ECSA GA4 REPORT

Quality Assurance 344

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Introduction

This report analyses sales data for a company. The aim is to give insight to the process managers about the performance, capability, reliability and where to improve the quality of the products and service.

The report starts with an overview of how the data was sorted, followed by the descriptive statistics to gain insights of the data. Then the statistical process control is performed by displaying control charts for X and S-bar. Charts of the various class items are displayed and commented on. There after the optimization and performance of the delivery process is investigated. The report follow to give an overview of a manova that is applicable in this scenario and finally investigate the reliability of the service and products

Part 1: Data wrangling

The data for the sales of a specific company contain information on specific products sold. The data consists of 180000 instances and 10 variables describing and specifying each item sold.
The data has been processed to remove missing values as well as invalid instances and sorting the data by date. The data was then ordered by year ,month ,day and x-value

	ncount	ID	X	AGE	Class	Price	Year	Month	Day	Delivery.time	Why.Bought
1	1	47101	463	50	Clothing	1030.86	2021	1	1	9.0	Recommended
2	2	88087	2627	21	Clothing	428.03	2021	1	1	10.0	Recommended
3	3	25418	3374	68	Household	13184.41	2021	1	1	48.5	Website
4	4	13566	5288	94	Household	7021.90	2021	1	1	42.0	Recommended
5	5	84692	8182	35	Clothing	475.18	2021	1	1	9.0	Recommended
6	6	46305	9272	72	Clothing	580.98	2021	1	1	8.5	Random
7	7	92105	9712	45	Household	6877.00	2021	1	1	43.0	Recommended
8	8	21614	12163	27	Clothing	513.13	2021	1	1	9.5	Recommended
9	9	12174	12195	56	Household	14538.64	2021	1	1	41.5	EMail
10	10	84558	20004	74	Food	255.41	2021	1	1	2.0	Recommended
11	11	15630	20509	32	Clothing	164.56	2021	1	1	9.0	Recommended
12	12	81216	21970	87	Clothing	173.76	2021	1	1	10.0	Recommended

Figure 1: Preview of valid entries set

The valid entries data set has 79 978 entries as seen in figure 1. The invalid set contain 22 entries.

Part 2: Descriptive statistics

2.1 Description of the data

The variables which describe each entry, has the following characteristics:

- X: Row number
- ID: Unique value to easily identify a specific entry
- AGE: The age of the client
- Class: There are seven classes in which the different items had been divided in and which describe the type of item. These classes include clothing, food, gifts, household, luxury, sweets and technology.
- Price: The value of the item bought.
- Year: The year in which the item was bought.
- Month: The month in which the item was bought.
- Day: The day of the month in which the item was bought.

A statistical analysis was performed on the data to get an overview and to see the insights discovered from the data.

2.2 Visual and statistical analysis

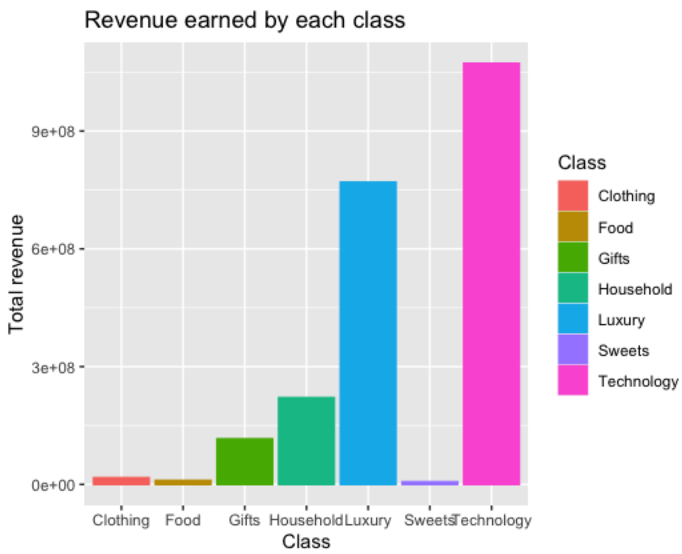


Figure 2: Bar plot of revenue earned by each class

The total revenues earned by each class are displayed in figure 2. The Technology-class earns about 21 million, which is by far the most, but the luxury class cannot be ignored, since it indicates a very good 2nd revenue-income. The food and sweets classes earn the least revenue of less than 1.3 million. Although revenue is a good indication of the importance of a class, you also have to look at how many items had been sold to get a better understanding of the demand as well as well as the customer’s preferences.

Figure 3: Bar plot of number of units sold

The bars in figure 3 compare the number of units sold. It was found that the gift class had sold the most items and technology was second. It is also insightful to note that luxury class sells the least units, but bring in second most revenue as can be seen in Fig 2.

Considering the revenue and volume of the items sold, luxury and technology are important product lines since it generates the most money. Management should thus focus on these lines and prioritise the quality of these products.

2.3 Advertising and target market

When considering an advertising campaign to boost the sales, it is important to identify the target market. It can be done to identify the highest revenue earned, the units sold and within that, according to age and needs and several other aspects.

Financially it can be worth considering which advertising methods will be effective on that specific target market and worth spending money on.

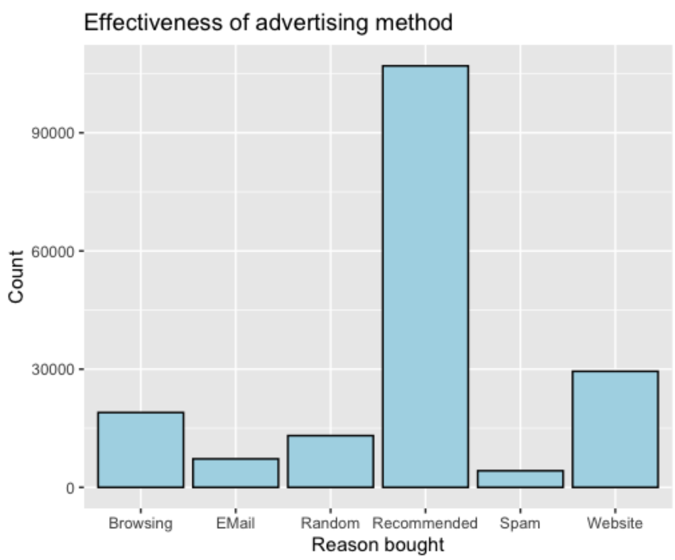


Figure 4: Effectiveness of advertising method

The bar graph in figure 4 gives an indication of how the customer learned about this item's existence and shows the reason why the product-item was bought. It can be seen that most products were bought upon recommendation, secondly the website and thirdly browsing. Least items were bought because of spam-advertising and therefor it would be recommended that a company should consider removing this type of advertising and rather focus on boosting the effective methods for example expanding and updating their website. Since most products was bought on the recommendation of other people, the company should actively focus on upholding their good quality and service.

From previous graphs, it is known that the 4 item-classes which have the highest Revenue-income, are technology, luxury, household and then gifts (fig 2). It you compare those to the outcome in figure 3, which is the units sold, the spread of items is different. It had been found that household class are almost and the end, and luxury classes very low on the list. It will be useful to look into more depth into the target-markets of the last 2 mentioned and focus on advertising in whose areas, since the revenue income on that are very good.

Figure 5 compare the distribution of age of the customers to each of the item-classes. It was found that in general the youngest customers are 18 years old and the oldest customer is 108. The specific item-classes of household and luxury items can be specifically looked at with focus on advertising, in effort to increase the sales and thus increase the revenue income.

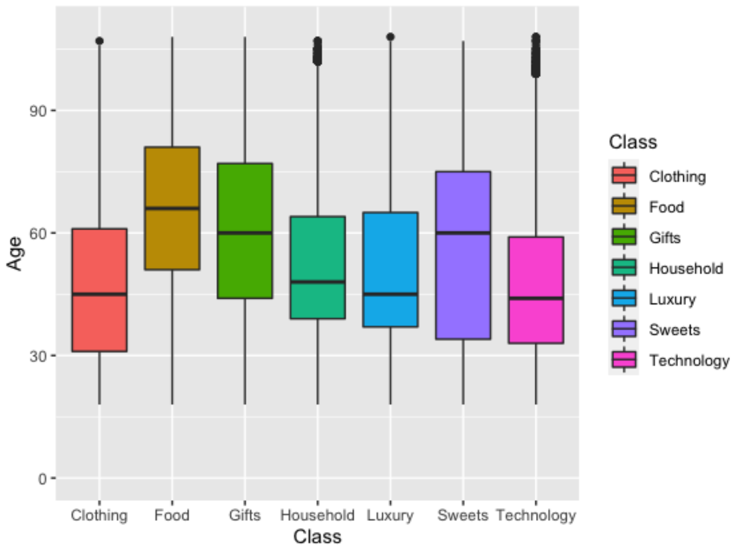


Figure 5: Age of target market compared to the different item-classes

In the target markets, it can be seen that the age of the people who buy household items, are between the ages of 39 and 66 years with a mean age of 52.96 years. The average ages of people who buy the luxury items is between the ages of 37 and 67 with a mean age of 52.5 years. Luxury item's box plot is skewed to the bottom. This is logical, as older people have more disposable income due to well-paying jobs and children that are already self-sufficient. It will be recommended that the advertising in these 2 item-classes must focus on applicable market-aspects of ages around 52 years.

The technology- class, which is an item with high revenue income, as well as high in items sold, is primarily bought by people between the ages of 32 and 60 with a mean age of 46.95 years.

Advertising and devising new product lines, the wants and needs of the age bracket of the item-classes with the highest revenue, should be carefully considered. Currently it is as written according to order of importance with technology, luxury items and household items and this items mean age-groups, which lie between 46 – 53 years, must be kept in mind with advertising campaigns.

The target age of the market for gifts is between 46 and 78 years old with a mean age of 61.78 years. Since gifts are also under the top 4 items of revenue income, and second on units sold, it can also be considered in advertising campaigns. It needs to be mentioned that the mean age is older than those of the other important items and might need a different approach in marketing and advertising.

The other item-classes which will be mentioned, are of less importance compared to revenue income, but it is still important in overall sales and exposure of the company.
The mean age of customers that buy sweets is 57.64 years, with a target age market between 35 and 75 years old.   As can be seen in figure 5, the box plot is skewed to the top, suggesting that those < 60 years (the median) is a bigger buying power than those above.

The mean age of the customers that buy clothes are 47.82 years. The target age-market for clothing are adults between the ages of 31 and 62 years. As these are working adults, the company should ensure that they stock clothes that would fit into that age-categories' lifestyles. It can contain professional clothing that can be worn to the office and comfortable, but neat leisure wear are staples.

The mean age of customers that buy food is 65.56 years and the target market-age are mature adults between the ages of 52 and 81 who buy food items.   The mean age of customers that buy sweets is 57.64, with target age between 35 and 75 years of age. As can be seen above, the box plot is skewed to the top, suggesting that those < 60 (the median) have a bigger buying power than those above. This would make sense as elderly people are less likely to indulge in sweets.

The company's average customer seems to be mature adults who are probably well employed.

2.4 Delivery time compared to Price

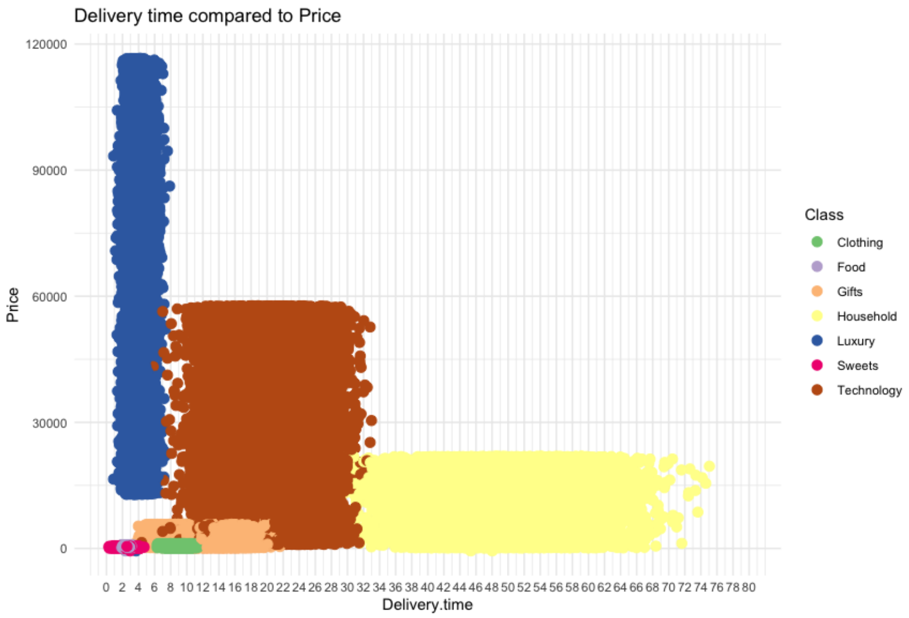


Figure 6: Delivery time compared to price

There are many conclusions to be drawn from this graph in figure 6. Short delivery times do not always come with a higher price. For luxury items that is of high value items, a short delivery time is expected. More general items sold such as sweets, food and clothing, low prices and fast delivery is important to satisfy customers and to keep their clients.
Delivery times for household items as well as technology, vary quite a lot depending on the type of product.

2.5 Yearly trends

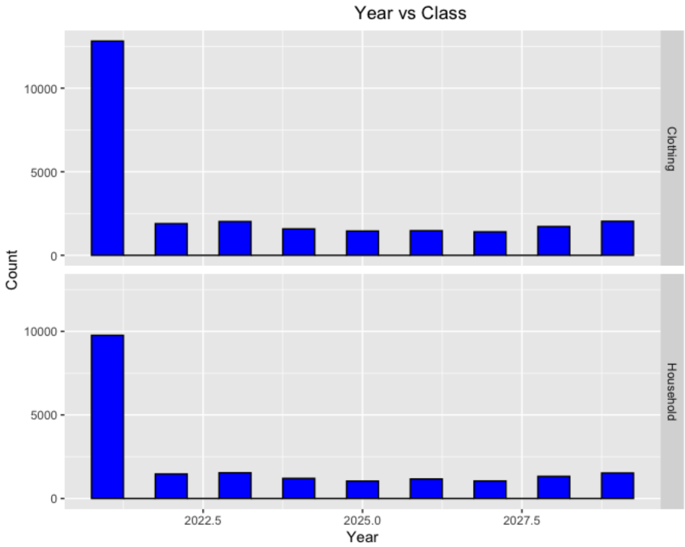


Figure 8: Yearly sales for household and clothing items

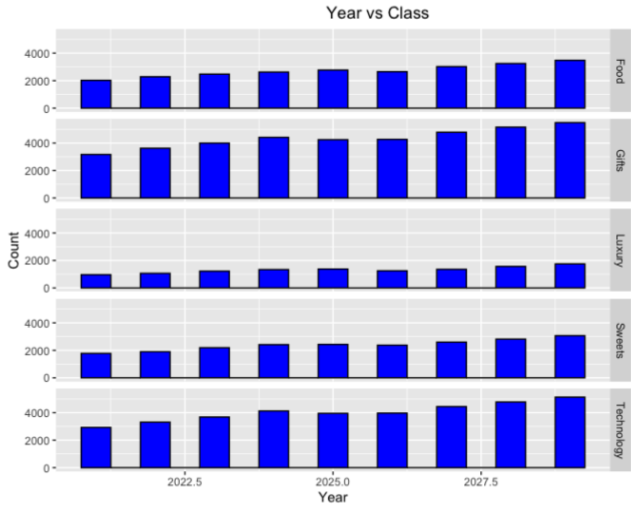


Figure 7: Yearly sales for different classes

Figure 7 focus specifically to the household and clothing items over a period, since the trend of these 2 items differentiate from the other classes. Initially high volumes of sales for household and clothing items took place, but then it went down drastically in the following year. The good thing was that once the sales dropped, it stayed constant over the rest of the period of years. Management must keep in mind that it could either be a data reliability issue in the first period, or they could investigate why sales went down.

Figure 8 compare all the other class-items over a period of time, and it shows gradual upward trends in sales per year for all the other class items.

2.6 Delivery times of Item-classes

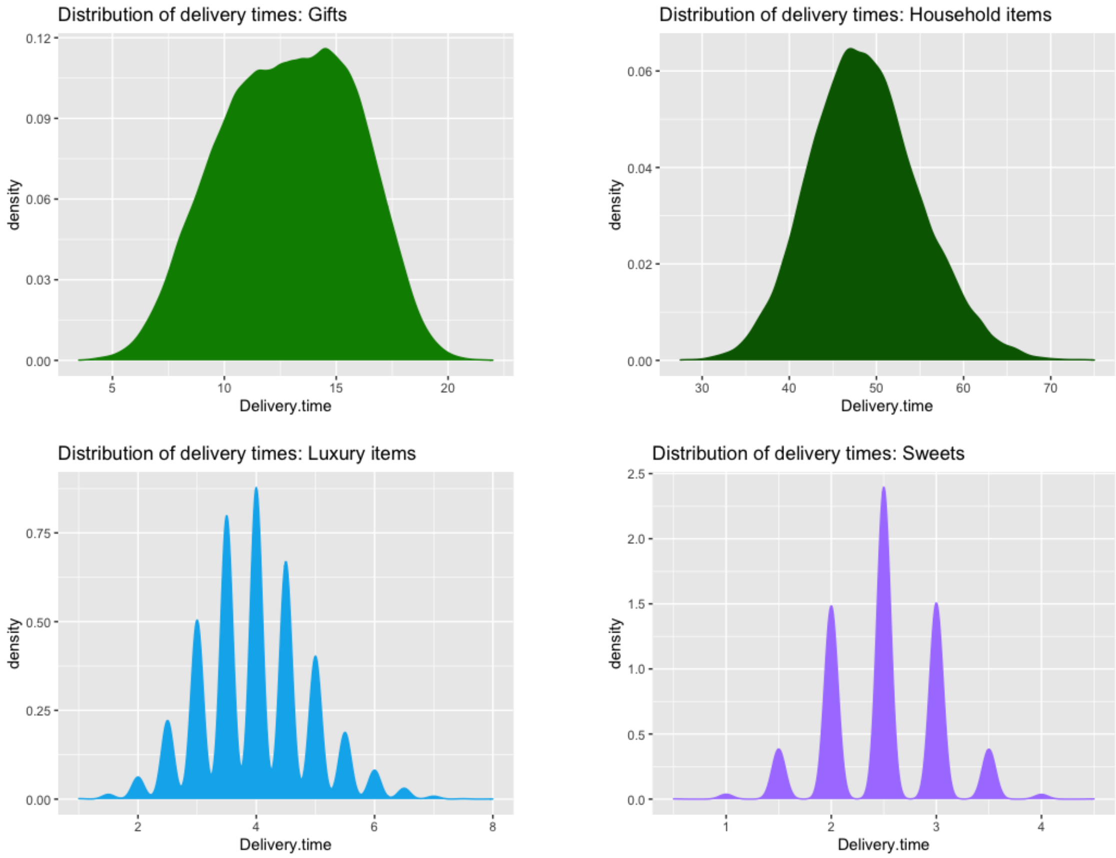


Figure 9: Delivery time distributions of different class items

Not a traditional normal distribution for most items, but rather various normal distributions around the different means can be seen for the delivery time distributions of **clothing, food, luxury, and sweets (Fig 9)**. The delivery times of **gift** items has an approximately normal distribution because the distribution is symmetrical around the mean. For household items, a normal, but slightly skewed distribution to the right, can be seen.

Figure 10: Delivery time distributions of technology items

2.7 Process Capability

The delivery time distributions of technology items have a normal distribution as can be seen in figure 10. Assuming a USL of 24 and a LSL of 0. Having a LSL of 0 make sense since the minimum delivery time cannot be less than zero.

The mean delivery times for technology is 20.377, and sigma is 3.2955278. Process capability can be estimated using the following results.
Cp = 1.2137661
Cpu = 0.3667148
Cpl = 2.0608175
Cpk = 0.3667148 → this is the minimum between the Cpu and Cpl

Capability performance (Cpk) and capability potential (Cp) measures how the process is running within its specification limits and producing acceptable output. Cp is a ratio to determani how Cpk measures how close you are to your target and how consistent you are around your average performance. The larger the index, the less likely it is that a delivery time will be outside the specifications.

Part 3: Statistical process control (SPC) for the X- & S-Charts

Statistical process control charts are a powerful tool to monitor and analyse the process stability by displaying the variation of the specific process. Variation has a great impact on the quality of a product and it is therefore important to make sure the variation is controlled in order to deliver an outcome that will meet the customer's expectation (Berardinelli, 2022).

The variation is controlled when neither the mean of the standard deviation is outside the control limits (outside the red lines on the graphs of figure 13). Although these processes look reliable, it is important to assess the process over a longer period of time in order to measure the real performance of the processes.

A process can be found unstable if something has caused variation. A special cause of variation can be assignable to a defect, a fault, a mistake, a delay, a breakdown, an accident, and/or a shortage in the process. When special causes are present, process quality is unpredictable (Berardinelli, 2022).

3.1 Initialization of Control Limits: First 30 samples

X-Chart Limits:

The x-chart in Figure 11 is used to indicate the change in mean delivery time for each class item.

Classes	UCL	UCL2	UCL1	CL	LCL1	LCL2	LCL
Clothing	9.404934	9.259956	9.114978	8.970000	8.825022	8.680044	8.535066
Household	50.248328	49.019626	47.790924	46.562222	45.333520	44.104818	42.876117
Food	2.709458	2.636305	2.563153	2.490000	2.416847	2.343695	2.270542
Technology	22.974616	22.107892	21.241168	20.374444	19.507721	18.640997	17.774273
Sweets	2.897042	2.757287	2.617532	2.477778	2.338023	2.198269	2.058514
Gifts	9.488565	9.112747	8.736929	8.361111	7.985293	7.609475	7.233658
Luxury	5.493965	5.241162	4.988359	4.735556	4.482752	4.229949	3.977146

Figure 11: X-Chart

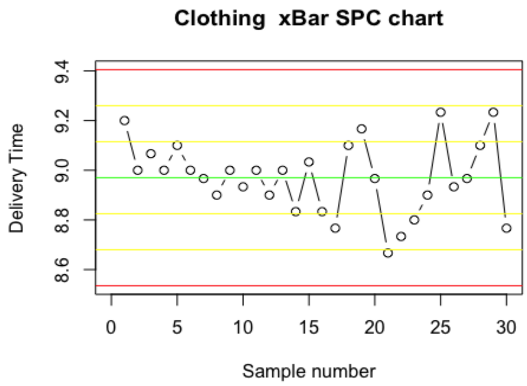
S-Chart:

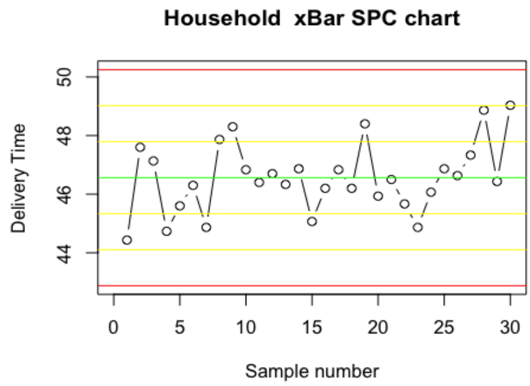
The s-charts in figure 12 indicates the standard deviation for the delivery time different class items of a process over time.

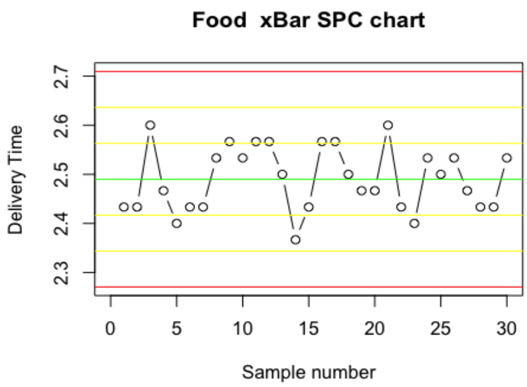
Classes	UCL	UCL2	UCL1	CL	LCL1	LCL2	LCL
Clothing	0.8665596	0.7614552	0.6563509	0.5512465	0.4461422	0.3410379	0.2359335
Household	7.3441801	6.4534101	5.5626402	4.6718703	3.7811003	2.8903304	1.9995605
Food	0.4372466	0.3842133	0.3311800	0.2781467	0.2251134	0.1720801	0.1190468
Technology	5.1805697	4.5522224	3.9238751	3.2955278	2.6671805	2.0388332	1.4104859
Sweets	0.8353391	0.7340215	0.6327039	0.5313862	0.4300686	0.3287509	0.2274333
Gifts	2.2463333	1.9738773	1.7014213	1.4289652	1.1565092	0.8840532	0.6115971
Luxury	1.5110518	1.3277775	1.1445032	0.9612289	0.7779546	0.5946803	0.4114060

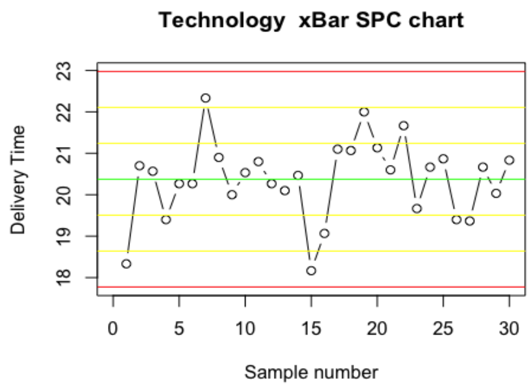
Figure 12: S-Chart for different class items

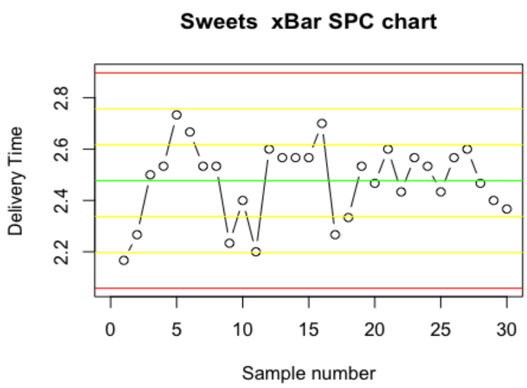
3.1.1 Chart Analysis

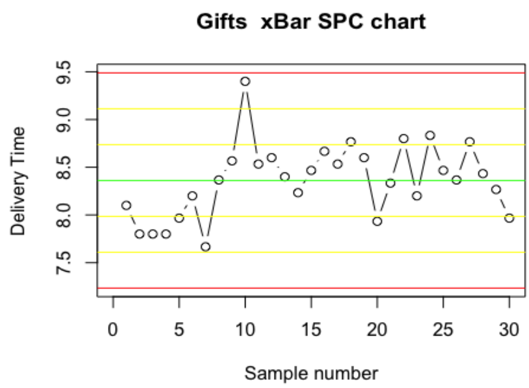












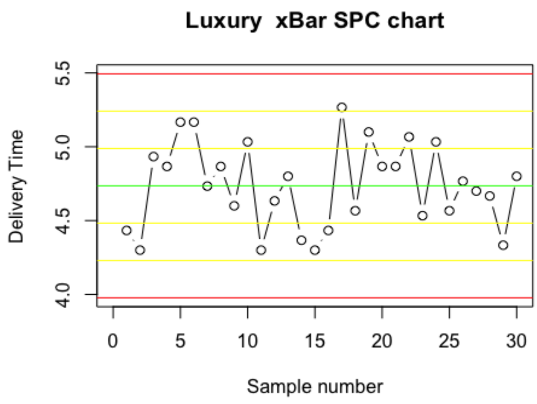


Figure 13: X-bar charts of first 30 samples

Looking at figure 13 it looks like the variation in delivery times means of the different class items, the processes seem to be under control, but it is also important to look at the variation in standard deviation as can be seen in figure 14. Here it can be seen that there is a slightly upward trend.

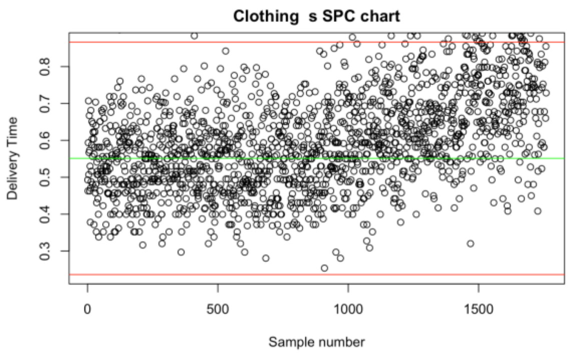


Figure 14: Variation in standard deviation of clothing

These control charts are used to assess whether a process is out of control. It could either really be out of control and management should thus look into this issue, or the data could be tampered with in order to make it look like it is in control.

A process is seen as out of control when the following events occur:
- Any points outside the control limits (red lines on graphs).
- If there is a few consecutive samples beyond control limits (about seven).
- Two out of three beyond two sigma line on the same side of the centre line. (Yellow lines on graphs)
- When a pattern is present an error can be expected.
- A series of points near the centre line.

Not identifying or wrongly identifying these issues can lead to Type I&II errors which will be discussed in section 4.2 and 4.3 of the report.

Part 4: Optimising the delivery processes

4.1. Out of control analysis (A)

When continuing to draw samples, the entire process control performance could be analysed. Figure 15 displays a typical example of such a X-bar chart.

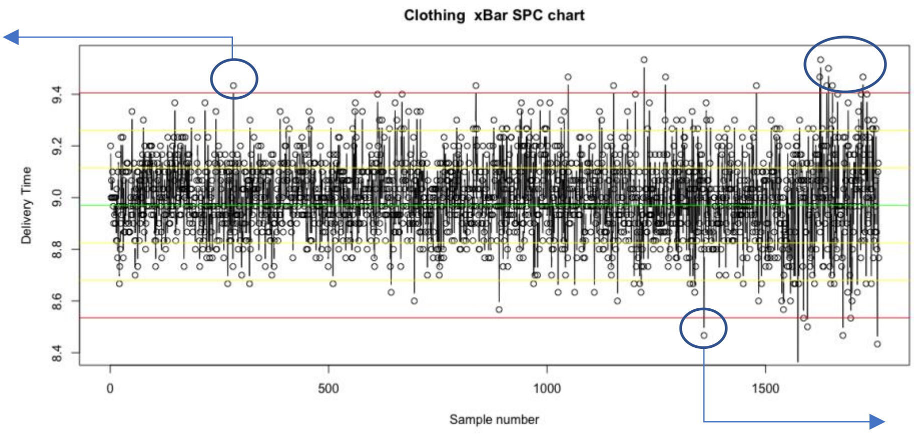


Figure 15: All sample analysis of clothing

A sample is seen to be out of control when the mean is either above or below the specified control limits. Circled in blue, in figure 15, one can see the sample means that the process was out of control; thus any instance outside the red lines is not within specifications. When there are many samples outside these limits, the process should be investigated and corrected accordingly.

The table in Figure 16 shows the sample number where the mean of the sample was above the control limit as well as the total samples that were above the limit. This indicates that the process is out of control.

Classes	Total	First	Second	Third	Third_Last	Second_Last	Last
Clothing	13	282	837	1,048	1,644	1,653	1,723
Household	392	679	693	720	1,335	1,336	1,337
Food	3	432	1,149	1,408			
Technology	1	643					
Sweets	4	942	1,243	1,294			1,358
Gifts	2,287	213	216	218	2,607	2,608	2,609
Luxury		none					

*Figure 16: Summary of sample with X-bar **above** upper limits*

Classes	Total	First	Second	Third	Third_Last	Second_Last	Last
Clothing	7	1359	1,574	1,587	1,677	1,695	1,756
Household	3	252	387	643			
Food	1	75					
Technology	18	37	345	353	1,933	2,009	2,071
Sweets	0	none					
Gifts	0	none					
Luxury	440	142	171	184	789	790	791

*Figure 17: Summary of sample with X-bar **below** lower limits*

The item-classes of clothing, food, technology and **sweets** seem to be in control, since they have low numbers of instances outside the control limits. They have the same form as the plot in figure 17.

This is however not the case for **household**, **gifts** and **luxury** items and here the trend differs from the other items.

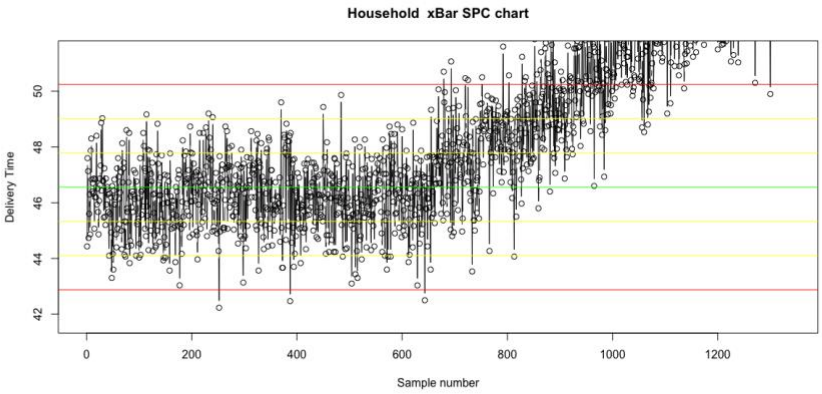


Figure 18: Whole process analysis for technology

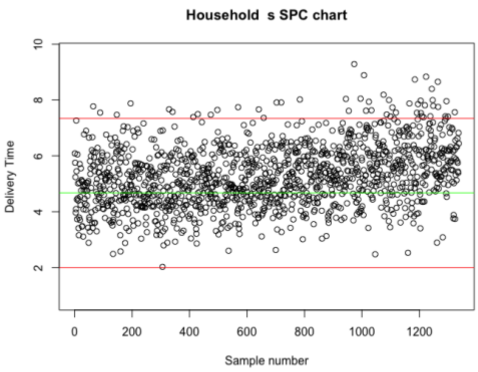


Figure 19: S-chart for household items

When you look at figure 18, it is evident that the delivery times for the household sample are getting more and more out of control. Although the distribution seems to stay the same, with a small upward trend seen in figure 19, the mean (centreline) greatly increases with time. The quality and reliability of these items are getting worst and worst. Management should definitely look into this issue with regards to the household-items.

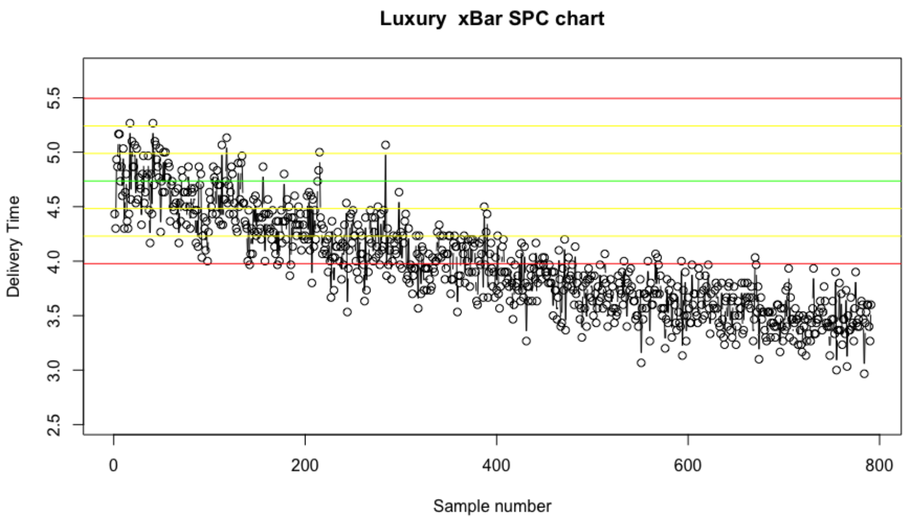


Figure 20: Whole process analysis for luxury items

Figure 20 give an indication of the delivery time of the items and a definite downward trend is visible in the delivery time. This could either mean that the process is improving and delivery times are decreasing, or the measurements are faulty and should be investigated.

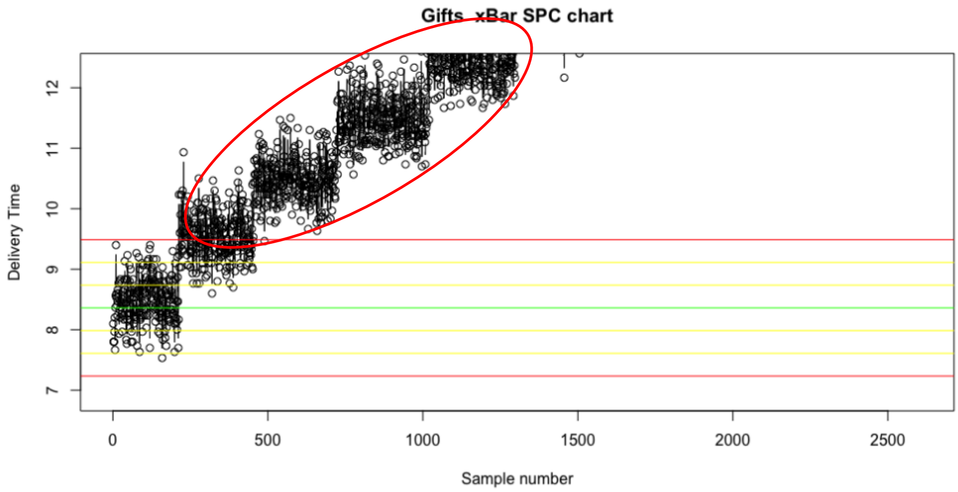


Figure 21: Whole process analysis for gifts

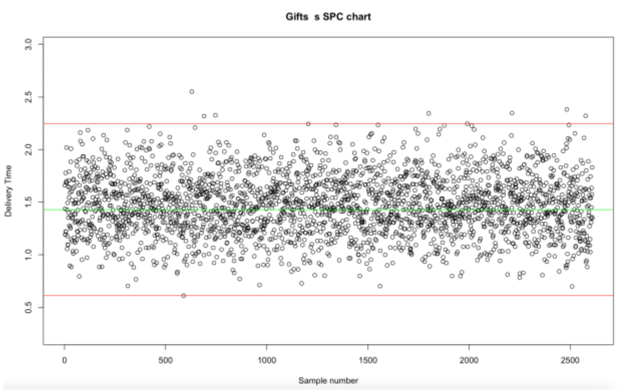


Figure 22: Sbar chart of gifts items

The delivery time variation of gifts have performs quite odd (Fig 21). All of the samples above index number 220 is outside the control limits (indicated with red circle). All though most of the sample means are outside the control limits, most of the standard deviations is within the limits meaning that the process variation is close to the means (figure 22). This situation would require further investigation. The process displays a pattern which could be an indication of tampered data.

4.1. Out of control analysis. (B)

Classes	index	Total
Clothing	1,186	14
Household	1,202	7
Food	1,598	6
Technology	2,384	21
Sweets	1,371	10
Gifts	2,476	20
Luxury	271	5

Figure 23: Most consecutive samples with standard deviation between 0.4 and -0.3

Looking at figure 23 it can be seen that technology have the most consecutive numbers of 21 samples with consecutive standard deviations between 0.4 and -0.3. This item is followed by gifts with 20 and clothing with 14. Having small standard deviation is usually a good thing. Management can use this information to assess what went right in that part of the process and try to repeat that.

4.2 Likelihood of making Type I Error

A type I error is known as a producers risk. It is rejecting the null hypothesis when it is actually true. In simple words, the probability of showing something is wrong when there is not, signal a false alarm.

The Type I Error for 4.1.A

Calculating the probability of finding a X-Bar sample outside the outer control limits. The outer control limits are the -3 and +3 sigma control limits. The probability of a Type I Error is calculated in RStudio as follows:

[1 – pnorm(3)]*2 = 0.002699
The probability of a Type I Error for A is 0.2699%.

The Type I Error for 4.1.B

Use R-studio to do calculation:

Pnorm(0.4)-pnorm(-0.3)=0.2733332

Probability of Type I Error = 27.33%

4.3 Delivery cost minimized

R329 is lost per item for every day a technology class item is delivered past 26 hours. The cost to reduce this time is R2.5 per item per hour.

Figure 24: Plot showing optimal delivery time and cost

The straight lines in figure 24 indicate the different delivery times. The original average delivery time for technology was 49.7 days and is represented in red. A blue line shows the relationship between the total cost and delivery time. The dark green line represents the optimal number of days to minimize delivery costs.

4.4 Likelihood of making a type II, Consumer's Error, for A

A type II error is the probability of not rejecting a null hypothesis when it is actually false. This will result when test are telling you it is correct when it is not.

The mean delivery time for technology items is 21.241168 with
Technology_Ucl <-22.97462
Technology_Lcl<-17.77427

Calculated in R the Type II error is 48.83196 % (Fig 25).

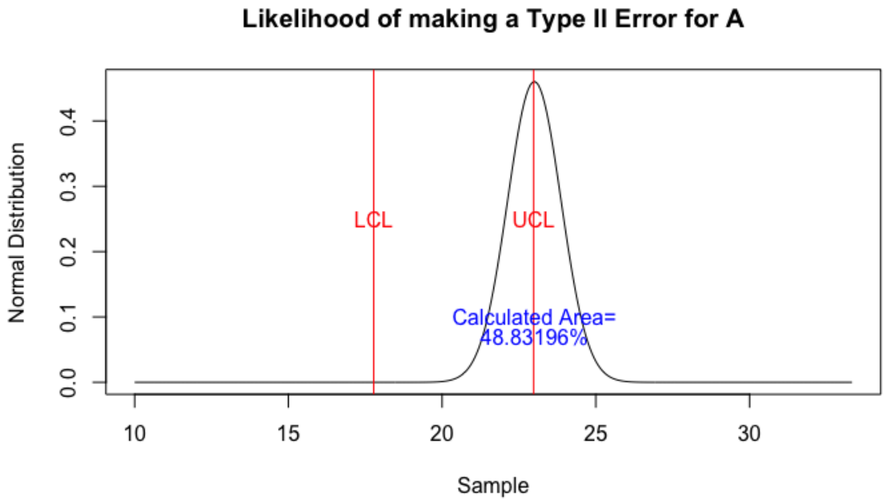


Figure 25: Visual explanation of type II error

Part 5: DOE and MANOVA

A MANOVA is a multivariate analysis of the variance. It can be described as multiple one way - AVOVAs, but has more power to detect a difference. MANOVA looks at the means of two or more unrelated groups, classes in this case, across a combination of the dependent variables, descriptive features. (MANOVA Test in R: Multivariate Analysis of Variance - Easy Guides - Wiki - STHDA, 2022)

A MANOVA is set up to predict whether the class of the item will influence their delivery and price
One independent variable-> Classes
Two or more dependent variables-> Price and Delivery Time

The null hypothesis is that the means for all classes are the same.

$H0_{deliveytime}$: The class of an item have no significant influence on the delivery time of an item.
$H1_{deliveytime}$: The class of an item does have a significant influence on the delivery time of an item.
$H0_{price}$: The class of an item have no significant influence on the price of an item.
$H1_{price}$: The class of an item does have a significant influence on the price of an item.

```
 Response Delivery.time :
                Df   Sum Sq Mean Sq F value    Pr(>F)
Class            6 33456906 5576151  629515 < 2.2e-16 ***
Residuals   179954  1594005       9
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

 Response Price :
                Df     Sum Sq    Mean Sq F value    Pr(>F)
Class            6 5.7156e+13 9.5259e+12   80224 < 2.2e-16 ***
Residuals   179954 2.1368e+13 1.1874e+08
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 26: Manova Analysis

As seen in figure 26 both p-values of both null hypothesis are very small, 2e16. This means that both Ho will be rejected. A conclusion that the classes will influence the price and delivery time can be drawn. In figure 27 and 28 it is evident that the distributions of each class for price and delivery time greatly differ.

Figure 27: Variation in delivery time of classes

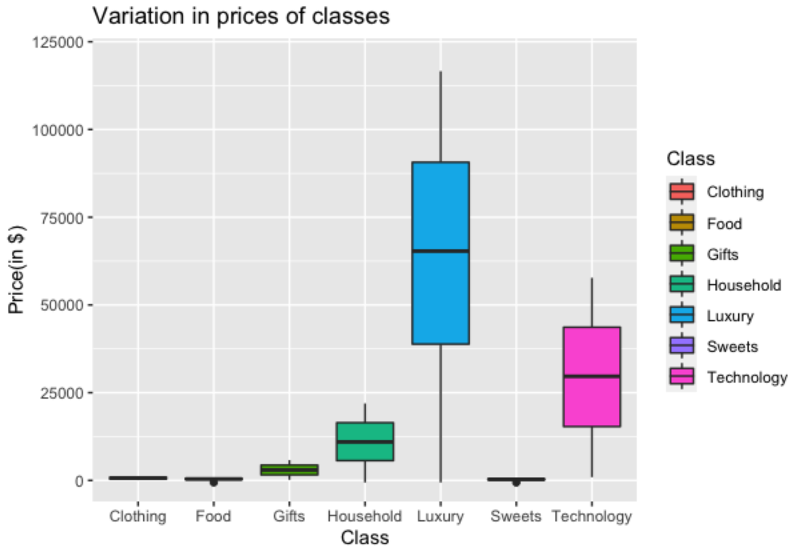


Figure 28: Variation in prices of classes

Part 6: Reliability of the service and products

6.1. Taguchi's Loss

Taguchi has defined Loss is when a product is not accepted due to not complying with the specifications, thus outside the LSL and USL. Also explained that customer satisfaction drops when there is a loss of quality. Loss is a parabolic curve mathematically given by $L = k(y\text{-}m)^2$

Question 6:

$L = k(y\text{-}m)^2 = 45$ met $(y\text{-}m) = 0.04$

$k = 45/(0.04)^2 = 28125$

⇨ $L = 28125(y-0.06)^2$

Question 7:

a.

$L = k(y\text{-}m)^2 = 35$ met $(y\text{-}m) = 0.04$

$k = 35/(0.04)^2 = 21875$

⇨ $L = 21875(y-0.06)^2$

b.

⇨ $L = 21875\,(0.027)^2 = 15.95$

6.2. Reliability:

a. $R_{\text{series}} = R_A + R_B + R_C$
$= 0.85 \times 0.92 \times 0.9 = 0.7038$
= 70.38% reliability

If there is no backup machines the reliability of the process working is 70.38%. This is the combined probability that machine A,B and C will not fail.

b. If management were to include backup machines the reliability will greatly increase since both machine would have to fail before the process is stopped.

$$
\begin{aligned}
R_{\text{parallel}} &= [1-(1-RA)(1-RA)]\times[1-(1-RB)(1-RB)]\times[1-(1-RC)(1-RC)] \\
&= [1-(0.15)(0.15)]\times[1-(0.08)(0.08)]\times[1-(0.1)(0.1)] \\
&= 0.9775\times0.9936\times0.99 \\
&= 0.9615 \\
&= 96.15\%\ \text{reliability}
\end{aligned}
$$

The reliability is now 96.16%, which is a significant improvement of 26%.

6.3 Reliability and probability

To estimate on how many days per year reliable deliveries could be expected, it can be calculated as follows:

Looking at the driver reliability the probability of having enough drivers available is 0.8484614.
If company has 21 trucks, then the probability of having enough working trucks for operating is 0.4420258.
Making the number of days efficient operating per year is (0.8484614*0.4420258) * 365= 150.8937 days

If the number of truck were increased to 22 trucks, then the probability of having enough working trucks for operating is 0.6399049.
The number of days efficient operating per year has increased to (0.8484614*0. 6399049) * 365 = 218.4434 days per year.

Conclusion

The data has been wangled to extract the valid instances from the sales data. It had been organized and presented to analyse the delivery process by putting together useful information for the company to improve their processes and to shorten the delivery time. Different statistical methodology were applied to reach the goal of maximizing profit and to better customer satisfaction.

Reference

Berardinelli, C., 2022. [online] Available at: <https://www.isixsigma.com/tools-templates/control-charts/a-guide-to-control-charts/> [Accessed 17 October 2022].

Sthda.com. 2022. *MANOVA Test in R: Multivariate Analysis of Variance - Easy Guides - Wiki - STHDA*. [online] Available at: <http://www.sthda.com/english/wiki/manova-test-in-r-multivariate-analysis-of-variance> [Accessed 14 October 2022].