|---|---|---|---|---|
| Fobus Magazine Pouch (Glock) | 1 | 457 | 2222600 | 99.0818 | C |
| Fobus Paddle Holster (Glock) | 1 | 457 | 2223057 | 99.1022 | C |
| Avion slim-fit eye protection | 5 | 435 | 2223492 | 99.1216 | C |
| DAA PDR Low-Ride | 1 | 435 | 2223927 | 99.1410 | C |
| Single action trigger, Custom | 1 | 435 | 2224362 | 99.1604 | C |
| 30, Detent plunger LHS | 11 | 430 | 2224792 | 99.1795 | C |
| Aluminium shoe (SP-01) | 3 | 430 | 2225222 | 99.1987 | C |
| 15, Ejector (P-07 / P-09) | 6 | 420 | 2225642 | 99.2174 | C |
| Mamba single mag carrier (CZ 83) | 1 | 413 | 2226055 | 99.2358 | C |
| Viridian ECR (Instant-On) upgrade kit | 2 | 392 | 2226447 | 99.2533 | C |
| 32, Magazine catch, o-type (CZ75B) | 1 | 391 | 2226838 | 99.2707 | C |
| 50, Extractor (.40 S&W) | 2 | 391 | 2227229 | 99.2882 | C |
| Ross dress belt, decorative | 1 | 391 | 2227620 | 99.3056 | C |
| 06, Trigger pin (CZ75) | 12 | 390 | 2228010 | 99.3230 | C |
| CGW recoil spring 15 (P-07/P-09) | 3 | 390 | 2228400 | 99.3404 | C |
| CGW recoil spring 18 (P-09) | 3 | 390 | 2228790 | 99.3577 | C |
| Lyman Kinetic Bullet Puller | 1 | 378 | 2229168 | 99.3746 | C |
| IMI Red dot riser | 1 | 370 | 2229538 | 99.3911 | C |
| Extra Power Sear Spring (P-07/P-09) | 4 | 364 | 2229902 | 99.4073 | C |
| 33, Magazine catch spring (CZ 75 B) | 11 | 350 | 2230252 | 99.4229 | C |
| J hook kydex | 3 | 348 | 2230600 | 99.4384 | C |
| Wolff recoil spring (CZ 83) | 2 | 348 | 2230948 | 99.4539 | C |
| Wolff Recoil spring (CZ75 Compact) | 2 | 348 | 2231296 | 99.4695 | C |
| 32, Magazine catch, D-type (SP-01) | 1 | 339 | 2231635 | 99.4846 | C |
| Pit Viper (P-07) | 1 | 339 | 2231974 | 99.4997 | C |
| 37, 57, Firing pin retaining pin | 9 | 336 | 2232310 | 99.5147 | C |
| 38, Mag base lock (CZ 75) | 6 | 332 | 2232642 | 99.5295 | C |
| 52, Extractor spring (CZ 75 B) | 24 | 330 | 2232972 | 99.5442 | C |
| Talon grips - Grip Tape (P-07) | 1 | 330 | 2233302 | 99.5589 | C |
| 24, Magazine brake (Shadow) | 4 | 312 | 2233614 | 99.5728 | C |
| 40, Extractor spring (P-07/P-09) | 6 | 312 | 2233926 | 99.5867 | C |
| Fiber optic rod DAA | 8 | 312 | 2234238 | 99.6006 | C |
| 24, Magazine brake (CZ 75B) | 6 | 296 | 2234534 | 99.6138 | C |
| DPM replacement spring set (P-07) | 3 | 288 | 2234822 | 99.6266 | C |
| 09, Trigger bar (P-07/P-09) | 1 | 283 | 2235105 | 99.6393 | C |
| 39, Recoil spring (P-07) | 3 | 261 | 2235366 | 99.6509 | C |
| Gift voucher | 1 | 261 | 2235627 | 99.6625 | C |
| 12, Disconnector (P-07/P-09) | 2 | 260 | 2235887 | 99.6741 | C |
| Bulge Buster push rod (9mm) | 2 | 260 | 2236147 | 99.6857 | C |
| 30, Detent plunger (P-01 Omega) | 6 | 258 | 2236405 | 99.6972 | C |
| Design Tech V2 Molle attachment | 4 | 252 | 2236657 | 99.7085 | C |
| 38, Mag base lock (SP-01) | 10 | 249 | 2236906 | 99.7196 | C |
| 03, Slide stop spring (L shaped) | 9 | 240 | 2237146 | 99.7303 | C |
| 13, Sear pin (CZ 75 B) | 6 | 234 | 2237380 | 99.7407 | C |
| Magazine spring, K-Mag | 4 | 234 | 2237614 | 99.7511 | C |
| Magwell main spring plug (P-09) | 1 | 230 | 2237844 | 99.7614 | C |
| Magazine spring, Wolff +5% (CZ 75 Compact) | 4 | 218 | 2238062 | 99.7711 | C |
| Appendix Specific Platform (CZ 83) | 1 | 217 | 2238279 | 99.7808 | C |
| Metal front sight with green phos dot (P07) | 1 | 217 | 2238496 | 99.7904 | C |
| 43, Safety latch spring (P-07/P-09) | 7 | 215 | 2238711 | 99.8000 | C |
| 42, Guide rod (Shadow) | 10 | 210 | 2238921 | 99.8094 | C |
| 41, Recoil spring (P-01) | 3 | 208 | 2239129 | 99.8187 | C |
| 30, Trigger pin (P-07/P-09) | 3 | 200 | 2239329 | 99.8276 | C |
| CZC Recoil spring (Compact) | 2 | 200 | 2239529 | 99.8365 | C |
| 03, Slide stop spring (r shaped) | 7 | 195 | 2239724 | 99.8452 | C |
| 45, Hammer spring (CZ 75 Compact) | 5 | 195 | 2239919 | 99.8539 | C |
| 29, Hammer pin (P-07/P-09) | 4 | 183 | 2240102 | 99.8620 | C |
| 55, Magazine spring (CZ83) | 4 | 174 | 2240276 | 99.8698 | C |
| Ross Leather OWB 7 (CZ 83) | 2 | 174 | 2240450 | 99.8775 | C |
| 28, Sear pin (P-07/P-09) | 3 | 166 | 2240616 | 99.8849 | C |
| Design Tech V2 Thumb retention | 4 | 156 | 2240772 | 99.8919 | C |
| Magazine base, K-Mag | 3 | 152 | 2240924 | 99.8987 | C |
| DPM replacement spring set (TS) | 1 | 148 | 2241072 | 99.9053 | C |
| 48, Decocking lever spring (P-07/P-09) | 3 | 144 | 2241216 | 99.9117 | C |
| 27, Main spring plug with loop (P-07) | 2 | 140 | 2241356 | 99.9179 | C |
| 59, Firing pin block stop spring | 3 | 140 | 2241496 | 99.9242 | C |
| 32, Main spring plug pin (P-07/P-09) | 3 | 130 | 2241626 | 99.9300 | C |
| Shotmaxx carry case | 2 | 126 | 2241752 | 99.9356 | C |
| 47, Slide stop spring (P-07) | 7 | 120 | 2241872 | 99.9409 | C |
| Design Tech V2 Resistance retention | 4 | 120 | 2241992 | 99.9463 | C |
| 69, Recoil buffer (TS) | 5 | 117 | 2242109 | 99.9515 | C |
| Belt Clip, Metal | 1 | 109 | 2242218 | 99.9564 | C |

| | | | | | |
|---|---|---|---|---|---|
| CGW Tempered firing pin retaining pin (CZ 75B) | 1 | 109 | 2242327 | 99.9612 | C |
| 13, Recoil spring (CZ 83) | 1 | 87 | 2242414 | 99.9651 | C |
| 24, Magazine brake (Compact) | 1 | 87 | 2242501 | 99.9690 | C |
| Design Tech V2 Belt Clip attachment | 2 | 87 | 2242588 | 99.9729 | C |
| 41, Recoil spring (TS .40) | 2 | 86 | 2242674 | 99.9767 | C |
| 34, Magazine catch pin (P-07/P-09) | 4 | 78 | 2242752 | 99.9802 | C |
| 42, Guide rod (CZ 75) | 1 | 65 | 2242817 | 99.9831 | C |
| 25, Magazine brake pin (CZ 75) | 3 | 52 | 2242869 | 99.9854 | C |
| 42, Slide stop spring, L-shaped (CZ 83) | 2 | 44 | 2242913 | 99.9873 | C |
| 08, Trigger spring (TS) | 1 | 43 | 2242956 | 99.9893 | C |
| 64, Barrel Bushing (TS) | 1 | 43 | 2242999 | 99.9912 | C |
| 3M Classic earplugs | 20 | 36 | 2243035 | 99.9928 | C |
| 06, Trigger pin (Phantom) | 1 | 30 | 2243065 | 99.9941 | C |
| 31, Magazine catch plug (P-07/P-09) | 1 | 30 | 2243095 | 99.9955 | C |
| 52, Extractor spring (TS) | 1 | 30 | 2243125 | 99.9968 | C |
| Design Tech V2 Retention spring | 2 | 26 | 2243151 | 99.9979 | C |
| Unspecified | 27 | 24 | 2243175 | 99.9990 | C |
| 56, Trigger overtravel screw (Shadow) | 1 | 22 | 2243197 | 100.0000 | C |

## Appendix C

Appendix C consists of four parts. The first part shows how the safety stock for the model results was calculated. The safety stock is used as a buffer to account for any discrepancies in the demand forecast results. It is also be used for any shortages that may occur during the lead-time.

**Safety Stock Calculations**

| Saftey Stock Calculations = (maximum daily usage * maximum lead time) - (average daily usage * average lead time in days) | | | | |
|---|---|---|---|---|
| | Item 1 | Item 2 | Item 3 | |
| Maximum daily usage (in units) | 5 | 4 | 9 | |
| Maximum lead time (in days) | 12 | 5 | 4 | |
| Average daily usage (in units) | 1 | 2 | 3 | |
| Average lead time (in days) | 7 | 3 | 2 | |
| Saftey Stock for 2017 (in units) | 53 | 14 | 30 | |

Part 2 shows how the calculations of the actual inventory costs for item one for 2017 were calculated.

**Actual inventory cost calculations for item 1 for 2017**

| Holding costs and Ordering Cost Calculations for item one for the year 2017 | | | | | | |
|---|---|---|---|---|---|---|
| | | Actual Demand | Amount of stock ordered | Ending Inventory | Holding Costs =(0.75* ending inventory) | Ordering Costs = number of orders* 10572 |
| 2017 | January | 24 | 453 | 429 | 321.75 | 10572 |
| | February | 32 | | 397 | 297.75 | |
| | March | 36 | | 361 | 270.75 | |
| | April | 116 | | 245 | 183.75 | |
| | May | 54 | | 191 | 143.25 | |
| | June | 26 | | 165 | 123.75 | |
| | July | 14 | | 151 | 113.25 | |
| | August | 14 | | 137 | 102.75 | |
| | September | 14 | | 123 | 92.25 | |
| | October | 8 | | 115 | 86.25 | |
| | November | 8 | | 107 | 80.25 | |
| | December | 2 | | 105 | 78.75 | |
| | Total Holding Costs | | | | 1894.5 | |
| | Total Ordering Costs | | | | 10572 | |
| | Total costs | | | | 12466.5 | |

Part 3 shows how the calculations of the actual inventory costs for item two for 2017 were calculated.

**Actual inventory costs for item two for 2017**

| Holding costs and Ordering Cost Calculations for item two for the year 2017 | | | | | | |
|---|---|---|---|---|---|---|
| | | Actual Demand | Amount of stock ordered | Ending Inventory | Holding Costs =(4.63* ending inventory) | Ordering Costs = number of orders* 1000 |
| 2017 | January | 12 | 20 | 8 | 37.04 | 1000 |
| | February | 18 | 20 | 10 | 46.3 | 1000 |
| | March | 6 | 30 | 34 | 157.42 | 1000 |
| | April | 55 | 30 | 9 | 41.67 | 1000 |
| | May | 26 | 30 | 13 | 60.19 | 1000 |
| | June | 9 | 30 | 34 | 157.42 | 1000 |
| | July | 6 | 20 | 48 | 222.24 | 1000 |
| | August | 5 | 20 | 63 | 291.69 | 1000 |
| | September | 10 | 20 | 73 | 337.99 | 1000 |
| | October | 31 | 20 | 62 | 287.06 | 1000 |
| | November | 26 | 20 | 56 | 259.28 | 1000 |
| | December | 18 | | 38 | 175.94 | |
| | Total Holding Costs | | | | 2074.24 | |
| | Total Ordering Costs | | | | 11000 | |
| | Total costs | | | | 13074.24 | |

Part 4 shows how the calculations of the actual inventory costs for item three for 2017 were calculated.

**Actual inventory costs for item three for 2017**

| Holding costs and Ordering Cost Calculations for item three for the year 2017 | | | | | | |
|---|---|---|---|---|---|---|
| | | Actual Demand | Amount of stock ordered | Ending Inventory | Holding Costs =(0.81* ending inventory) | Ordering Costs = number of orders* 430 |
| 2017 | January | 22 | 30 | 8 | 6.48 | 430 |
| | February | 34 | 30 | 4 | 3.24 | 430 |
| | March | 24 | 25 | 5 | 4.05 | 430 |
| | April | 4 | 25 | 26 | 21.06 | 430 |
| | May | 20 | 25 | 31 | 25.11 | 430 |
| | June | 36 | 25 | 20 | 16.2 | 430 |
| | July | 32 | 25 | 13 | 10.53 | 430 |
| | August | 14 | 25 | 24 | 19.44 | 430 |
| | September | 6 | 25 | 43 | 34.83 | 430 |
| | October | 8 | 25 | 60 | 48.6 | 430 |
| | November | 24 | | 36 | 29.16 | |
| | December | 22 | | 14 | 11.34 | |
| | Total Holding Costs | | | | 230.04 | |
| | Total Ordering Costs | | | | 4300 | |
| | Total costs | | | | 4530.04 | |