ECSA Final Report:

The Department of Industrial Engineering
Stellenbosch University

Quality Assurance 344

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Table of Contents:

List of Figures:

List of Tables:

Introduction:

This report applies advanced statistical techniques and quality assurance principles to solve real-world industrial challenges, in line with the 2024 ECSA GA4 requirements. It focuses on process stability, resource optimisation, and performance variability across service and manufacturing environments. Using tools such as ANOVA, control charts, and capability indices, the analysis identifies key areas for improvement in delivery times, picking efficiency, and product demand.

Strategic staffing models were developed for both coffee shop and car rental scenarios, demonstrating how personnel adjustments directly influence profitability and reliability. Real-time data simulations supported decisions that balance cost, service quality, and operational efficiency.

By integrating statistical reasoning with live operational data, the project offers a practical framework for enhancing process control, reducing waste, and supporting sustainable industrial performance.

Part 1:

Data Loading and inspection:

The data given will be used to do an analysis. The following things can be seen by the dataset:

Products_Headoffice: 360 observations with 5 variables. It includes the Product ID, Category, Description, Selling price and the Markup.

Products_Data: 60 observations with 5 variables. It includes the Product ID, Category, Description, Selling Price and the Markup.

Customer_Data: 5000 observations with 5 variables. It includes the Customer ID, Gender, Age, Income and the City.

Sales2022and2023: 100000 observations with 9 variables. It includes the Customer ID, Product ID, Quantity, Order time, Order Day, Order Month, Order Year, Picking Hours and the Delivery Hours

	ProductID	Category	Description	SellingPrice	Markup
1	SOF001	Software	coral silk	521.72	15.65
2	SOF002	Software	black silk	466.95	28.42
3	SOF003	Software	burlywood marble	496.43	20.07
4	SOF004	Software	black marble	389.33	17.25
5	SOF005	Software	chartreuse sandpaper	482.64	17.60
6	SOF006	Software	cornflowerblue marble	539.33	25.57
7	SOF007	Software	blue marble	495.13	10.23
8	SOF008	Software	cornflowerblue marble	465.73	21.89
9	SOF009	Software	black bright	452.40	19.64
10	SOF010	Software	cornflowerblue matt	399.43	17.08
11	NA011	Software	aliceblue silk	823.51	14.59
12	NA012	Software	coral marble	987.13	27.59
13	NA013	Software	cornflowerblue sandpaper	1176.31	18.30
14	NA014	Software	azure silk	1061.21	20.03

Table 1: products_Headoffice

	ProductID	Category	Description	SellingPrice	Markup
1	SOF001	Software	coral matt	511.53	25.05
2	SOF002	Cloud Subscription	cyan silk	505.26	10.43
3	SOF003	Laptop	burlywood marble	493.69	16.18
4	SOF004	Monitor	blue silk	542.56	17.19
5	SOF005	Keyboard	aliceblue wood	516.15	11.01
6	SOF006	Mouse	black silk	478.93	16.99
7	SOF007	Software	black bright	527.56	16.79
8	SOF008	Cloud Subscription	burlywood silk	549.02	11.95
9	SOF009	Laptop	azure sandpaper	540.41	11.34
10	SOF010	Monitor	chocolate sandpaper	396.72	23.47
11	CLO011	Keyboard	burlywood silk	1070.54	16.41
12	CLO012	Mouse	azure silk	963.14	10.13
13	CLO013	Software	chartreuse silk	1067.54	16.80
14	CLO014	Cloud Subscription	burlywood silk	1083.11	21.25

Table 2: products_data

	CustomerID	Gender	Age	Income	City
1	CUST001	Male	16	65000	New York
2	CUST002	Female	31	20000	Houston
3	CUST003	Male	29	10000	Chicago
4	CUST004	Male	33	30000	San Francisco
5	CUST005	Female	21	50000	San Francisco
6	CUST006	Male	32	80000	Miami
7	CUST007	Female	31	100000	Los Angeles
8	CUST008	Male	27	90000	Los Angeles
9	CUST009	Female	26	35000	Chicago
10	CUST010	Male	28	105000	San Francisco
11	CUST011	Female	19	40000	Los Angeles
12	CUST012	Female	34	70000	Houston
13	CUST013	Female	18	100000	Miami
14	CUST014	Male	34	10000	New York

Table 3: customer_data

	CustomerID	ProductID	Quantity	orderTime	orderDay	orderMonth	orderYear	pickingHours	deliveryHours	Date	Gender	Age	Income	City
1	CUST001	MOU056	4	13	5	5	2022	15.7216667	24.5440	2022-05-05	Male	16	65000	New York
2	CUST001	KEY045	1	17	26	8	2022	13.7216667	25.0440	2022-08-26	Male	16	65000	New York
3	CUST001	MOU055	2	19	13	4	2022	12.3883333	11.0440	2022-04-13	Male	16	65000	New York
4	CUST001	SOF004	43	14	16	2	2023	0.7149444	0.5523	2023-02-16	Male	16	65000	New York
5	CUST001	CLO017	2	11	1	1	2023	12.3908333	10.5460	2023-01-01	Male	16	65000	New York
6	CUST001	MOU059	2	5	2	8	2023	18.7241667	28.0460	2023-08-02	Male	16	65000	New York
7	CUST001	SOF005	13	22	16	11	2023	0.9816111	1.0773	2023-11-16	Male	16	65000	New York
8	CUST001	CLO011	28	17	1	9	2022	11.0550000	17.5440	2022-09-01	Male	16	65000	New York
9	CUST001	MOU055	4	16	18	5	2023	12.7241667	25.5460	2023-05-18	Male	16	65000	New York
10	CUST001	KEY045	20	12	30	8	2022	11.7216667	28.0440	2022-08-30	Male	16	65000	New York
11	CUST001	CLO020	1	12	29	5	2023	9.7241667	13.5460	2023-05-29	Male	16	65000	New York
12	CUST001	SOF001	36	9	23	6	2023	0.6705000	0.7523	2023-06-23	Male	16	65000	New York
13	CUST001	SOF002	32	12	30	3	2023	0.7371667	1.2773	2023-03-30	Male	16	65000	New York
14	CUST001	MOU053	2	18	30	11	2022	15.7216667	25.5440	2022-11-30	Male	16	65000	New York
15	CUST001	MOU051	18	10	10	4	2023	10.3908333	10.0460	2023-04-10	Male	16	65000	New York

Table 4: sales2022and2023

Summary Statistics:

Products_Headoffice:

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Std Dev
Selling Price	290.5	495.9	797.2	4411	5843.3	22420.1	6503.77
Markup	10.06	15.84	20.58	20.39	24.84	30	6.072598

Table 5: products_Headoffice

The selling price shows that there are both expensive and cheap products since the range is large. The markup shows that most of the products have a consistent profit margin.

Products_data:

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Std Dev
Selling Price	350.4	512.2	794.2	4493.6	6416.7	19725.2	6503.77
Markup	10.13	16.14	20.34	20.46	25.71	29.84	6.072598

Table 6: products_data

The selling price shows that there are both expensive and cheap products since the range is large. The markup shows that most of the products have a consistent profit margin.

Customer_Data:

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Std Dev
Age	16	33	51	51.55	68	105	21.2161
Income	5000	55000	85000	80797	105000	140000	33150.11

Table 7: customer_data

The income is a left-skew distribution showing that more people are earning at the lower end of the scale. On the table the age is uniformly distributed.

Sales2022and2023:

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Std Dev
Customer ID	1	3	6	13.5	23	50	NA
Product ID	1	3	6	13.5	23	50	NA
Quantity	1	3	6	13.5	23	50	13.76013
Order Time	1	9	13	12.93	17	23	5.495127
Order Day	1	8	15	15.5	23	30	8.646506
Order Month	1	4	6	6.448	9	12	3.283446
Order Year	2022	2022	2022	2022	2023	2023	0.4986115
Picking Hours	0.4259	9.3908	14.055	14.6955	18.7217	45.0575	10.38733
Delivery Hours	0.2772	11.546	19.546	17.4765	25.044	38.046	9.999944

Table 8: sales2022and2023

The table shows that most of the orders are for a small number of items. Larger orders are miniscule. Some orders require more effort and are more complex as can be seen on the table at the time spent picking and delivering hours. There are no peaks during the day when it comes to the order timing.

Missing Values:

After doing the r code in R Studio there are no missing values for any of the files namely products_Headoffice, products_data, customer_data and sales2022and2023.

Data Visualisation:

Figure 1: Selling price by category

The boxplot highlights pricing inconsistencies that may stem from mislabelling or catalogue errors. There is wide IQR in the categories for example the laptop that suggests high variability.

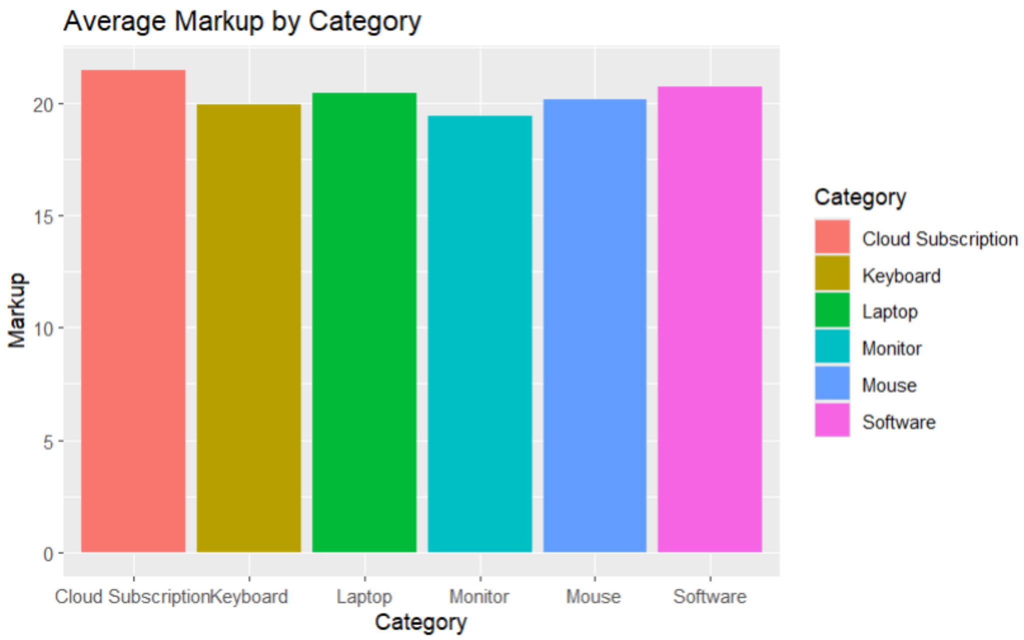

Figure 2: Average markup by category

The bar chart shows whether profit margins are consistently applied across the product lines. Unusually high or low markups indicate supplier cost anomalies or pricing strategy misalignment.

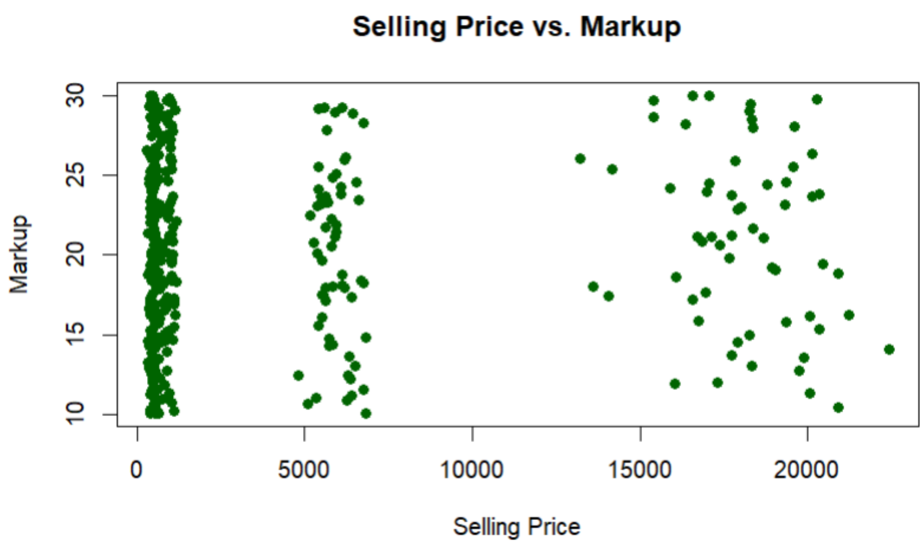

Figure 3: Selling price versus markup

The vertical clusters suggest fixed markup tiers applied to discrete price brands. This is good for consistency, but also hides inefficiencies. The lack of correlation indicates manual overrides, catalogue inconsistencies and non-standard pricing.

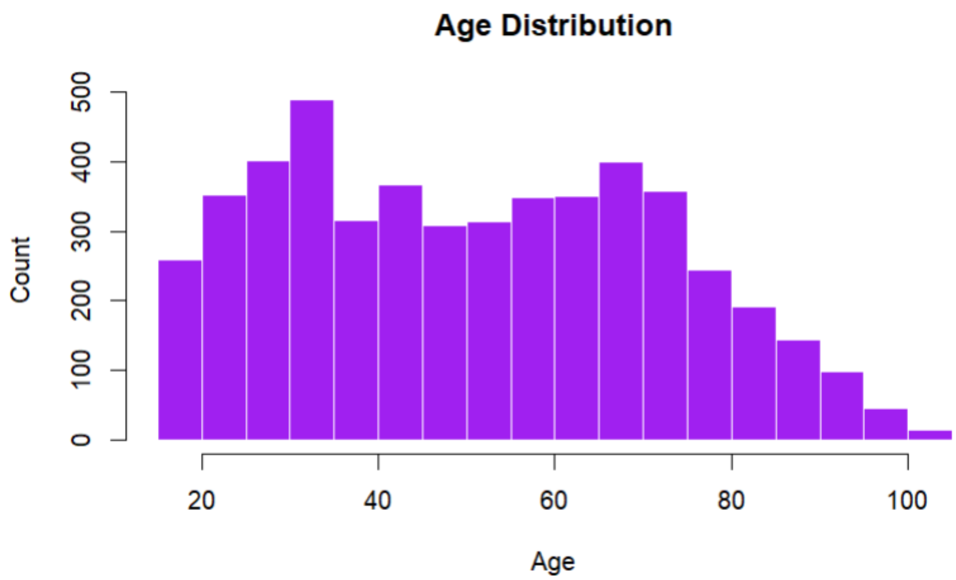

Figure 4: Age distribution

The data of the histogram is bimodal because there are two peaks, one at 30-40 years and another one at 50-60 years as shown above. Data is bimodal as there are two peaks, one at 30-40 years and 50-60 years as shown above. The graph also shows that the company has a very large customer base.

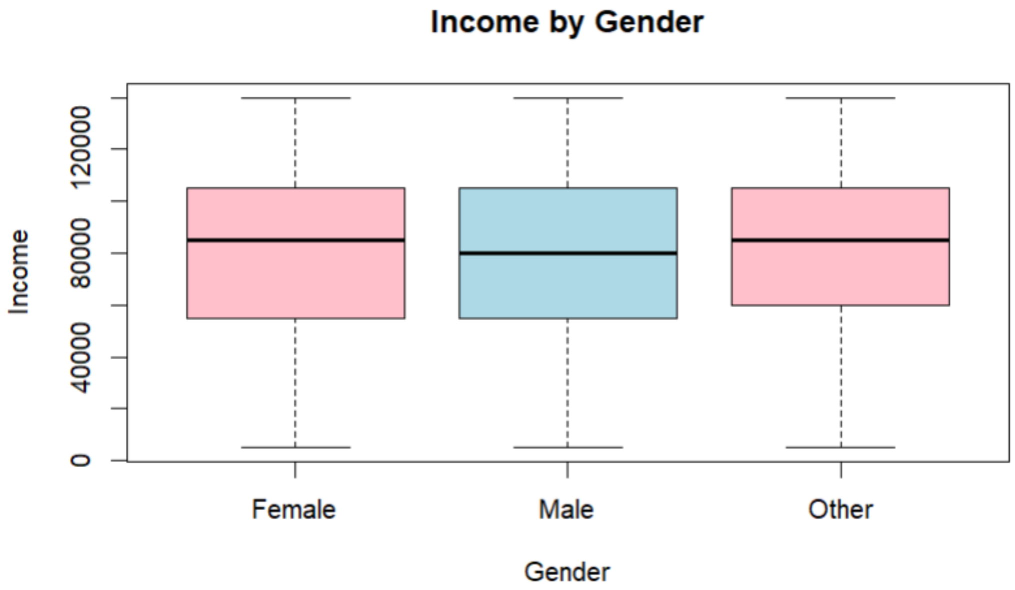

Figure 5: Income by gender

The boxplot shows that the customer targeting strategies are not biased. The plot shows no outliers or skewed distributions which means that there are no sampling biases.

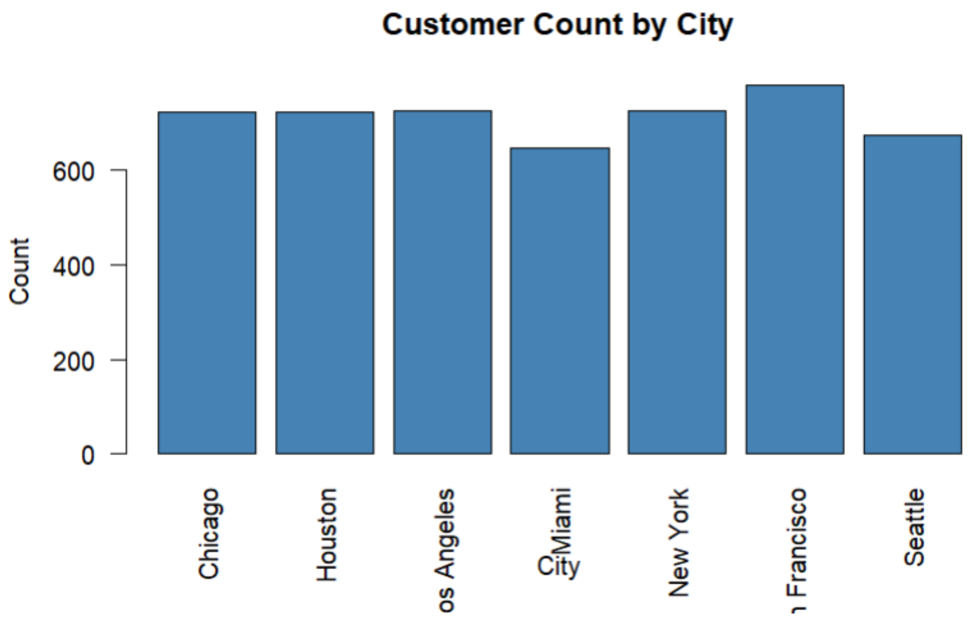

Figure 6: Customer count by city

The bar chart shows that the sampling amongst cities is balanced. If there were any anomalies it would have indicated that there are data gaps or duplicate entries.

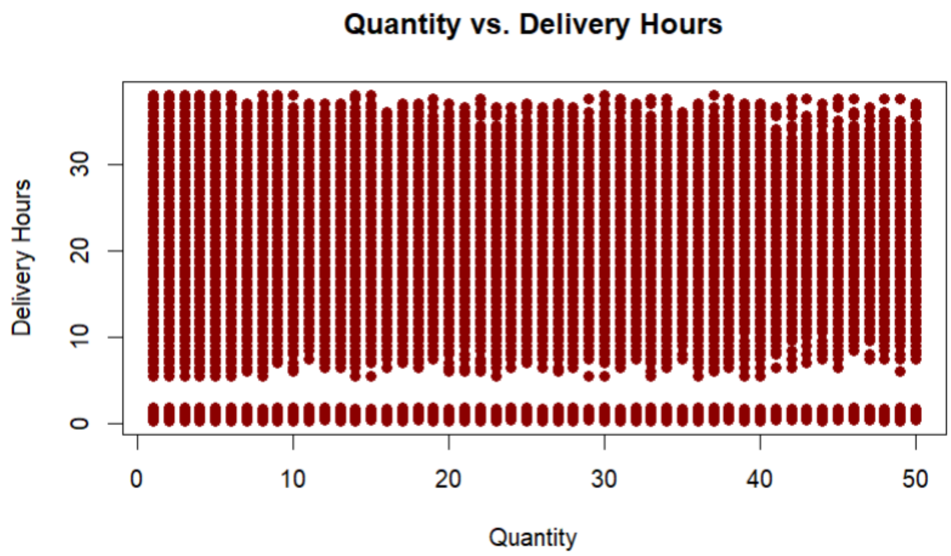

Figure 7: Quantity versus delivery hours

The uniform distribution with no clear pattern suggests that this is a non-scalable delivery process, it shows that the larger orders are not taking longer.

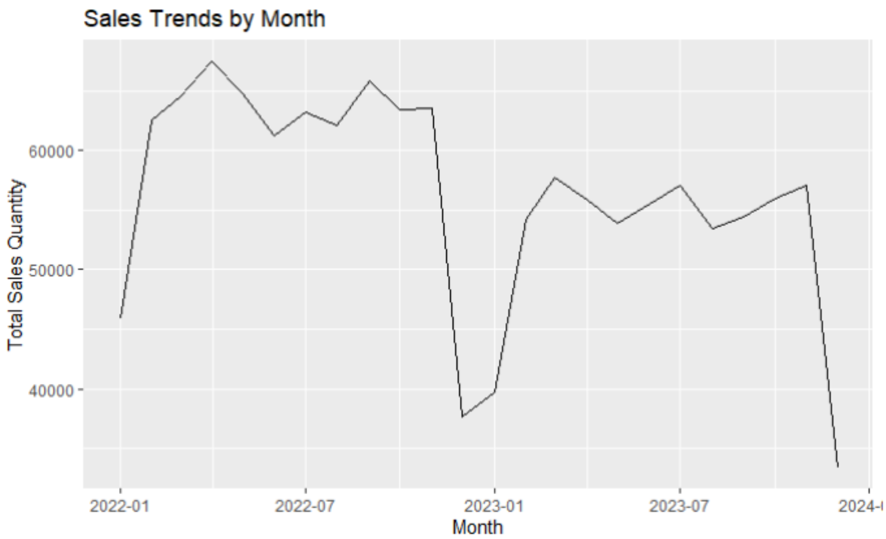

Figure 8: Sales trends by month

In the plot seasonal dips or surges can be seen in the sales which may indicate supply chain issues or product availability. The sudden drop in 2023 may signal bottlenecks, stockouts or customer dissatisfaction.

Part 3:

This section of the report discusses SPC (Statistical Process Control) and its significance in improving and maintaining the quality within the organisation. SPC is a data driven methodology for monitoring, controlling and improving processes by using statistical techniques to analyse data and identify variations (ASQ, 2025). It is important to note that the data needs 2 charts per process. The first chart shows the mean or average of each of the samples and the second chart shows the range and the standard deviation of each sample. Another thing to note is that the s-chart is checked before the x-bar chart.

3.1 Control Chart

For the analysis of the SPC, the csv file “sales2026and2027.csv” is used. An R-script is developed to construct the x- and s-charts. The data is sorted chronologically by the year, month, day and order time to ensure that the sequencing is correct. The initial 30 samples of 24 sales each are selected. These samples are used to construct the charts.

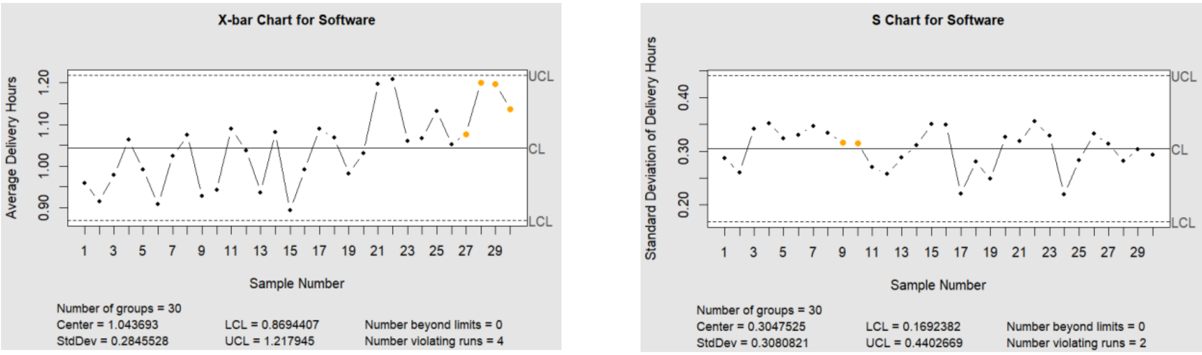

Figure 9: X-bar and S-chart for Software

The Software X-bar chart shows a mean of 1.04 and control limits between 0.87 and 1.22. All the data is within the control limits indicating that the process is stable. There is no evidence of out-of-control conditions. The x-bar chart shows that there are 4 violating runs suggesting a need for close monitoring to ensure continued control. The S-chart shows a mean of 0.30 and control limits between 0.17 and 0.44. All the data is in the control limits indicating that the process is stable with no out-of-control conditions. The s-chart shows that there are 2 violating runs. These breaches suggest fluctuations in variability, which, while it is not critical to the overall stability, it indicates potential inconsistencies in the process that warrant further analysis to prevent future variability issues.

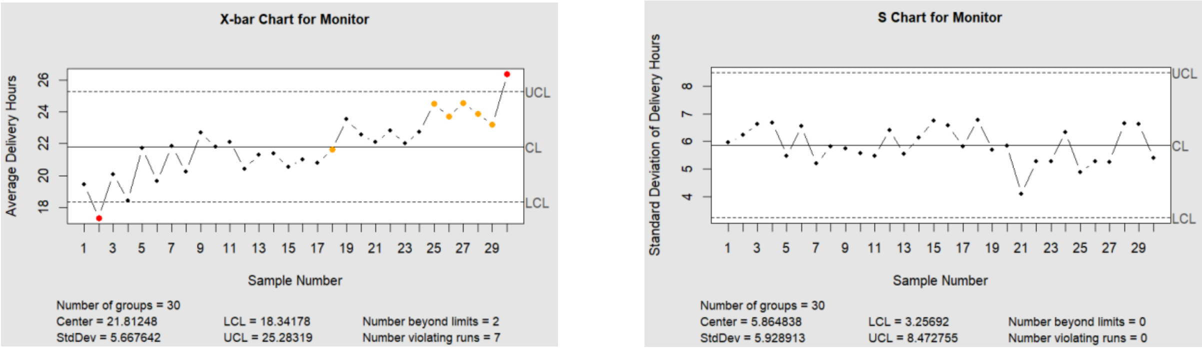

Figure 10: X-bar and S-chart for Monitor

The Monitor X-bar chart shows a mean of 21.81 with control limits between 18.34 and 25.28. Most of the data fall into the control limits meaning that the process is mostly stable. There is evidence that there a 2 out-of-control conditions suggesting that there are occasional deviations and further investigation is needed. The chart also shows that there are 7 violating runs that warrant further analysis. The S-chart shows a mean of 5.86 and control limits between 3.26 and 8.47. All the data is within the control limits meaning that the process is stable with no out-of-control conditions and no violating runs.

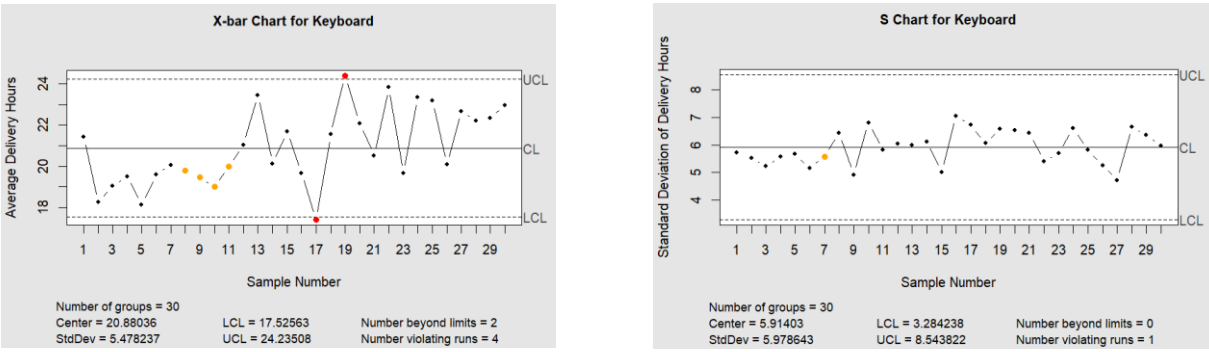

Figure 11: X-bar and S-chart for Keyboard

The Keyboard X-bar chart shows a mean of 20.88 with control limits between 17.53 and 24.24. Most of the data points are within these limits meaning that the process is mostly stable. There is evidence indicating that there are out-of-control conditions suggesting that there are occasional deviations and that further investigation is required. While the process is largely in control, there may be instances of underperformance. The chart has 4 violating runs which warrant further analysis. The S-chart shows a mean of 5.91 with control limits between 3.28 and 8.54. All the data points are within the control limits, meaning that the process is stable with no evidence of out-of-control conditions. The chart shows 1 violating run which will not impact the stability of the process.

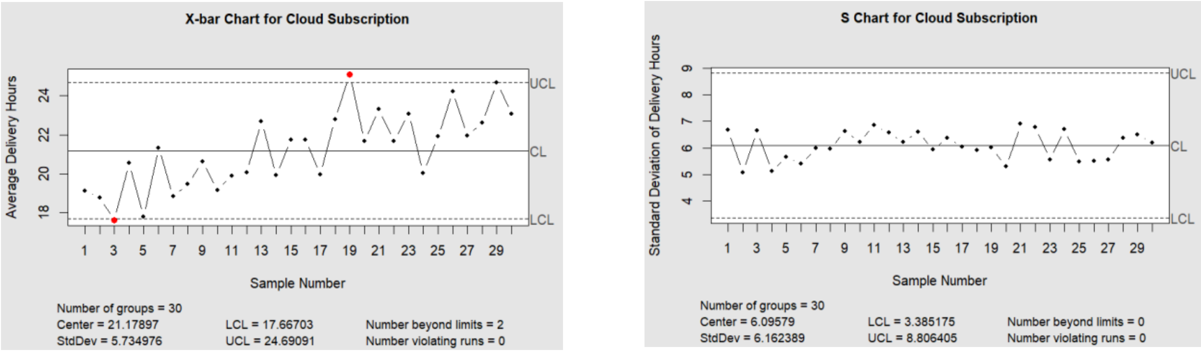

Figure 12: X-bar and S-chart for Cloud Subscription

The Cloud Subscription X-bar chart shows a mean of 21.18 and control limits between 17.67 and 24.69. Most of the data is in between the control limits with only 2 out-of-control conditions which indicates that the process is stable. There are also no violating runs in this chart. The S-chart shows a mean of 6.10 and control limits between 3.89 and 8.81. There are no out-of-control limits which indicates that the process is stable. There are also no violating runs.

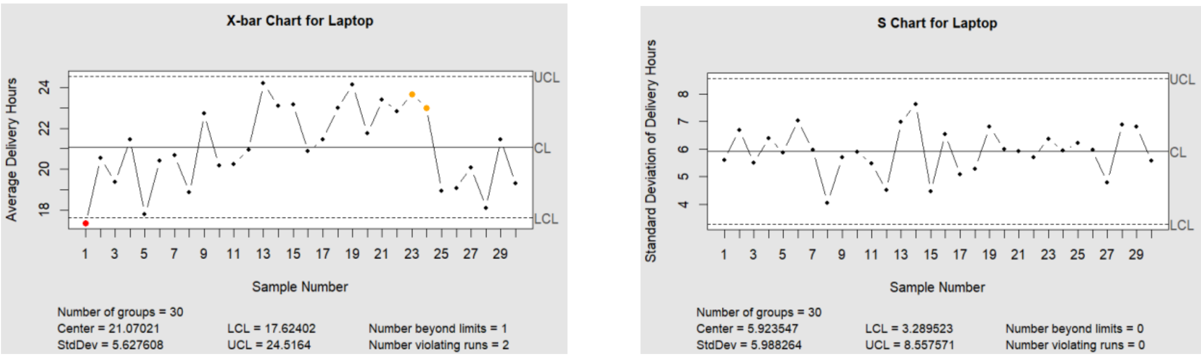

Figure 13: X-bar and S-chart for Laptop

The Laptop X-bar chart shows a mean of 21.07 and control limits between 17.62 and 24.52. Most of the data is within the control limits except 1 out-of-control condition which indicates that the process is stable. The chart has 2 violating runs which may warrant further analysis. The S-chart shows a mean of 5.92 and control limits between 3.29 and 8.56. All the data is in the control limits indicating no out-of-control limits and showing that the process is stable. The chart also has no violating runs.

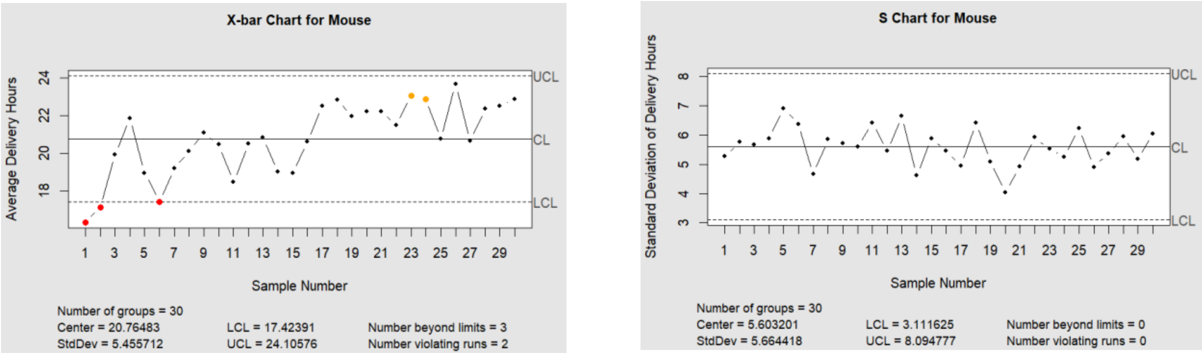

Figure 14: X-bar and S-chart for Mouse

The Mouse X-bar shows a mean of 20.76 and control limits between 17.42 and 24.11. Most of the data is in the control limits with only 3 out-of-control conditions which indicates that the process is mostly stable. The out-of-control conditions warrants further investigation to make sure there are no future underperformance. There are also 2 violating runs which warrants further investigation. The S-chart shows a mean of 5.60 and control limits between 3.11 and 8.09. There are no out-of-control conditions indicating that the process is stable. There are also no violating runs.

3.2 Process Monitoring

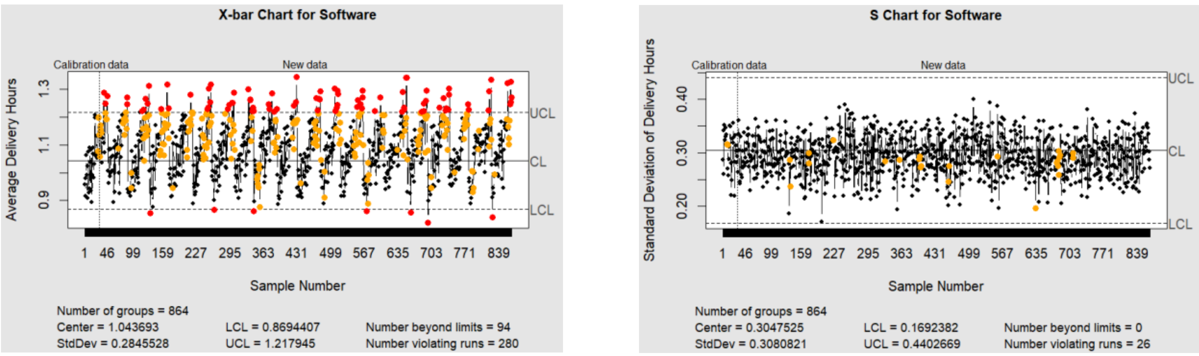

Figure 15: X-bar and S-chart for remaining of Software

The Software X-bar chart shows a mean of 1.04 and control limits between 0.87 and 1.22. The presence of 94 out-of-control conditions and 280 violating runs indicates recurring deviations that warrant closer attention. These out-of-control conditions suggest that the process occasionally experience shifts or anomalies that fall outside expected variation. This highlights the need for the software product manager to investigate potential sources of instability and reinforce process controls to prevent further drift. Most of the data lies in between the control limits indicating that it is mostly stable. The S-chart shows a mean of 0.30 and control limits between 0.17 and 0.44. All the data is in between the control limits with no out-of-control conditions indicating that the process is stable. There are 26 violating runs which suggest further analysis.

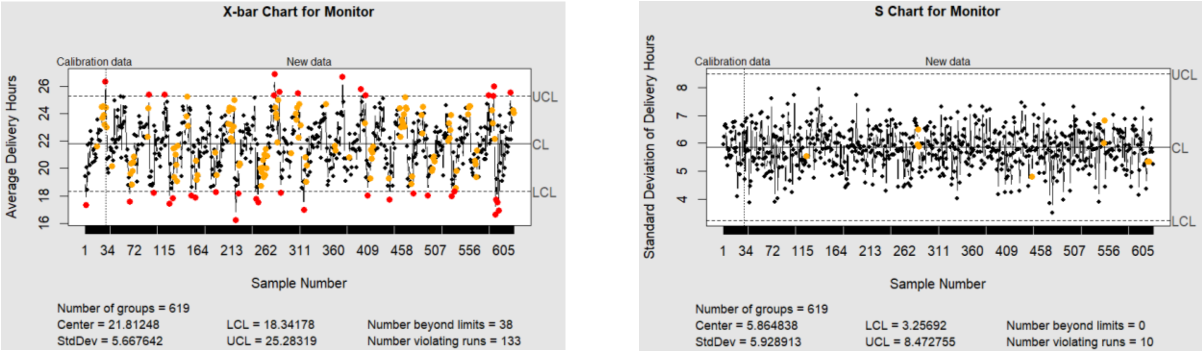

Figure 16: X-bar and S-chart for remaining of Monitor

The Monitor X-bar chart shows a mean of 21.81 and control limits between 18.34 and 25.28. The chart shows 38 out-of-control conditions which indicates that the process is statistically stable with 133 violating runs that warrant further analysis. The S-chart shows a mean of 5.86 and control limits between 3.26 and 8.47. All the data lies in between the control limits with no out-of-control conditions indicating that the process is stable. There are 10 violating runs which warrants further analysis.

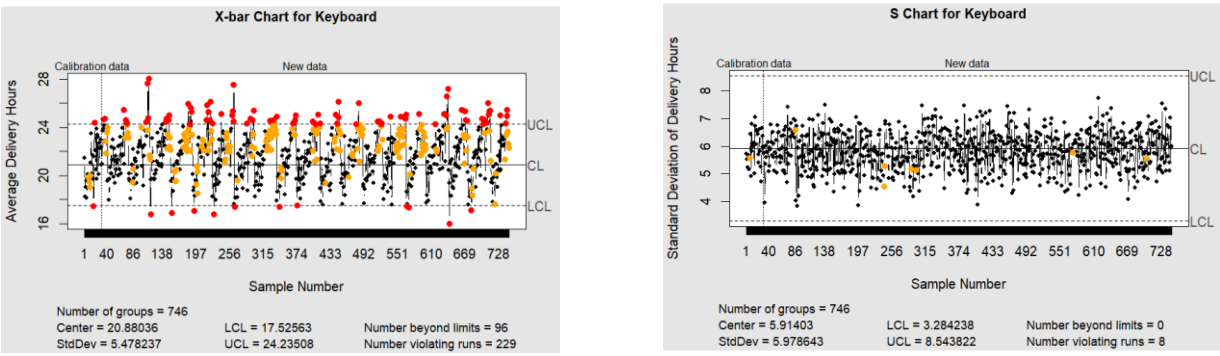

Figure 17: X-bar and S-chart for remaining of Keyboard

The Keyboard X-bar chart shows a mean of 20.88 and control limits between 17.53 and 24.24. Most of the data lies in between the control limits indicating that the process is stable. There are 229 violating runs which do not affect the stability of the process, but does warrant further analysis to prevent it in the future. The S-chart shows a mean of 5.91 and control limits between 3.28 and 8.54. All the data lies in between the control limits indicating that the process is stable. There are 8 violating runs which warrants further analysis.

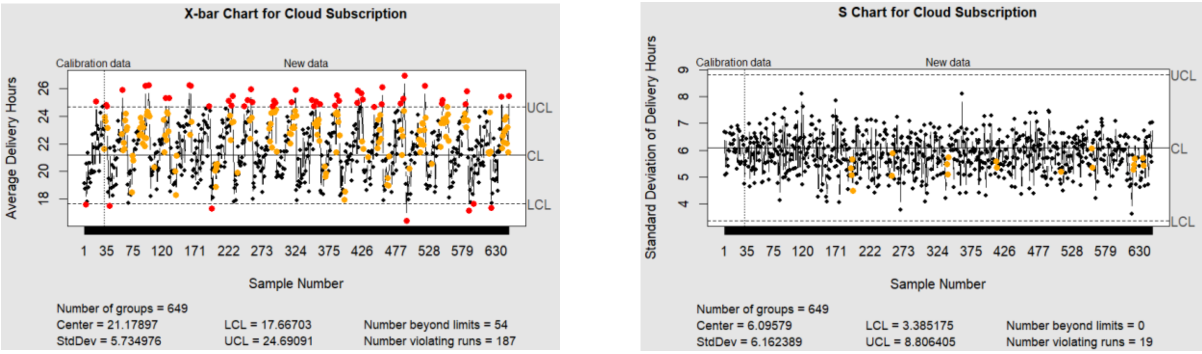

Figure 18: X-bar and S-chart for remaining of Cloud Subscription

The Cloud Subscription X-bar chart shows a mean of 21.18 and control limits between 17.67 and 24.69. There are 54 out-of-control conditions, but most data lie in between the control limits which indicates that the process is stable. There are also 187 violating runs which warrants further analysis. The S-chart shows a mean of 6.10 and control limits between 3.39 and 8.81. There are no out-of-control conditions and all the data lie in between the control limits which indicates that the process is stable. There are 19 violating runs which does not affect the stability of the process, but does warrant further analysis.

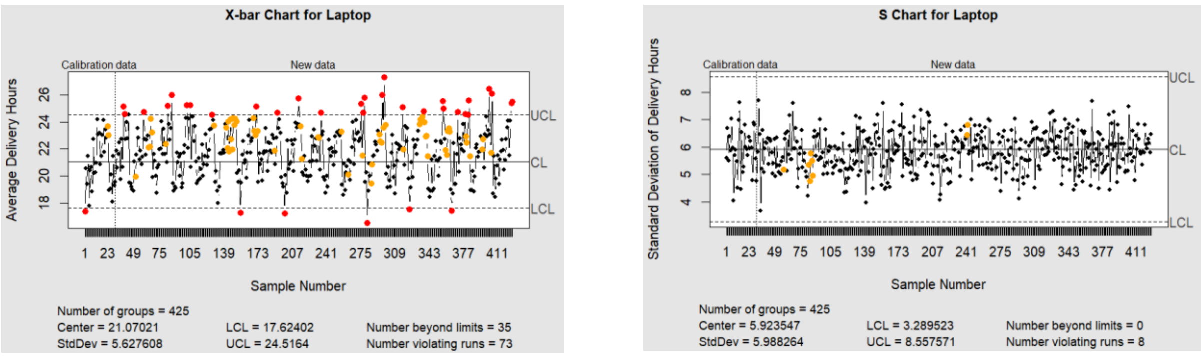

Figure 19: X-bara and S-chart for remaining of Laptop

The Laptop X-bar chart shows a mean of 21.07 and control limits between 17.62 and 24.52. There are 35 out-of-control conditions, but most of the data lie in between the control limits which indicate that the process is stable. There are also 73 violating runs which warrant further analysis. The S-chart shows a mean of 5.92 and control limits between 3.29 and 8.56. There are no out-of-control conditions and all the data lie in between the control limits indicating that the process is stable. There are 8 violating runs which warrants further analysis.

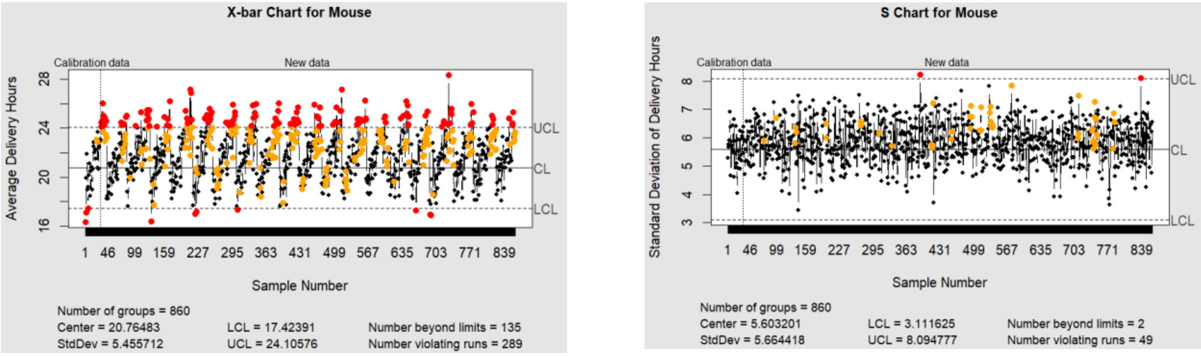

Figure 20: X-bar and S-chart for remaining of Mouse

The Mouse X-bar chart shows a mean of 20.76 and control limits between 17.42 and 24.11. There are 135 out-of-control conditions, but most of the data lies in between the control limits which indicate that the process is stable. There are 289 violating runs which do not affect the stability of the process, but warrants further analysis. The S-chart shows a mean of 5.60 and control limits between 3.11 and 8.09. There are 2 out-of-control conditions, but almost all the data is in between the control limits which indicate that the process is stable. There are also 49 violating runs which warrant further analysis.

	Number of out-of-control samples
Monitor	40
Software	94
Keyboard	98
Mouse	140
Cloud Subscription	56
Laptop	26

Table 9: Number of out-of-control samples per category

3.3 Process Capability

Category	**Cp**	**Cpu**	**Cpl**	**Cpk**
Cloud Subscription	0.863468	0.561740	1.165196	0.561740
Laptop	0.900956	0.585982	1.215930	0.585982
Keyboard	0.894511	0.574876	1.214146	0.574876
Monitor	0.934369	0.604104	1.264633	0.604104
Mouse	0.851572	0.553999	1.149144	0.553999
Software	17.033102	32.882406	1.183797	1.183797

Table 10: Process Capabilities

The process capability analysis shows that Software is the only product type with strong control and high capability, with Cp = 17.03 and Cpu = 32.88, indicating excellent performance well within specification limits. All other categories — including Monitor, Keyboard, Laptop, Mouse, and Cloud Subscription — have Cp values below 1 and Cpk values below 0.61, suggesting weaker control and poor centering. These processes may struggle to consistently meet the VOC and require improvement in both variation and alignment.

3.4 Identification of process control issues

Rule A:
There is no adjustment needed as the total number of instances that fall outside the limits of rule A is 0, where it would have instances if any of the samples are outside of the upper limit +- 3 sigma.

Rule B:
The table below shows the most consecutive samples in control

Category	Most consecutive in control
Cloud Subscription	10
Laptop	14
Keyboard	14
Monitor	10
Mouse	21
Software	13

Table 11: Most consecutive in control

Rule C:
The table below shows the total violations

Category	Total Violations
Cloud Subscription	206
Laptop	83
Keyboard	242
Monitor	150
Mouse	340
Software	312

Table 12:Total Violations

Part 4:

4.1 Type I (Manufacturer's) Error

A Type I Error, also known as a Manufacturer's Error in quality control, occurs when a process or product is incorrectly rejected even though it meets the required specifications. It is also known as a false alarm or a false positive (Bhandari, 2021). Below are the run-length rules output:

Rule A:
For L=7

αA = 0.5^7
= 0.0078125
Rule B:
For L=8

αB = 0.5^8
= 0.00390625
Rule C:
For L=9

αC = 0.5^9
= 0.001953125

The above answers for each equation show the probability that a false alarm will occur.
Rule C is the most conservative option while Rule A is the most sensitive option since the longer the required run equals the smaller the chance that a false alarm will occur.

4.2 Type II (Manufacturer's) Error

A Type II Error, also known as a Consumer's Risk in manufacturing, occurs when a process or product is incorrectly accepted even though it fails to meet specifications. It is also known as a false negative (Bhandari, 2021).
In this scenario the processes should be centred on:
25.05L
Limits:
UCL = 25.089L
LCL = 25.011L

Probability of failing to detect the shift is:
β = 0.8412
which indicates that there is an 84% chance that the chart will not signal that the process mean has shifted.
Detection power:
Detection Power = 1- β
= 1 – 0.8412
= 0.1588
= 0.16
Which indicates that there is only a 16% chance that the chart will indicate/signal the shift on any of the subgroups and indicates that the chart is insensitive to small mean shifts when the invariability increases.

4.3 Comparison

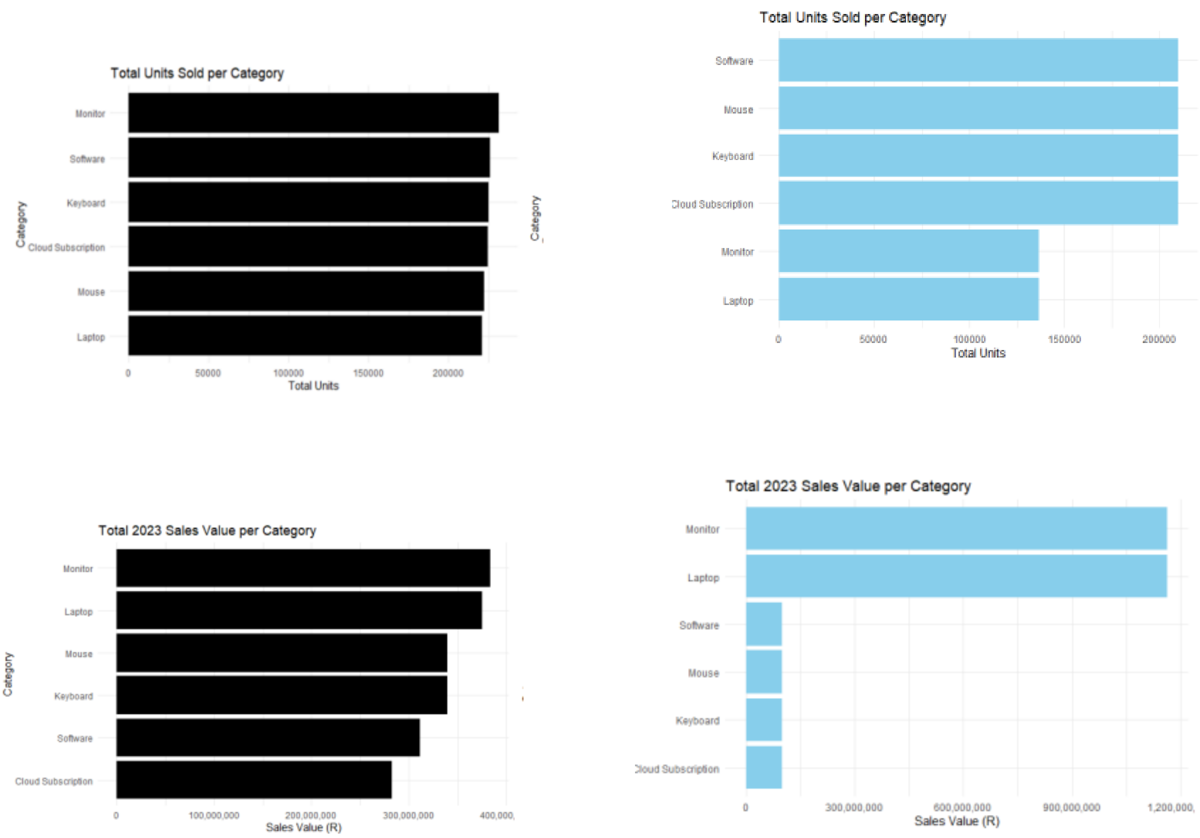

Figure 21: Comparison between before and after data adjustment

After the updated code for “product_Headoffice” was coded a clear difference was seen since the mistakes were fixed and it was put into a new file “products_data2025”. As can be seen in the Blue Bar Charts, the results have a more realistic variation between the product categories. Whereas the Black Bar Chart values were basically identical. Software and Cloud Subscription sold the highest number of units whereas the Monitors and Laptops had the highest number of values due to their high selling price. The updated file ("products_data2025") provides a more realistic and reliable reflection on the data.

Part 5:

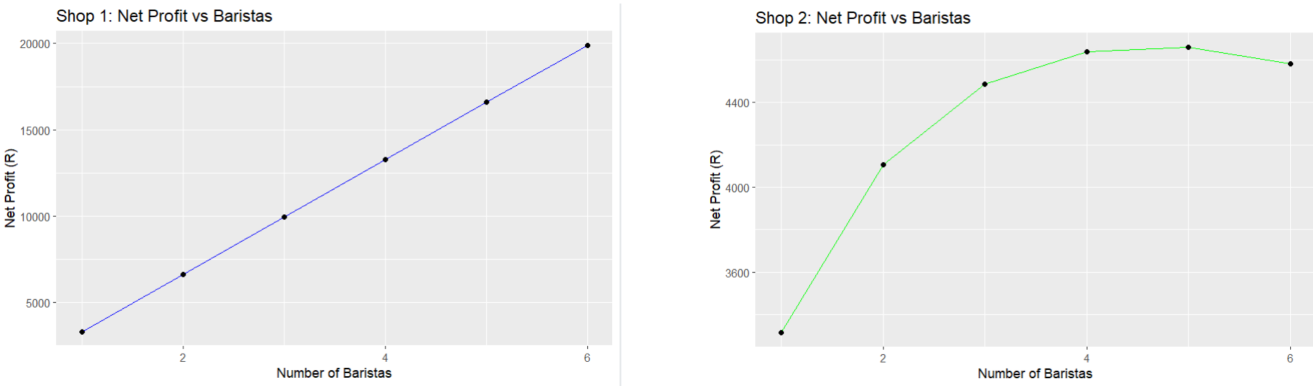

Figure 22: Net Profit vs Number of Baristas for Shop 1 and Shop 2

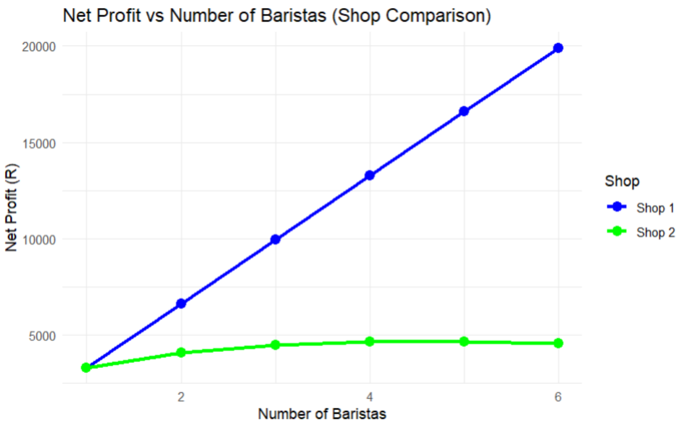

Figure 23: Net Profit vs Number of Baristas Comparison

Shop 1:
The Net Profit increases the more the number of baristas goes up. Therefore, it is a linear relationship between the net profit and the baristas. This indicates that the greater number of baristas are hired the higher the revenue will be. The maximum net profit is when 6 baristas are working at the same time. The net profit will roughly be R7.7 million per year with 6 baristas. The shop provides 99% of customers with reliable service.

Shop 2:
The shop shows a diminishing return. The net profit increases exponentially to 5 baristas and then it decreases when it hits 6 baristas. This indicates that additional staffing beyond this point is going to decrease the net profit, which means that money will be lost. The net profit will be roughly R1.8 million per year with 5 baristas. The shop provides 95% of customers with reliable service.

Shop 1 and 2:
After seeing the results from Shop 1 and Shop 2, the better option is to choose Shop 1 since it will bring in the most profit.

Part 6:

ANOVA compares group averages (means) while accounting for variation within each group (Spotfire, 2025). It helps answer the questions, for example:

- ✓ Do delivery times differ over the months?
- ✓ Is there a significant change in quantity between 2022 and 2023?

ANOVA tests whether there were significant changes in the Keyboard performances between the years 2022 and 2023. Null hypothesis assumes that there will be no significant changes in the variables in the years.

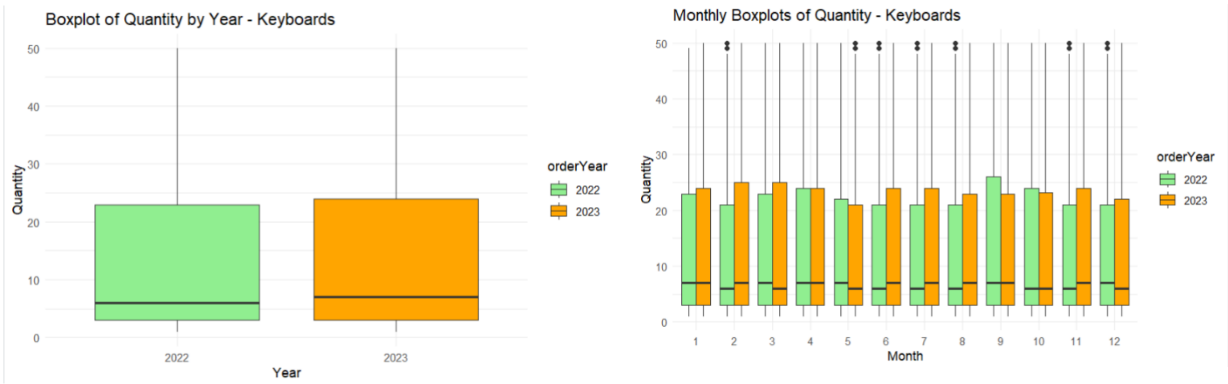

Figure 24: Boxplot of Quantity for the years and the months

The Quantity in 2023 shows a slightly higher median quantity than 2022, suggesting a modest increase in the keyboard orders. The interquartile range in both years are similar, indicating comparable variability in order volumes. There are no extreme outliers which suggest stable demand across both the years. The upward shift in the median quantity in 2023 may indicate an increased demand. The consistent spread across the years suggests that operational capacity kept up with the demand. Several months show higher quantities in 2023 than in 2022. Whereas in other months it is either similar or slightly lower quantities in 2023. The spread within the months varies. Months like February and July show tight distributions, while April and October have wider variability. The monthly boxplots reveal seasonal or campaign-driven fluctuations in the keyboard orders.

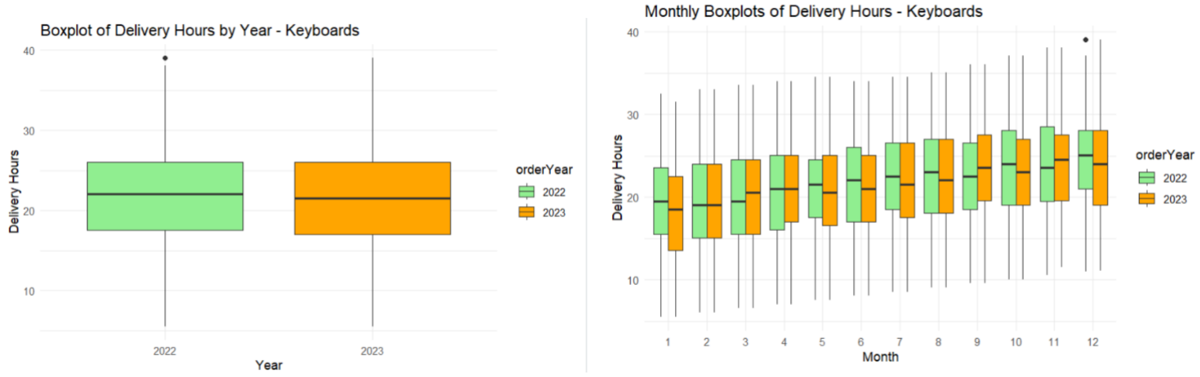

Figure 25: Boxplot of Delivery Hours for the years and the months

The median delivery hours are nearly identical for 2022 and 2023. The interquartile range is slightly narrower in 2023 compared to 2022 which suggest that 2023 has a more consistent delivery performance. 2022 includes a notable outlier above 40 hours indicating at least one extreme delay that year. The median (central) remained stable year-over-year, 2023 shows tighter control over delivery times. Some months show higher median delivery hours in 2022 than in 2023. The 2023 months show similar or lower delivery hours in 2023. The spread within the months varies. Months like February and September show a tight distribution, while April and November have a wider variability. Monthly delivery performance fluctuates, with 2023 generally showing more consistency and fewer extreme delays.

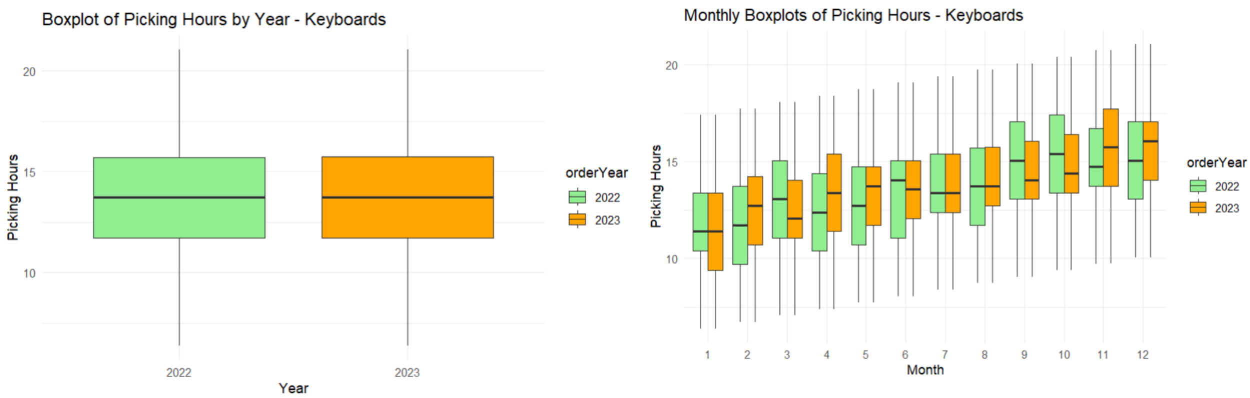

Figure 26: Boxplot of the Picking Hours for the years and the months

The Picking Hours in 2023 are slightly higher than in 2022. The interquartile range in 2023 is narrower, which suggests a more consistent performance. 2022 shows a wider range, indicating greater variability in picking times. Picking operations in 2023 appear more stable and slightly more time-consuming on average. Some months show higher picking hours in 2023 than in 2022. The spread within the months varies. Some months have tight distribution, while others show a wide variability. Monthly fluctuations suggest that the picking efficiency is influenced by seasonal factors or workload surges. The increase in 2023 for certain months may reflect operational bottlenecks or shifts in product mix.

Part 7:

7.1 Reliable service

From the chart we can see that reliable service occurs when 15 or more workers are on duty. From the chart we can do the following:
15 workers: 96 days
16 workers: 270 days

Total reliable days = 96 + 270
= 336 days

Annual Estimate:
Total number of days = 1+5+25+96+270
= 397
365 days in a year
Therefore:
Reliable service rate = $\frac{336}{365}$
= 0.921
= 92.1%
Therefore 92.1% days per year the service will be reliable.

7.2 Optimisation of profit

Problem days = days with less than 15 workers
= 1+5+25
= 31
Loss per problem day = R20 000
Cost to hire 1 extra worker = R25 000
Cost for 1 extra worker per year = 25 000*12
= 300 000
Annual loss = 20 000*31
= 620 000

Extra staff	Estimated problem days	Loss Avoided	Staff cost	Net impact
0	31	0	0	-620 000
1	10	420 000	300 000	+120 000
2	5	520 000	600 000	-80 000

Table 13: Staffing Optimisation

Therefore adding 1 additional worker. It reduces the problem days enough to yield a net profit improvement. That means that there would be a total of 17 employees working. This achieves a level of 99% where the service days have no problems.

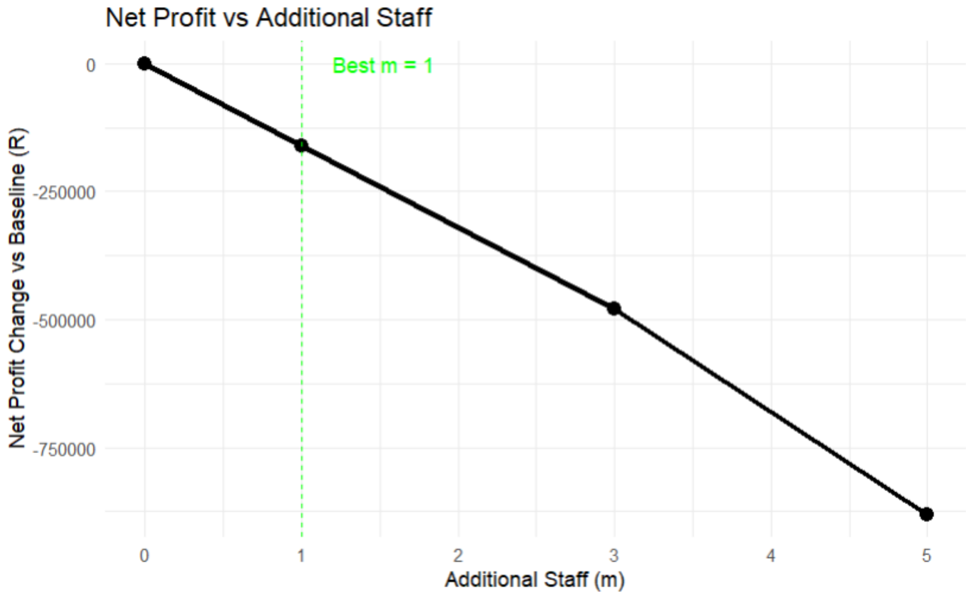

Figure 27: Net Profit versus Additional Staff

Conclusion:

This report applied statistical methods and engineering reasoning to address operational challenges in service and manufacturing environments. By refining the dataset, the analysis revealed key insights into product performance, delivery consistency, and resource variability. ANOVA identified significant fluctuations in picking and delivery times, guiding targeted improvements.

SPC tools such as X-bar and S-charts, along with capability indices, were used to assess process reliability across categories. Software operations showed strong control, while laptop production required closer monitoring. Descriptive statistics and visual diagnostics highlighted seasonal patterns and bottlenecks.

Staffing models for coffee shops and car rentals demonstrated how personnel adjustments impact profitability and reliability. Binomial modelling and simulation identified optimal staffing levels that minimize cost and maximize performance. Evaluating Type I and Type II errors further supported quality assurance decisions.

Overall, the project integrated theory with real-time data to meet ECSA GA4 outcomes, emphasizing continuous monitoring, strategic optimization, and data-driven control for sustainable industrial performance.

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