Cristallo Motorbikes

A Business Analysis Report

Analysing the Impact of Quality Score, Complaints, and Absenteeism of Employees on Quality of Electric Motorcycle Production

By

Arpit Rimza

EXECUTIVE SUMMARY

The purpose of this Business Analysis report is to provide data-driven recommendations and insights to address the senior management (Marketing, Purchasing, HR, and Production Directors) of Cristallo Motorcycles, an electric motorcycle manufacturing company and it covers an appraisal of the analysis conducted in accordance with the data provided on Production Quality and HR Absent. Relationships and patterns have been established between variables like Quality Score, Production Time, Type of Complaint for different Bike Models and Employee Absent Rates for different Job Titles and Shifts to understand how these affect the overall Production Quality. The methodology includes the use of Descriptive and Inferential statistical methods in a data analysis framework to look for trends and patterns in data for a number of variables and test the same using hypotheses testing methods (t-test, z-test, and chi-squared test) before coming to logical conclusions and provide recommendations so that the company can improve its processes and increase its capacity to meet the future demands in a sustainable manner. The analysis reveals that Bike Model 2 has some problems in terms of Quality Scores and Proportion of Complaints, hence, its production should be stopped and the higher Quality Models 3 and 4 should get greater emphasis instead. Power System 2 should replace the Power System 1 on the basis of high Quality Score and less Complaints. A particular focus has been made on the Absenteeism of Quality and Refit workers who are less experienced, aged and are not giving their best throughput. Amending certain Shifts where problems persist has also been recommended. The introduction of Performance Monitoring System (PMS) at each stage has been suggested based on the data apprehension and adding another level of Quality Checks to improve quality and reduce the rework rate. Further, the benefit of training the employees as a quality improvement initiative along with capacity expansion suggestions to cope with increasing demand will serve as the reference for management to put these recommendations into practice.

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1. INTRODUCTION

This Business Analysis report is intended for the Cristallo Motorcycle management team and includes an analysis of the Impact of Quality Score, Complaints, Training, and Absenteeism of Employees on Electric Motorcycle Production Quality. The provided dataset included information on Production Quality and Customer Complaints for the year 2019 and Absenteeism of Employees for 2020. As a team (Group - W9) of Business Analysts, an effort has been made to describe the company's present situation using statistical methods, data visualisation, and hypothesis testing and to provide insights and recommendations based on the data-driven observations to improve the existing processes to cope with increasing production demand.

Cristallo Motorcycles, an electric motorbike manufacturing firm, has been witnessing an increase in demand for its four bike models. The company has well-planned processes and resources in practice, however, customer complaints pertaining to quality issues, not being able to achieve the expected production capacity, and absenteeism of employees on key processes are adding to the stress of the respective management teams. Sources of these problems need to be identified and addressed to achieve sustainable growth.

2. METHODOLOGY

Inferential and descriptive statistics both have been employed in combination to analyse data and find patterns between data points of multiple variables and hypothesis testing to draw reasoned conclusions.

The below-mentioned flow chart represents the procedures followed to approach the case study:

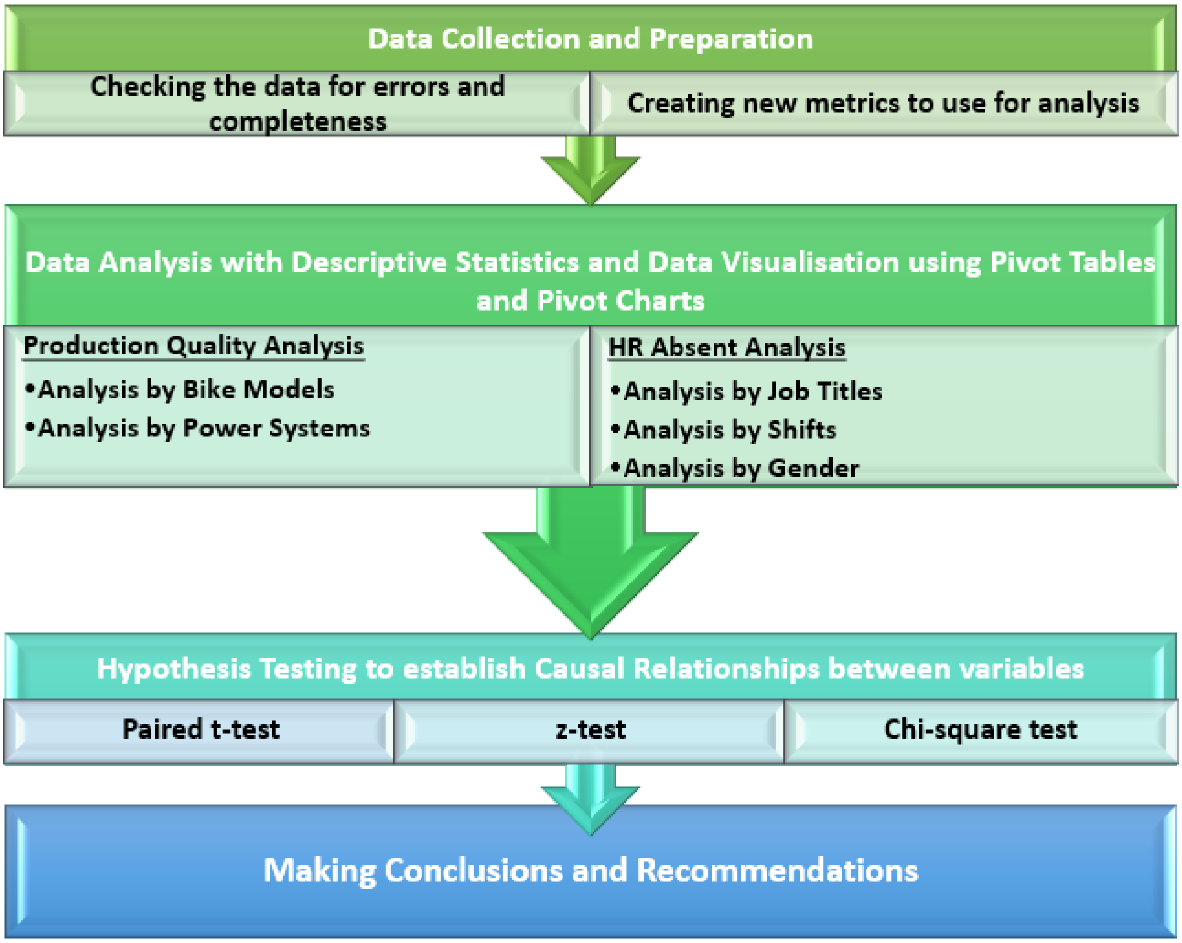


Figure 1: Methodology Used for Analysis

3. BUSINESS UNDERSTANDING

3.1 Current Business Situation

3.1.1 Business System and Processes

The following diagram describes the Cristallo Motorcycle System Model, inputs, outputs, and its processes.

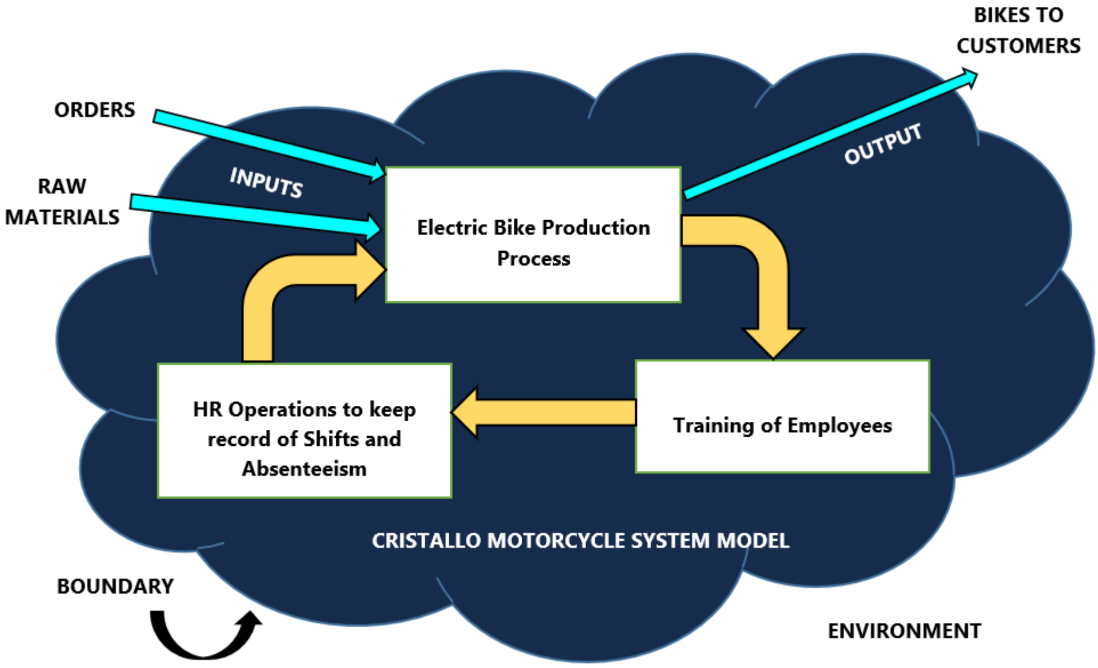


Figure 2: Business System Model

3.1.2 Company's Production Process

Cristallo Motorcycles is a manufacturer of specialist motorcycles with four production models which share the same basic frame.

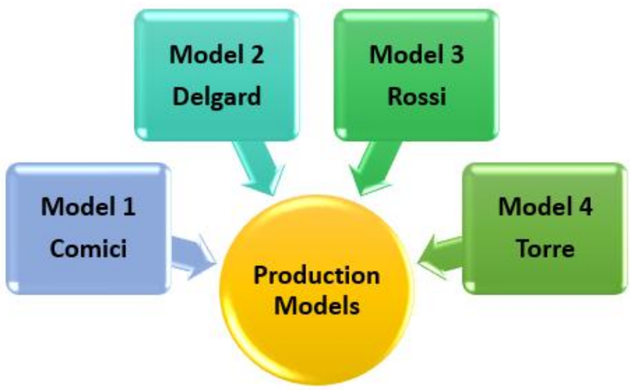


Figure 3: Types of Bike Models

Different suppliers deliver the large components required to manufacture the motorcycles which vary among the models. The production process involves the following steps:

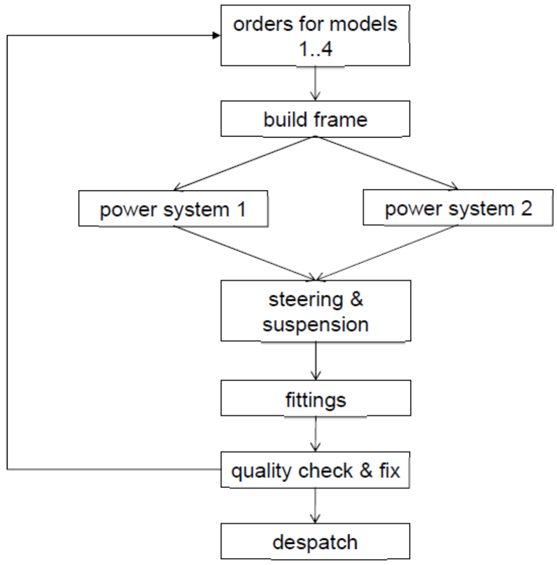


Figure 4: The Production Process

Following points are to be emphasised about the production process:

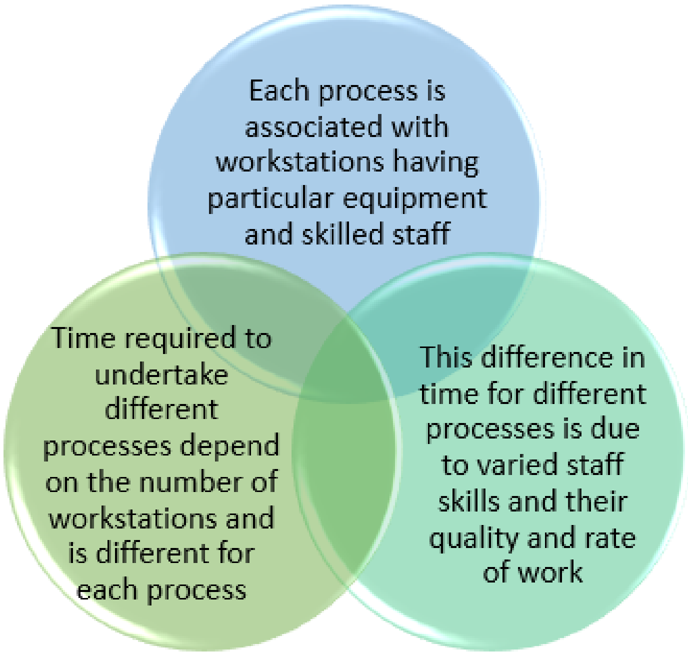


Figure 5: Additional Details about Processes

As per the 2019 data, the following is summarised:

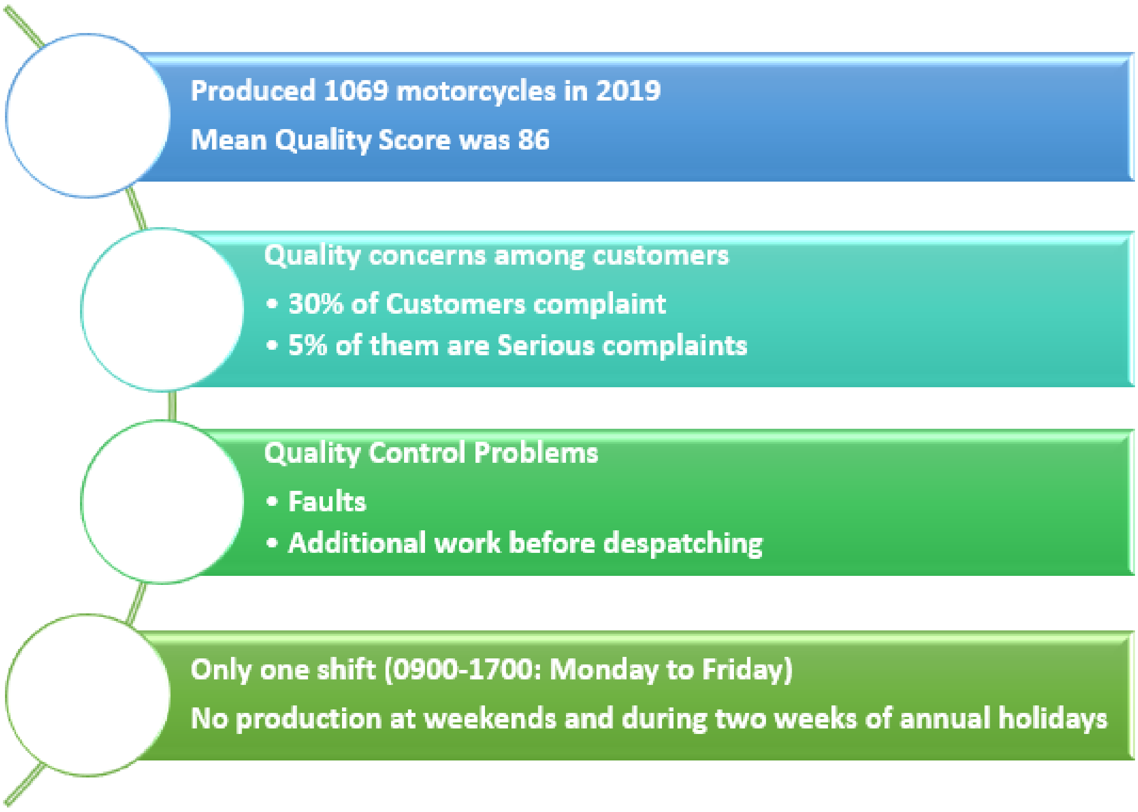


Figure 6: 2019 Data Summary

According to the 2020 data, the following is summarised:

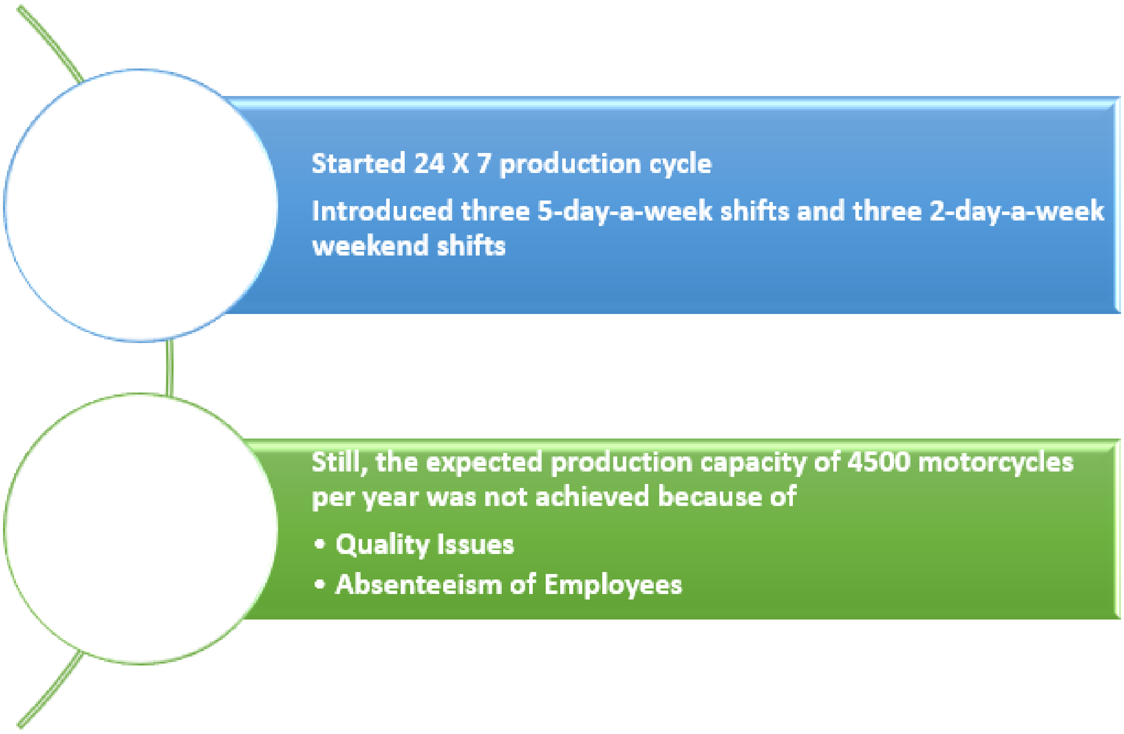


Figure 7: 2020 Data Summary

The amended 24 X 7 production cycle Shift timings for 2020 are:

Weekdays	Weekends
Monday to Friday: Day – 7am – 3pm Swing : 3pm – 11pm Night: 11pm – 7am	Saturday, Sunday Day – 7am – 3pm Swing : 3pm – 11pm Night: 11pm – 7am

Figure 8: Shift Chart for 2020

3.2 Primary Objectives

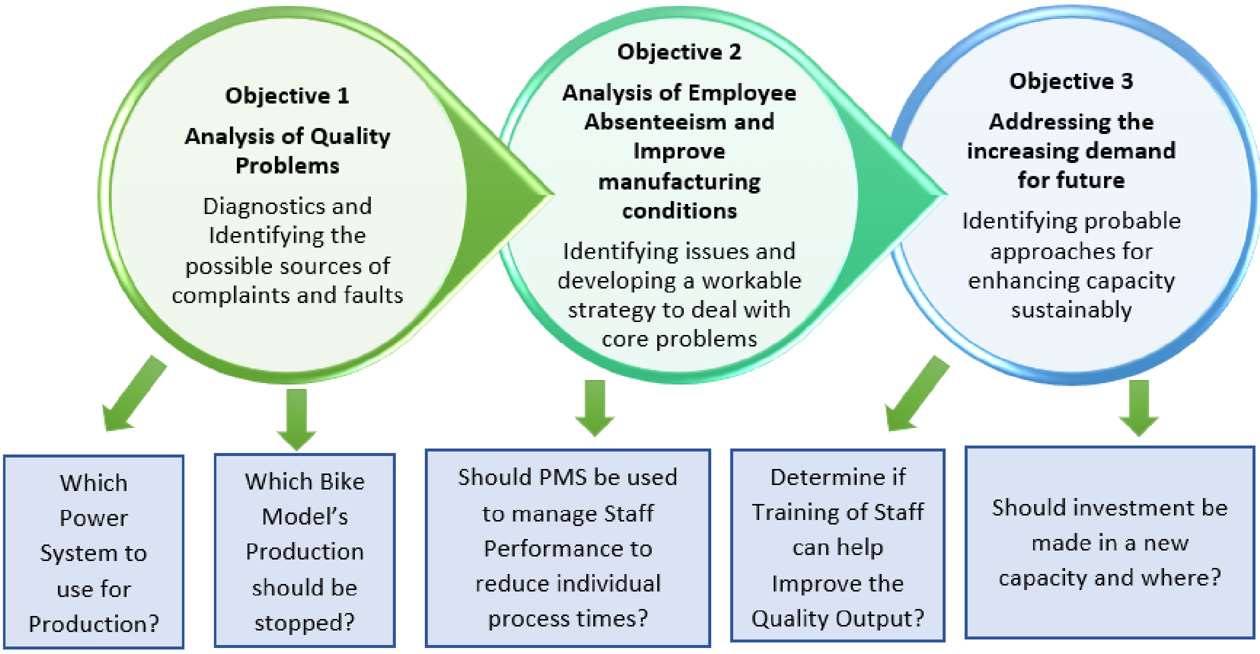


Figure 9: Primary Objectives

4. OBSERVATIONS WITH THE COMPANY DATA

4.1 About the dataset

The Quality Score is given after a thorough inspection of the entire motorcycle but before any defects are rectified (on a scale of 0-100).

Initially, the Complaints were coded as:

0	no complaint
1	minor complaint
2	significant complaint requiring some work at a garage
3	serious complaint often requiring the motorcycle to be returned to the factory

4.2 Creating new metrics

A new column "Total Time" has been calculated by adding the following individual process times:

order id	model	power system	frame time	power time	steering time	fitting time	quality time	quality score	complaint	date of despatch	Total Time
203	1	1	10.14	21.74	5.56	3.39	1.79	73	0	16-Mar-19	42.62
56	1	1	9.93	19.53	6.44	3.52	1.80	82	0	26-Jan-19	41.21
657	1	1	12.02	18.94	4.02	2.90	1.47	85	0	06-Aug-19	39.37
139	1	1	8.39	20.35	4.24	3.54	1.24	86	0	23-Feb-19	37.76
1033	1	1	9.89	20.05	4.86	3.75	1.34	86	0	04-Dec-19	39.89
87	1	1	8.92	17.81	3.70	3.38	1.54	90	0	07-Feb-19	35.36
339	1	1	10.45	17.97	5.32	3.63	1.31	91	0	01-May-19	38.67
15	1	1	9.68	17.37	7.60	2.43	0.73	92	0	12-Jan-19	37.81
685	1	1	9.95	18.64	5.08	2.52	2.04	92	0	23-Aug-19	38.22
351	1	1	5.66	19.21	6.54	2.43	1.61	93	0	03-May-19	35.46
436	1	1	11.12	16.77	5.14	3.27	1.70	93	0	29-May-19	37.99
929	1	1	7.77	19.54	4.36	2.66	1.64	93	0	26-Oct-19	35.98
936	1	1	4.46	21.14	6.44	2.03	1.79	93	0	30-Oct-19	35.86
197	1	1	9.73	16.95	3.40	3.58	1.48	94	0	14-Mar-19	35.13

Figure 10: Dataset with Addition of New Column "Total Time"

Another new column "Nature of Complaint" was created by assigning the following:

- For complaints analysis, 0 (no complaints) observations have been removed
- 1 (Minor) and 2 (Significant) Complaints have been aggregated into "Moderate" Complaints
- 3 (Serious) Complaints have been coded as "Serious" Complaints

order id	model	power system	frame time	power time	steering time	fitting time	quality time	quality score	complaint	date of despatch	Total Time	Nature of Complaint
757	1	1	11.61	15.56	7.20	3.60	1.52	96	1	06-Sep-19	39.50	Moderate
208	1	1	9.52	16.00	4.47	2.64	1.56	99	1	19-Mar-19	34.20	Moderate
318	1	1	9.39	17.57	5.54	1.45	1.48	99	1	20-Apr-19	35.43	Moderate
1017	1	1	9.37	16.86	5.85	2.53	0.86	100	1	27-Nov-19	35.46	Moderate
270	1	1	10.18	14.82	3.76	2.69	1.12	97	1	04-Apr-19	32.56	Moderate
1005	1	1	9.15	16.94	5.33	2.75	1.46	97	1	23-Nov-19	35.64	Moderate
106	1	1	8.26	14.67	6.11	3.50	1.53	96	1	13-Feb-19	34.05	Moderate
407	1	1	8.96	14.76	6.12	3.20	1.56	95	1	21-May-19	34.61	Moderate
883	1	1	9.91	15.52	3.40	2.15	1.36	95	1	12-Oct-19	32.34	Moderate
907	1	1	10.56	14.85	6.01	4.26	2.36	94	1	19-Oct-19	38.04	Moderate
1014	1	1	12.25	14.56	4.12	2.36	1.57	91	1	26-Nov-19	34.85	Moderate

Figure 11: Dataset with Addition of New Column "Nature of Complaint"

4.3 Production Quality Analysis

4.3.1 Analysis for different Bike Models

(a) Average Quality Score for different Models

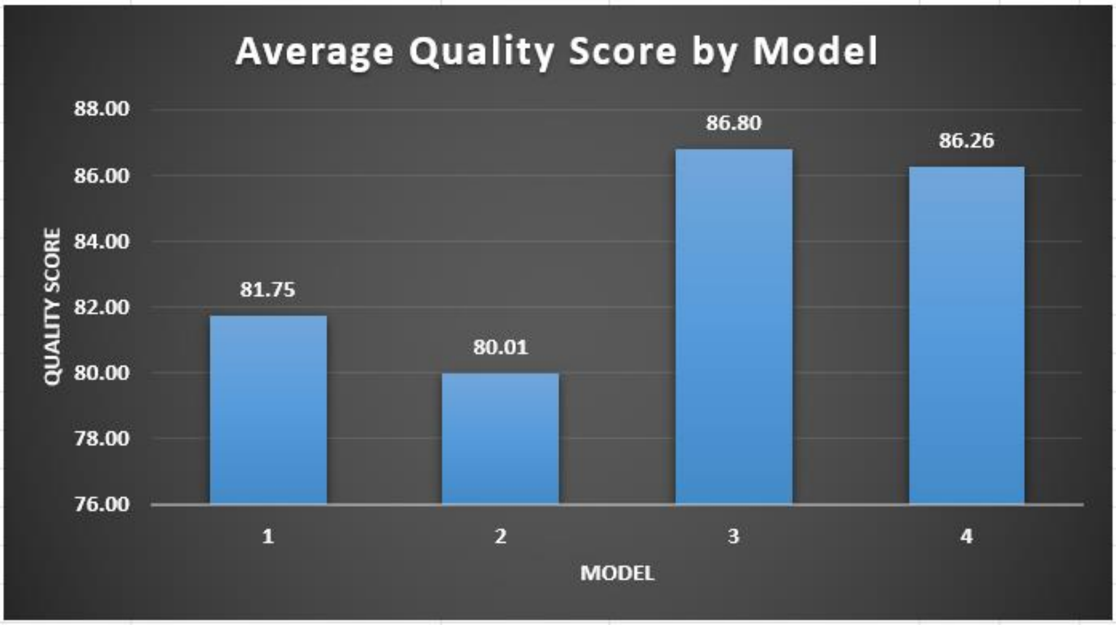


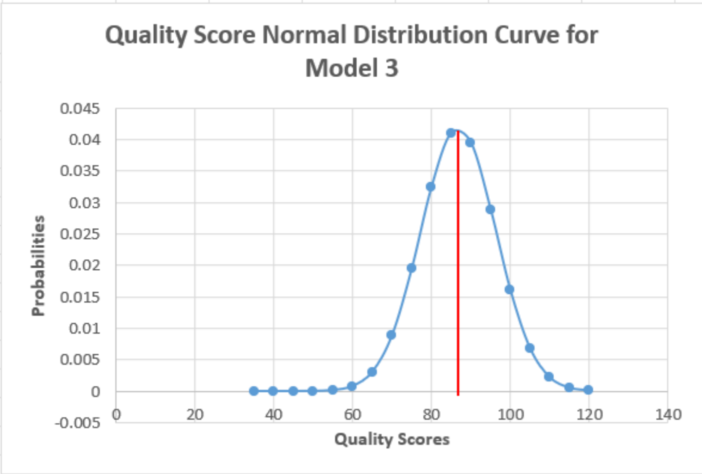
Figure 12: Average Quality Score by Model

- Model 3 and Model 4 have the highest Average Quality Scores (marginal difference)
- Model 2 has the worst Average Quality Score

(b) Calculating Probabilities of achieving Mean Quality Score

- In the case study (Section 4), it is mentioned that the Mean Quality Score is 86. It is expected that the same will prevail in future.
- The Probabilities that each model yielding a Quality Score of more than 86% has been calculated and Model 3 has the highest probability

Quality Score Bin Size	Probabilities
35	1.65707E-08
40	2.48659E-07
45	2.83511E-06
50	2.45607E-05
55	0.000161664
60	0.000808522
65	0.003072364
70	0.008870682
75	0.019460092
80	0.032436674
85	0.04108008
90	0.03953027
95	0.02890226
100	0.016056001
105	0.00677714
110	0.002173497
115	0.000529633
120	9.80607E-05



Mean Quality Score	**86.8**
Standard Deviation	**9.54**

Probability of Quality Score being greater than 86	P(x>86)
z value	-0.08386
P(z<-0.08)	0.4681
Probability of Quality Score Greater than 86	46.81%

Figure 13: Probability of Model 3 achieving Mean Quality Score of 86

- There is a 46.81% probability that Model 3 will exceed the Mean Quality Score of 86.
- More detailed analysis of the probabilities for four Models can be found at Appendix A.

(c) Average Total Production Time taken for Different Models

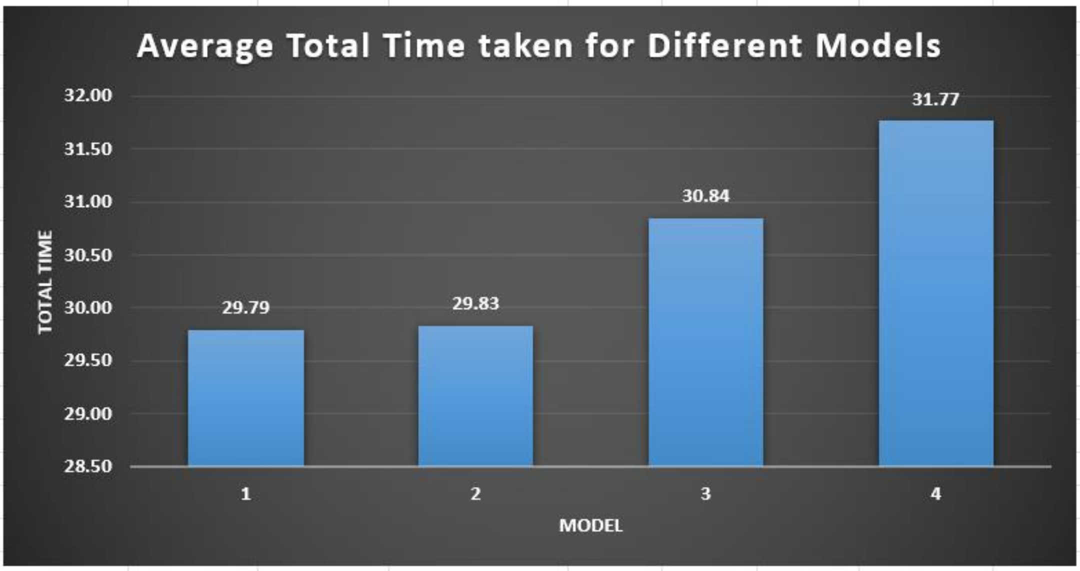


Figure 14: Average Total Time taken for Different Models

- Model 4 takes the maximum production time and has a high Average Quality Score
- Model 3 has moderate production time but has the maximum Average Quality Score
- Model 1 and Model 2 take the minimum production time and have less Average Quality Score

(d) Average Time Taken for Individual Processes

Table 1: Average Time Taken for Individual Processes

Model	Average of frame time	Average of power time	Average of fitting time	Average of quality time	Average of steering time
Model 1	7.81	12.61	2.96	1.51	4.90
Model 2	7.83	12.80	2.93	1.49	4.77
Model 3	7.46	14.11	3.00	1.51	4.76
Model 4	7.69	14.71	3.04	1.47	4.86
Total	**7.75**	**13.22**	**2.97**	**1.50**	**4.83**

- Installing Power Systems is the most time-consuming stage in the production process
- Quality Checks process takes the least time in production process

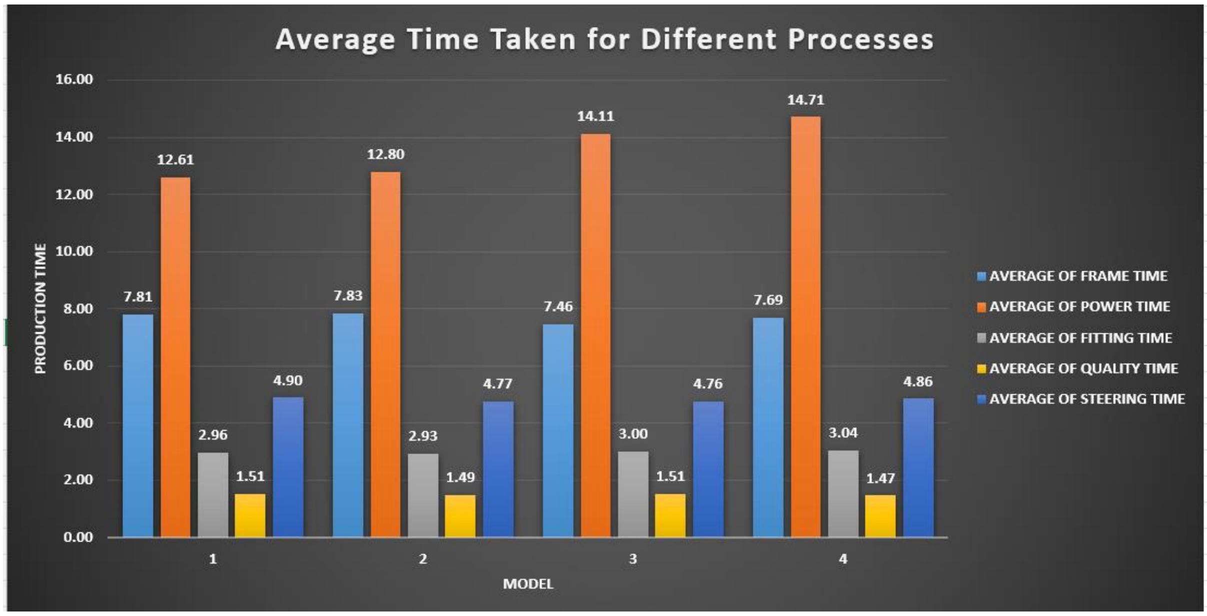


Figure 15: Average Time Taken for Different Processes

- Models 3 and 4 take more Average Power Time than Models 1 and 2

(e) Nature of Complaints for different Models

Table 2: Nature of Complaints for different Models

Model	Model 1	Model 2	Model 3	Model 4	Total
Moderate	72	87	26	79	**264**
Serious	21	21	4	9	**55**
Total	**93**	**108**	**30**	**88**	**319**
% Moderate Complaints	**77%**	81%	87%	**90%**	
% Serious Complaints	**23%**	19%	13%	**10%**	

- Model 4 has the highest % and Model 1 has the lowest % of Moderate Complaints
- Model 1 has the highest % and Model 4 has the lowest % of Serious Complaints
- Models 3 and 4 have low % of Serious Complaints but high % of Moderate Complaints
- Models 1 and 2 are poor in terms of Quality Score and also have high % of Serious Complaints

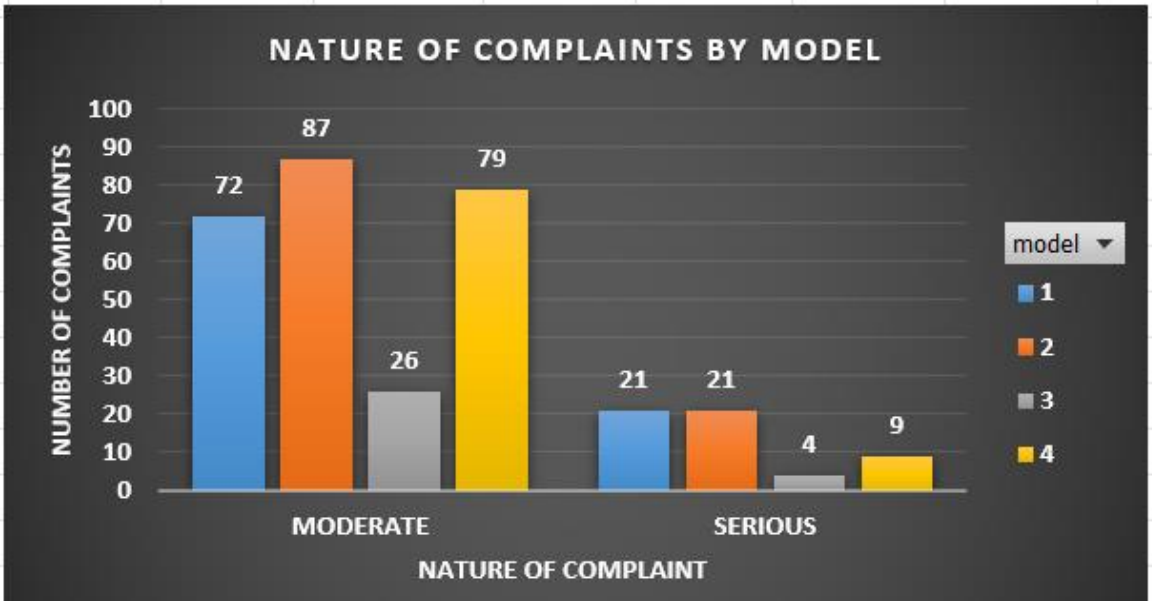


Figure 16: Nature of Complaints by Model

- Maximum Complaints are for Model 2 and minimum complaints are for Model 3 (Model 3 has the best Quality Score)

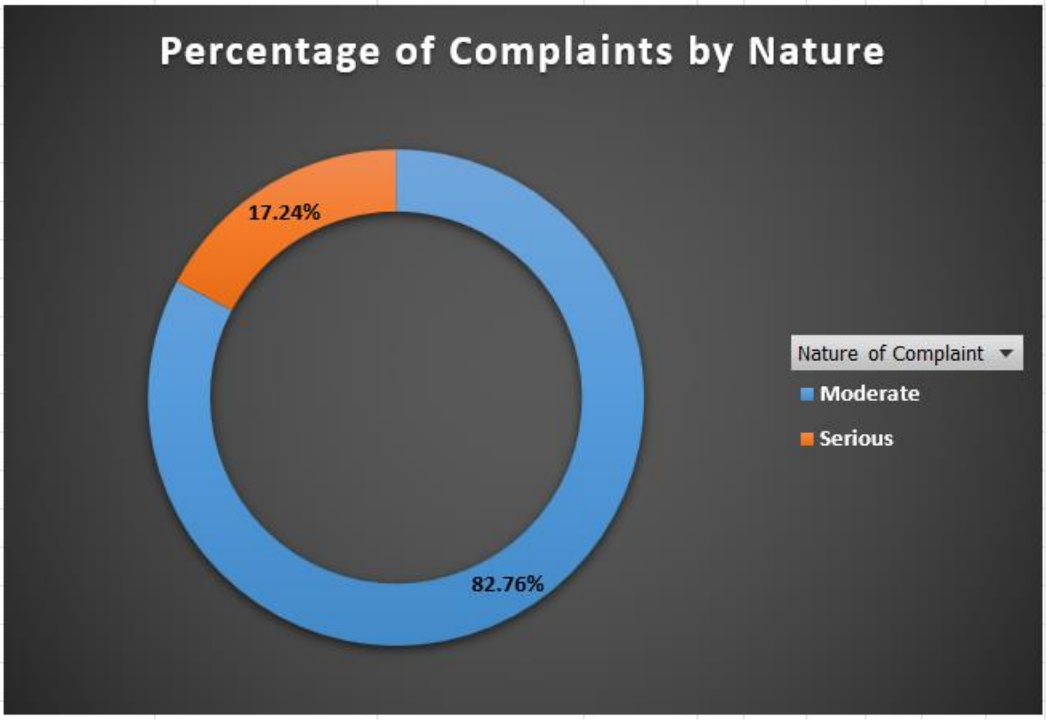


Figure 17: Percentage of Complaints by Nature

- Moderate Complaints occupy a significant portion of the total complaints (82.76%) which does not need bike to be sent to factory for rework

(f) Number of Bikes Dispatched per Model in different Months of 2019

Table 3: Number of Bikes Dispatched

Model	Model 1	Model 2	Model 3	Model 4	Grand Total
January	26	28	11	9	**74**
February	31	33	12	12	**88**
March	35	33	18	12	**98**
April	35	31	12	10	**88**
May	36	33	21	17	**107**
June	32	34	10	13	**89**
July	38	33	14	20	**105**
August	38	29	22	12	**101**
September	28	34	11	19	**92**
October	29	39	18	19	**105**
November	31	31	15	9	**86**
December	12	17	3	4	**36**
Grand Total	**371**	**375**	**167**	**156**	**1069**

- Model 1 and 2 bikes were the most dispatched despite having less Quality Scores and Model 3 and 4 bikes had low dispatch quantities despite having high Quality Scores

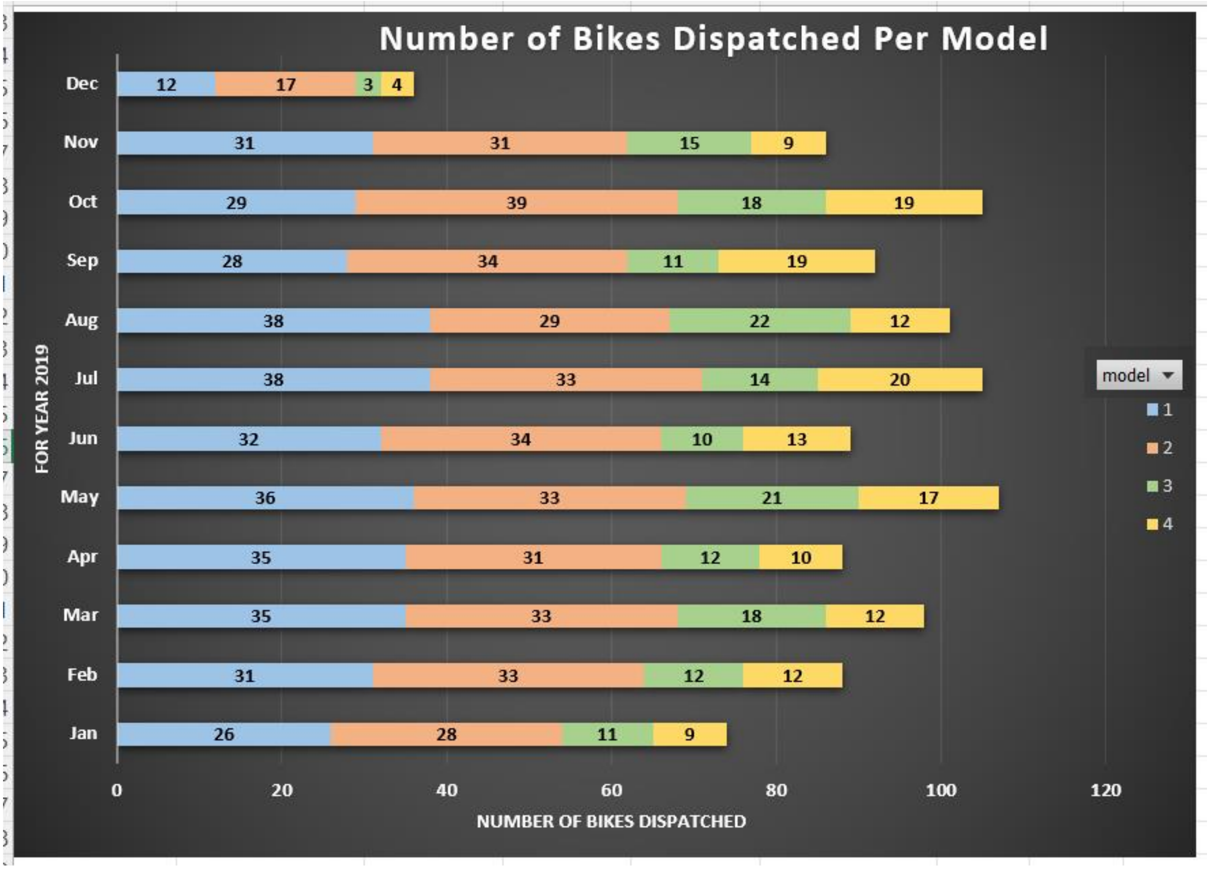


Figure 18: Number of Bike Dispatched per Model

Table 4: Maximum and Minimum number of Bikes Dispatched

Model	Maximum Bikes Dispatched	Minimum Bikes Dispatched
Model 1	July and August (38)	December (12)
Model 2	October (39)	December (17)
Model 3	August (22)	December (3)
Model 4	July (20)	December (4)

- Overall, the maximum number of bikes was dispatched in May
- Overall, the minimum number of bikes were dispatched in December, this might be due to the two weeks of holidays during Christmas/New Year when the production stopped

(g) Percentage of Complaints to Bikes dispatched for different models

Table 5: Percentage of Complaints by Models

Model	Model 1	Model 2	Model 3	Model 4	Total
Number of Bikes Dispatched	371	375	167	156	1069
Total Complaints	93	108	30	88	319
% of Complaints	25.07%	28.80%	**17.96%**	**56.41%**	29.84%

- Model 4 has the highest % and Model 3 has the lowest % of Complaints out of the Total Bikes dispatched

Table 6: Percentage of Serious Complaints by Model

Model	Model 1	Model 2	Model 3	Model 4	Total
Number of Bikes Dispatched	371	375	167	156	1069
Serious Complaints	21	21	4	9	55
% of Serious Complaints	5.66%	5.60%	**2.40%**	**5.77%**	5.14%

- Model 4 has the highest % and Model 3 has the lowest % of Serious Complaints out of the Total Bikes dispatched

Table 7: Percentage of Moderate Complaints by Model

Model	Model 1	Model 2	Model 3	Model 4	Total
Number of Bikes Dispatched	371	375	167	156	1069
Moderate Complaints	72	87	26	79	264
% of Moderate Complaints	19.41%	23.20%	**15.57%**	**50.64%**	24.70%

- Model 4 has the highest % and Model 3 has the lowest % of Moderate Complaints out of the Total Bikes dispatched
- Despite having High Quality Score Model 4 has the highest % of Moderate and Serious Complaints

4.3.2 Analysis for Power Systems

(a) Average Quality Score for Power Systems 1 and 2

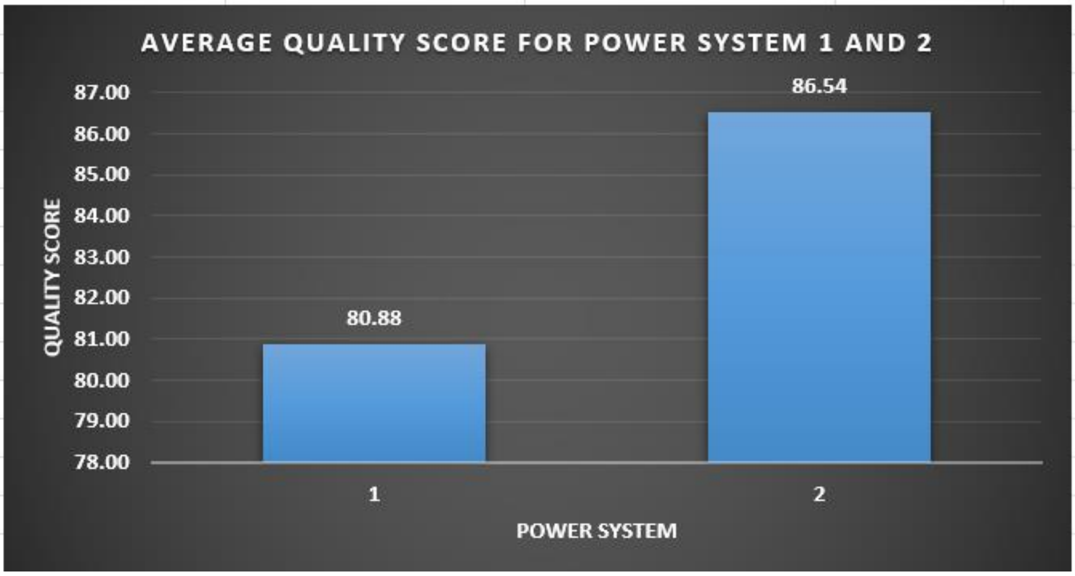


Figure 19: Average Quality Score by Power System

- Average Quality Score for Power System 2 is higher than that of Power System 1 (Power System 1 is used for Models 1 and 2, and Power System 2 is used for Models 3 and 4)

(b) Average Total Time for Power Systems 1 and 2

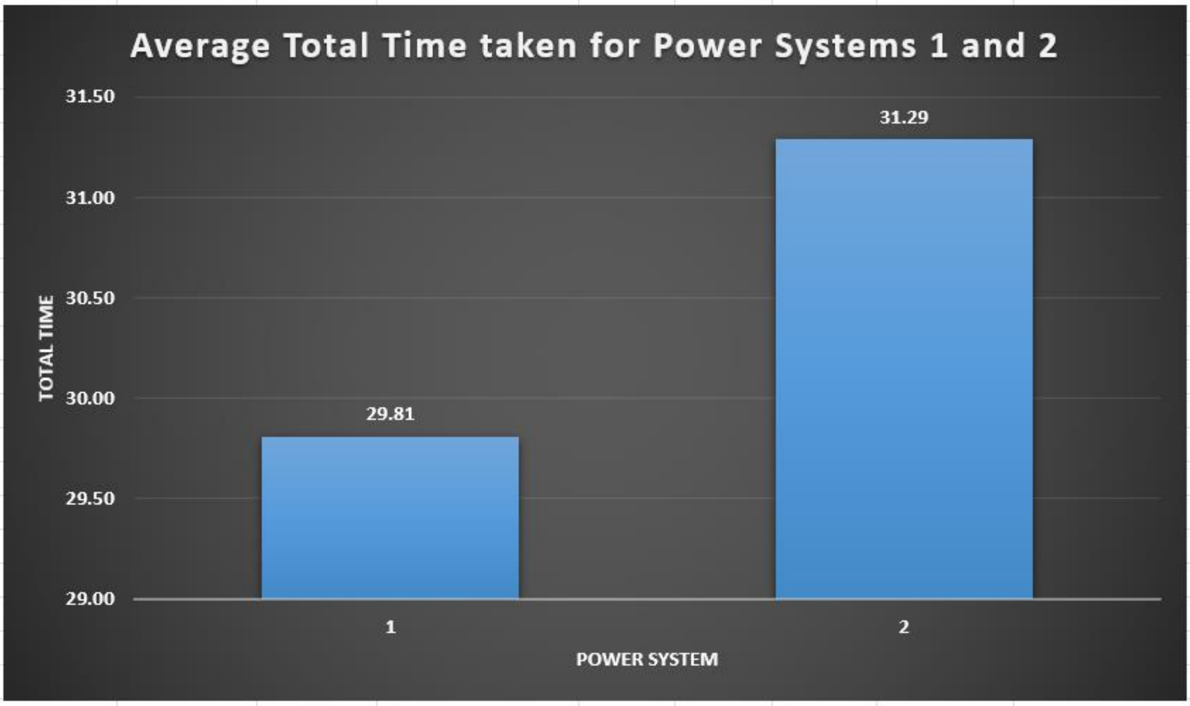


Figure 20: Average Total Time by Power System

- Power System 2 takes more time for production and has a higher Quality Score

(c) Nature of Complaints for Power Systems 1 and 2

Table 8: Nature of Complaints by Power System

Nature of Complaints	Power System 1	Power System 2	Total
Moderate	159	105	**264**
Serious	42	13	**55**
Total	201	118	**319**
% Moderate Complaints	**79%**	**89%**	
% Serious Complaints	**21%**	**11%**	

- Power System 1 has a higher % of Serious Complaints and has low Quality Score
- Power System 2 has a higher % of Moderate Complaints and has high Quality Score

4.4 HR Absent Analysis

4.4.1 Analysis by Job Titles

(a) Absent Hours for different Job Titles

Table 9: Absent Hours for different Job Titles

Job Titles	Average of Absent Hours	Sum of Absent Hours
Fittings	13.93	334.25
Frame Builder	19.49	467.84
PS1 Installer	57.24	1373.86
PS2 Installer	20.07	481.56
Quality and Refit	153.32	3679.72
Steering and Suspension	19.21	461.14
Grand Total	**47.21**	**6798.37**

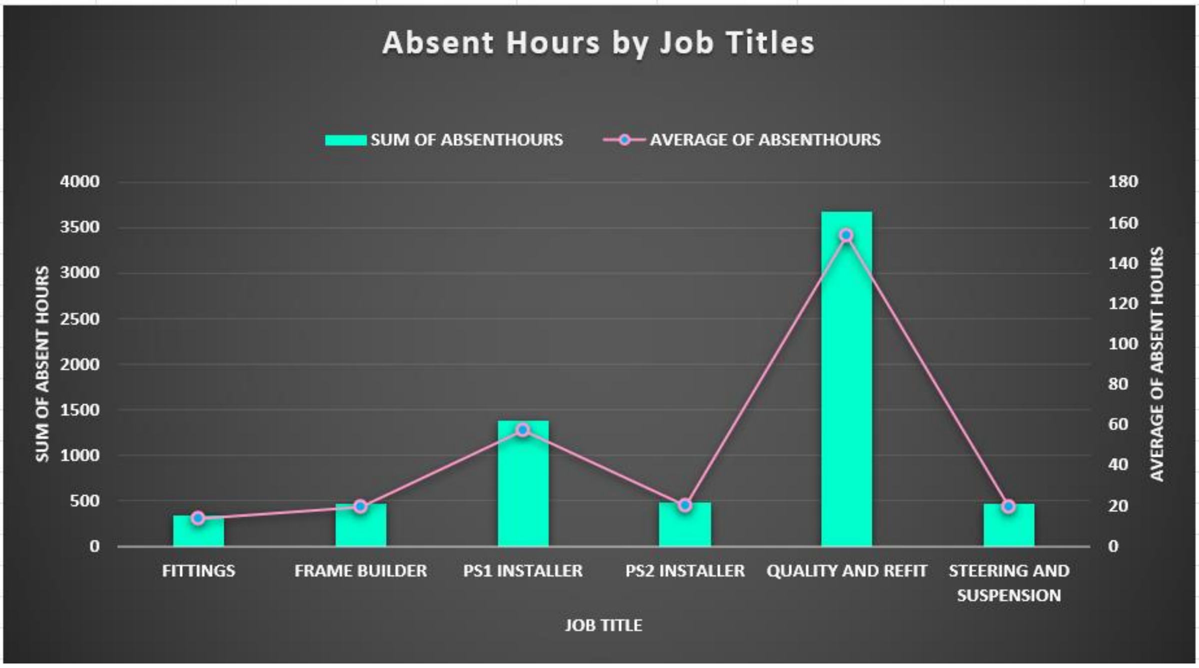


Figure 21: Absent Hours by Job Titles

- Quality and Refit workers were absent the most which affected the quality of production
- Power Station 1 installers were also absent for a high amount of time which might have led to low Quality Score and high % of Serious Complaints
- Fittings, Frame Builders, and Steering and Suspension workers have very low Average Absent Hours which might not have affected the Production much

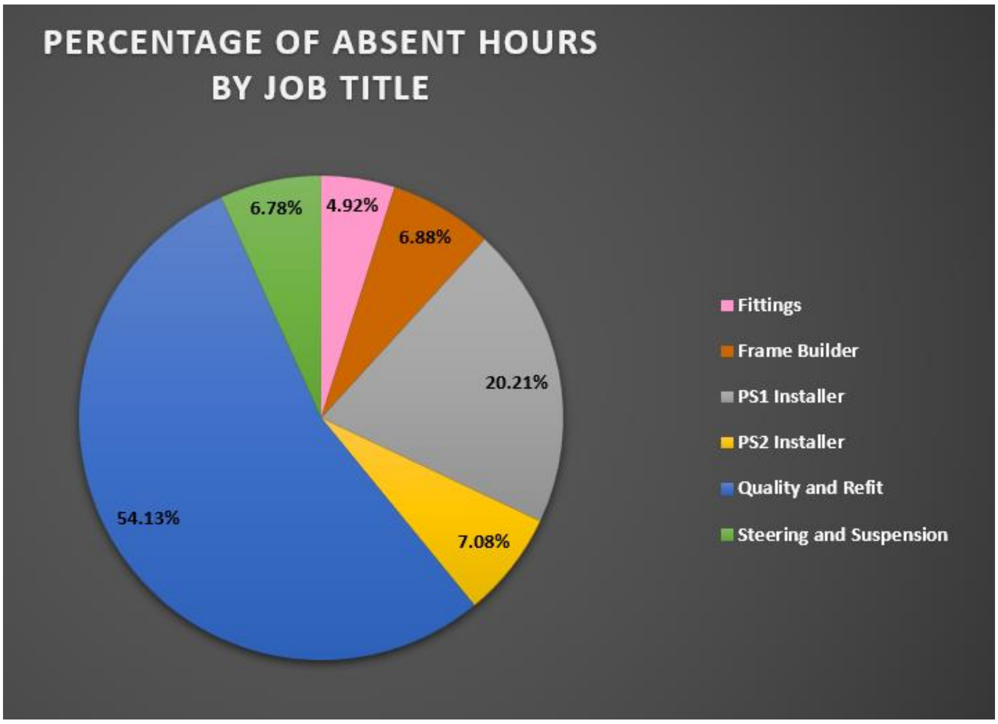


Figure 22: Percentage of Absent Hours by Job Title

- Quality and Refit workers contribute towards more than half of the total Absent Hours

(b) Relationship between Absent Hours and Length of Service

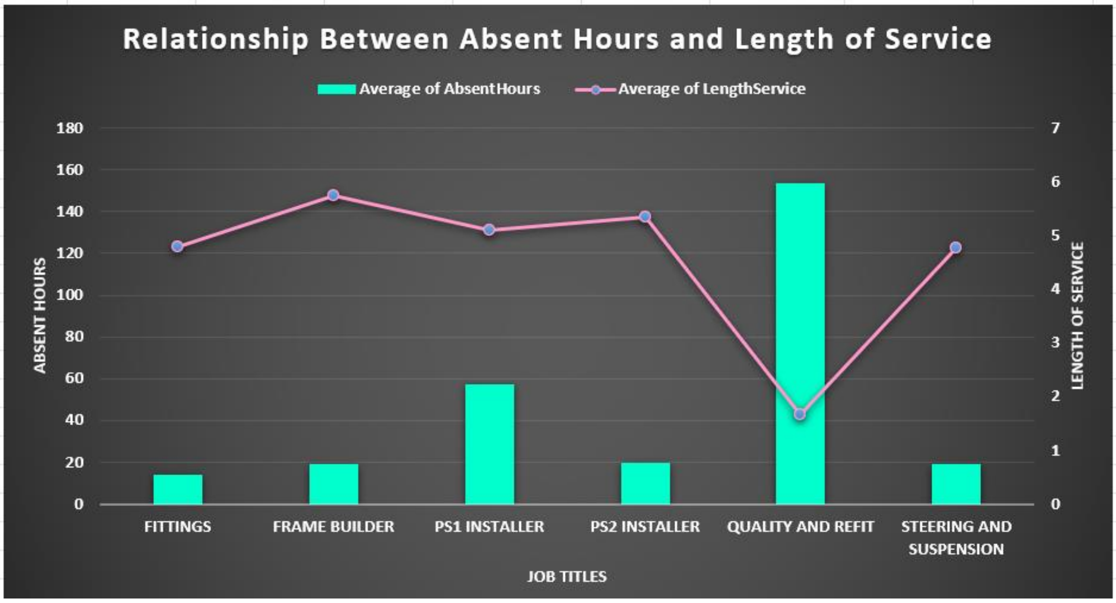


Figure 23: Relationship between Absent Hours and Length of Service

- The Absent Hours and Length of Service are almost negatively correlated, i.e., the workers having less Length of Service are the ones with the most Absent Hours, less experienced employees seem to be most absent
- Quality and Refit workers have the minimum Length of Service and are most Absent, which is extremely affecting the Production Quality
- The other category of workers have fewer Absent Hours but a high Length of Service, meaning they take their jobs seriously
- Power Station 1 Installers have a high Length of Service but also have moderate Absent Hours, meaning they affect the Production which might have led to low Quality Score and high % of Serious Complaints

(c) Relationship between Absent Hours and Age

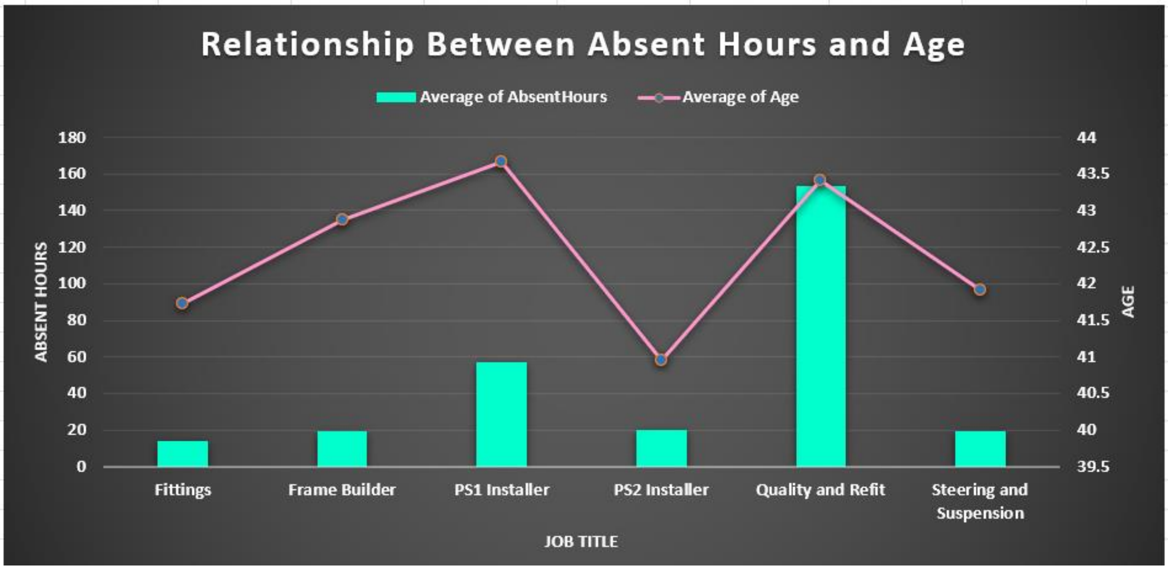


Figure 24: Relationship between Absent Hours and Age

- Quality and Refit workers and PS1 Installers both have high Average Age and are also Absent the most, meaning for these two categories, the workers of higher age are highly absent

(d) Relationship between Absent Hours and Distance to Work

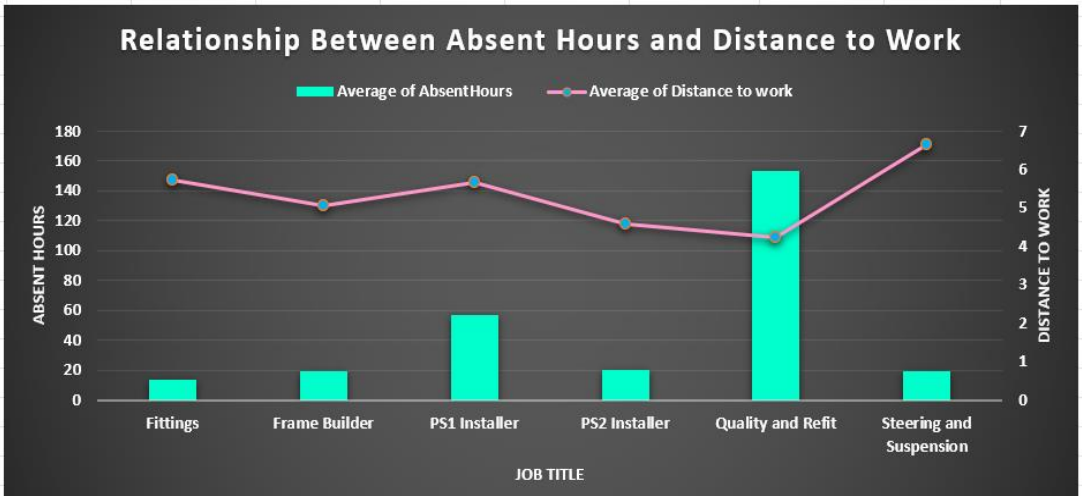


Figure 25: Relationship between Absent Hours and Distance to Work

- Quality and Refit workers have the least Average Distance to Work but still have the Highest Absent Hours, hence, there seems to be a serious problem with Quality Workers

4.4.2 Analysis by Shifts

(a) Absent Hours by Shift

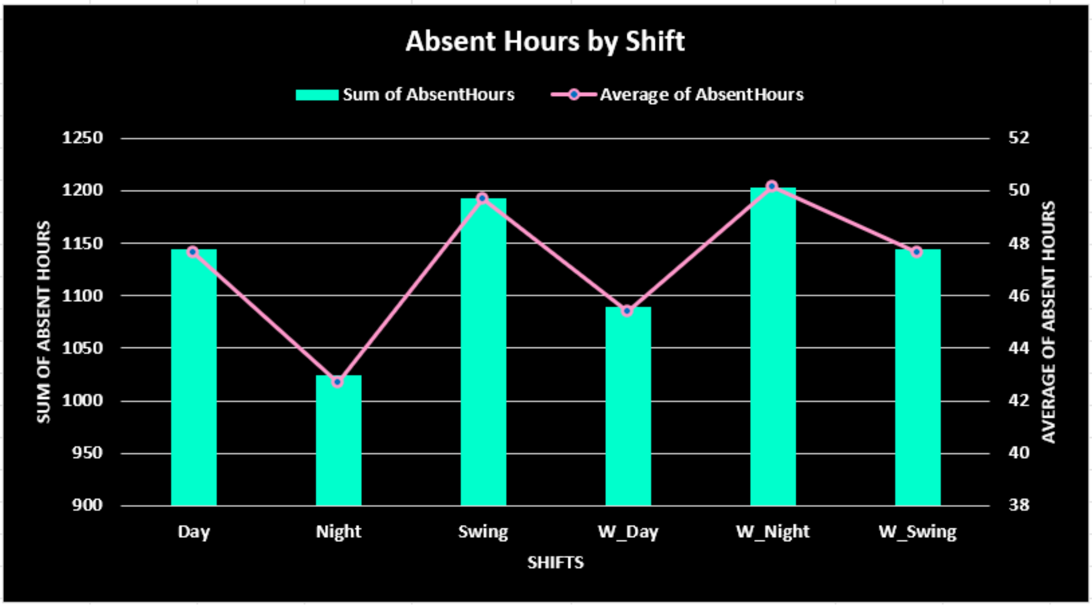


Figure 26: Absent Hours by Shift

- Employees have problems working on Night Shift during weekends, but are comfortable working on Night Shift during weekdays

(b) Absent Hours by Gender across different Shifts

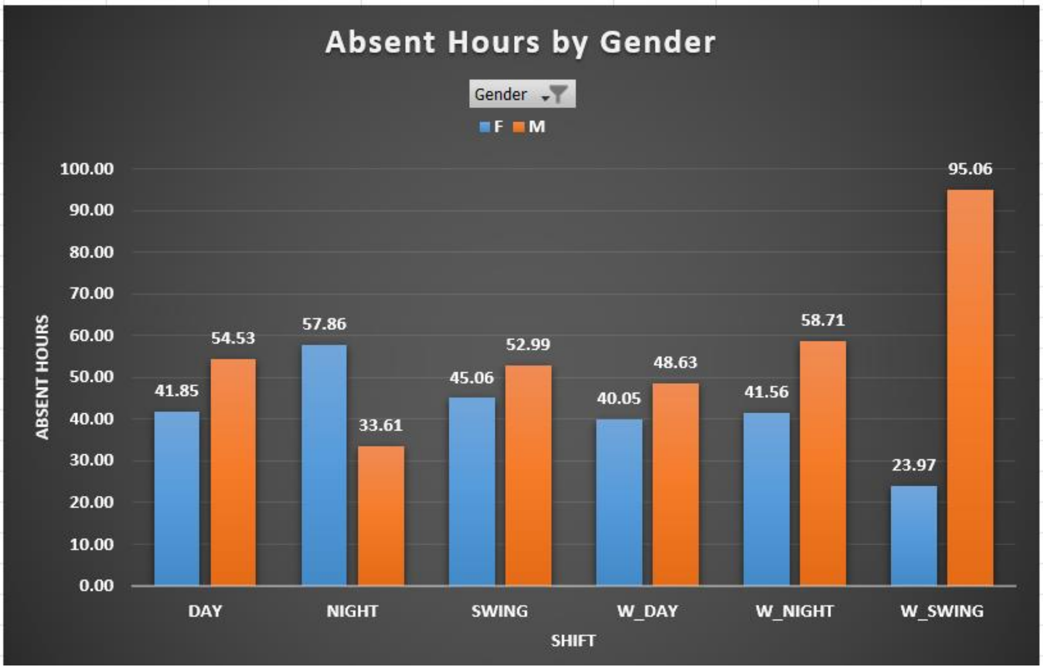


Figure 27: Absent Hours by Gender across different Shifts

- Males have problem working on weekend Swing Shift but are comfortable working on weekday Night Shift
- Females have problem working on weekday Night Shifts but are comfortable working on weekend Swing Shifts

(c) Distribution of Age across different Shifts

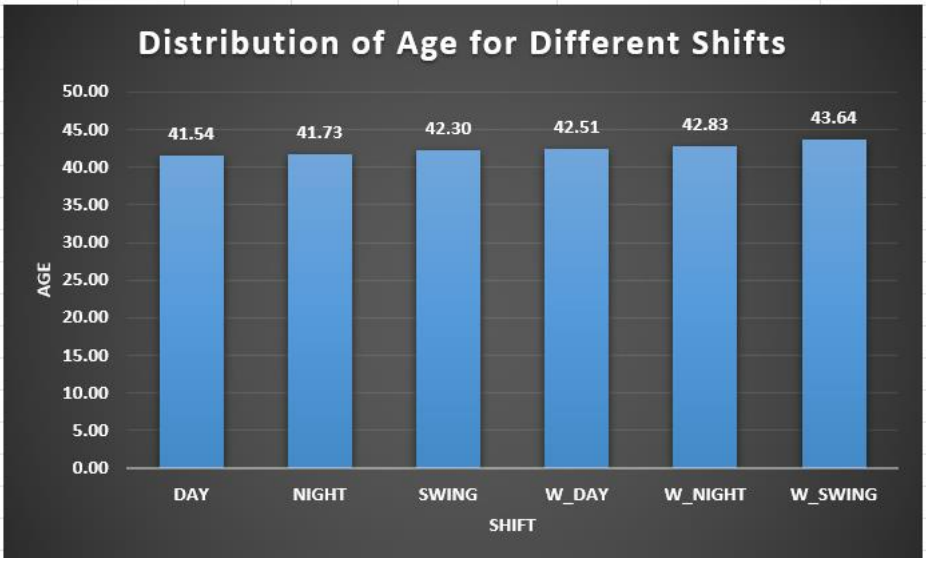


Figure 28: Distribution of Age across different Shifts

- There does not seem much variation in the Age of employees working in different shifts

4.4.3 Analysis by Gender

(a) Absent Hours by Gender

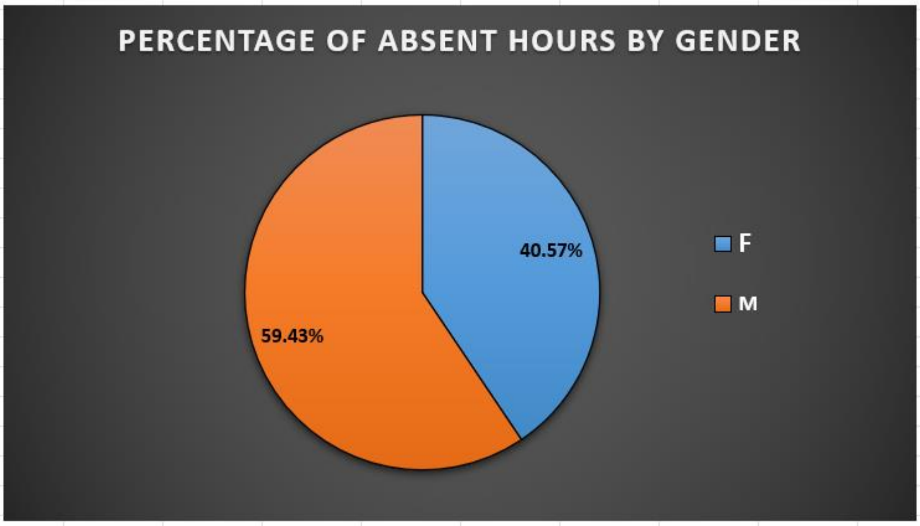


Figure 29: Absent Hours by Gender

- Males have a higher % of Average Absent Hours as compared to Females

(b) Average Age by Gender

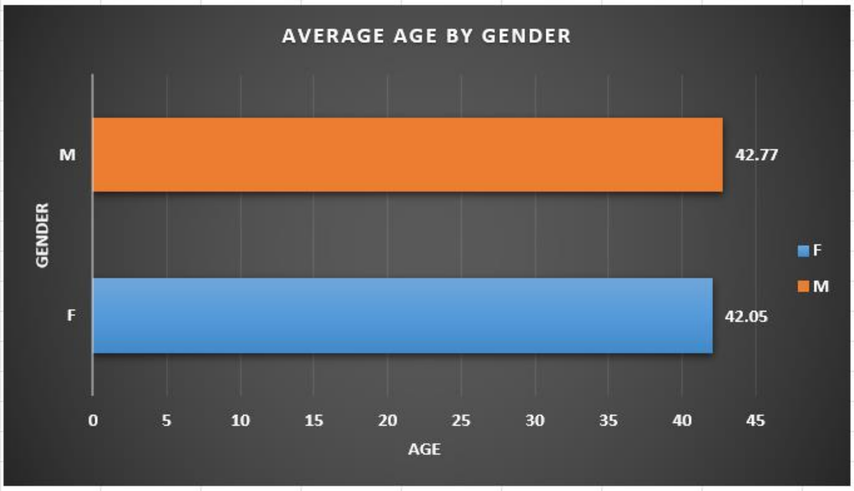


Figure 30: Average Age by Gender

- There is not much significant difference in Age for both the Genders

5. TESTING THE DATA

5.1 Paired t-test

It is hypothetical that the Quality Score will increase after the Training of employees. Same is tested using paired t-test since the dataset had 16 observations and t-test is used for samples less than 30.

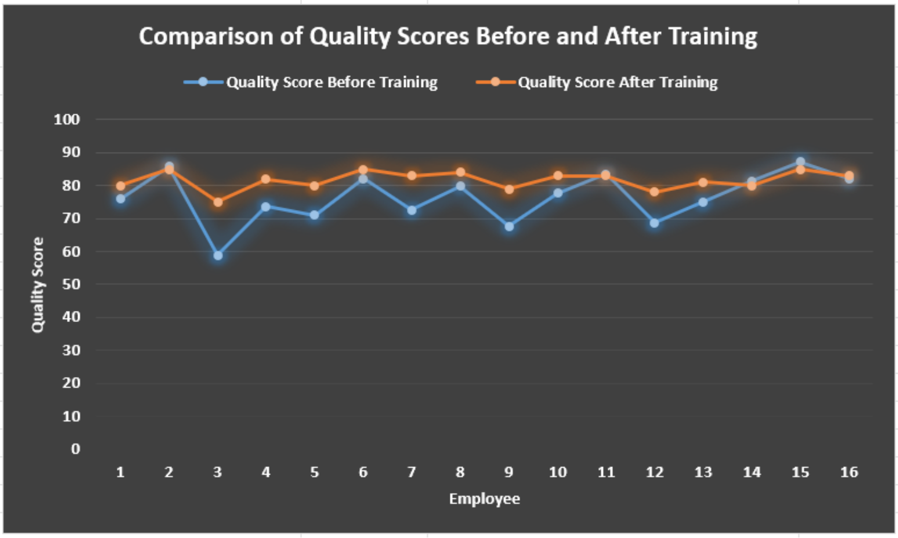


Figure 31: Comparison of Quality Score Before and After Training

To perform the t-test, the differences between the individual observations of the Quality Score before and after Training were calculated:

Number of samples is less than 30; Hence Paired t-test is used			
Employee	**Quality Score Before Training**	**Quality Score After Training**	**Difference**
1	75.9	80.00	4.13
2	85.8	85.00	-0.82
3	58.9	75.00	16.15
4	73.7	82.00	8.31
5	71.0	80.00	9.00
6	82.1	85.00	2.87
7	72.6	83.00	10.37
8	79.8	84.00	4.17
9	67.7	79.00	11.30
10	77.8	83.00	5.20
11	83.5	83.00	-0.54
12	68.7	78.00	9.33
13	75.1	81.00	5.89
14	81.5	80.00	-1.49
15	87.2	85.00	-2.21
16	82.2	83.00	0.81
Mean	**76.47**	**81.63**	**5.15**
Standard Deviation	**7.57**	**2.83**	**5.30**

Figure 32: Calculations for Paired t-test

The mean Quality Score has increased after Training, and the same will be tested using the Paired t-test.

H0: There is no difference in Average Quality Score After Training	
H1: The Average Quality Score has increased After Training	

Number of Samples	16	
Degree of Freedom	15	
t critical	2.131	for 95% confidence level (two-tailed test)

t = mean/ (std dev/sqrt(no of samples))	
t value	**3.890724155**

Since t value is positive and t value > t critical (3.89 > 2.131)	**H0 can be rejected and H1 can be accepted**

Hence it is concluded that the Average Quality Score has increased after Training

Figure 33: Paired t-test

The t-test concluded that the Average Quality Score increased after Training and hence, it can be efficient to train more employees to increase the Quality of Production in the future.

5.2 z-test

5.2.1 Testing if the Mean Quality Score is 86 or not (based on information provided in the case study, section 4)

It was hypothesized based on information provided in the case study that the Mean Quality Score was 86 for 2019, however, when the data was analysed, the Mean Quality Score was observed to be different. Since the situation involved comparing a change of means in samples, z-test is used.

As per the case study, section 4 says that the Mean Quality Score is 86.
However, the data provided in the excel sheet when analysed, revealed the following Descriptive Statistics:

Mean Quality Score	82.59
Standard Deviation	11.55
Count	1069

H0: Mean Quality Score is 86
H1: Mean Quality Score is not equal to 86

Significance Level = 5%
Critical Values = -1.96 and +1.96

test statistic	-9.652976466	
z critical	-1.96	for 95% confidence level (two-tailed test)

Since test statistic is negative and test statistic < z critical (-9.65 < -1.96)	H0 can be rejected

Hence it can be concluded that the Mean Quality Score is not 86

Figure 34: z-test 1

The z-test concluded that the Average Quality Score is less than 86 and is well below the figure mentioned in the case study.

5.2.2 Testing if the Average Total Time is different across Power Systems 1 and 2

H0: There is no difference; the Average Total Time is identical across the two Power Systems
H1: The Average Total Time for Power System 1 is less than that of Power System 2

Power System	Average of Total Time	Count of Total Time	StdDev of Total Time 2
1	29.81199826	746	4.24816394
2	31.28927011	323	4.771637551
Grand Total	30.25835823	1069	4.462527277

test statistic	-4.800936175	
z critical	-1.96	for 95% confidence level (two-tailed test)
Since test statistic is negative and test statistic < z critical (-4.8 < -1.96)		H0 can be rejected and H1 can be accepted

Hence it is concluded that the Average Total Time for Power System 1 is less than that of Power System 2

Figure 35: z-test 2

The z-test concluded that the Average Total Time for Power System 1 is less than that of Power System 2.

5.2.3 Testing if the Average Quality Score is different across Power Systems 1 and 2

H0: There is no difference; the Average Quality Score is identical across the two Power Systems

H1: The Average Quality Score for Power System 1 is less than that of Power System 2

Power System	Average of quality score	Count of quality score	StdDev of quality score
1	80.8766756	746	11.86086307
2	86.53869969	323	9.713003747
Grand Total	**82.58746492**	**1069**	**11.54745428**

test statistic	**-8.166806159**	
z critical	**-1.96**	for 95% confidence level (two-tailed test)
Since test statistic is negative and test statistic < z critical (-8.17 < -1.96)		**H0 can be rejected and H1 can be accepted**

Hence it is concluded that the Average Quality Score for Power System 1 is less than that of Power System 2

Figure 36: z-test 3

It is concluded that the Average Quality Score of Power System 1 is less than that of Power System 2.

The Quality Score and Total Production Time seem to be positively correlated. As the time taken for a bike production increases, the Quality Score also increases.

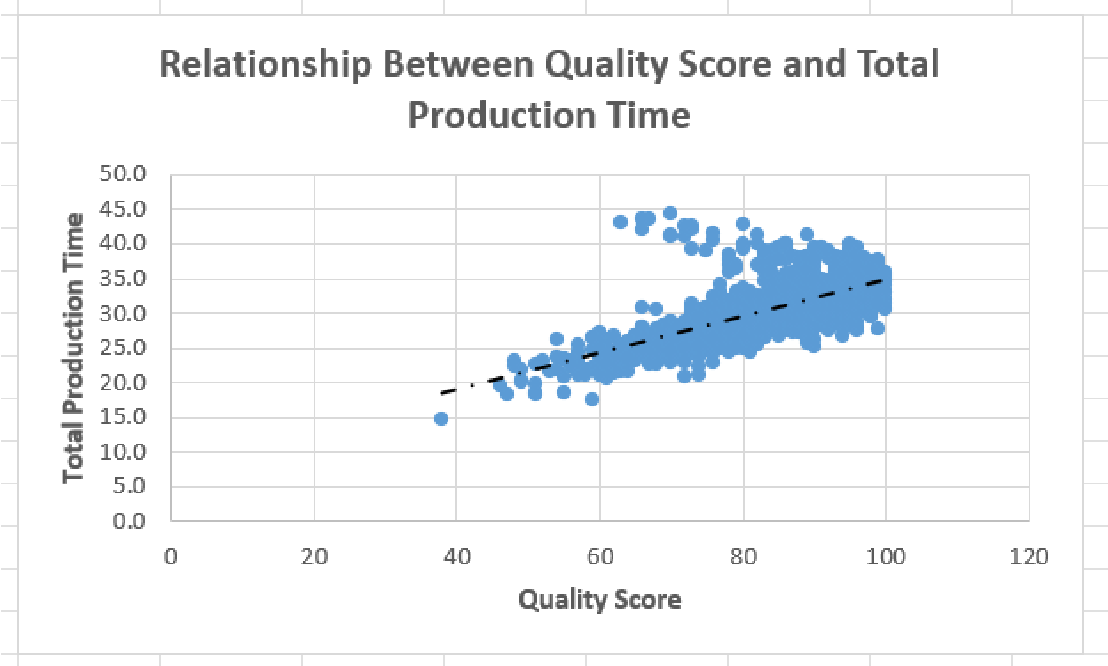


Figure 37: Relationship Between Quality Score and Total Production Time

The following causal map can be drawn based upon the testing; however, it is yet to be proved that Low Production Time causes Low Quality Score.

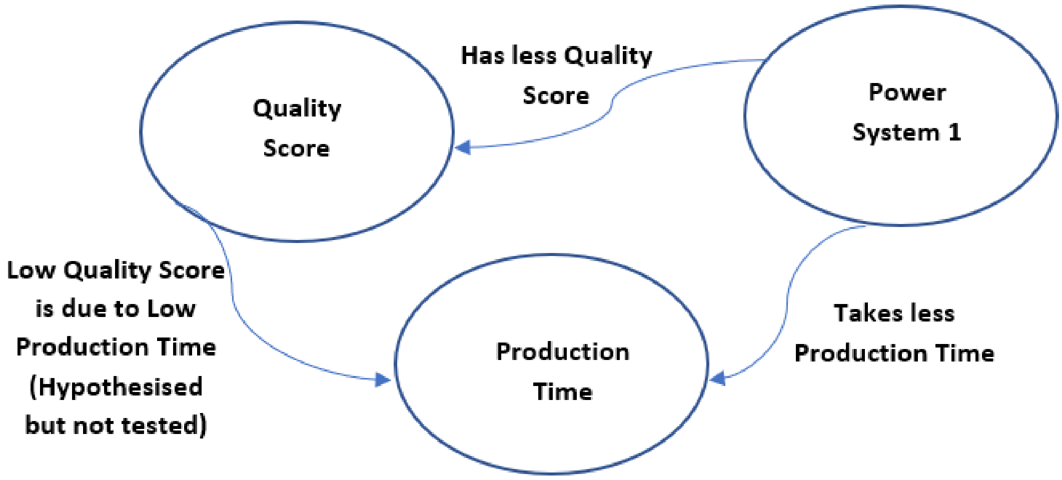


Figure 38: Causal Map

5.2.4 Testing if the Average Quality Score is different for Bikes having Serious and Moderate Complaint

H0: There is no difference; the Average Quality Score is identical across the two Nature of Complaints
H1: The Average Quality Score for Serious Nature Complaints is less than that for Moderate Complaints

Power System	Average of quality score	Count of quality score	StdDev of quality score
Moderate	80.40530303	264	11.77863513
Serious	67.43636364	55	10.44343429
Grand Total	**78.169279**	**319**	**12.54336615**

test statistic	**8.18833331**	
z critical	1.96	for 95% confidence level (two-tailed test)
Since test statistic is positive and test statistic > z critical (8.19 > 1.96)		**H0 can be rejected and H1 can be accepted**

Hence it is concluded that the Average Quality Score for Serious Complaints is less than that of Moderate Complaints

Figure 39: z-test 4

It is proved that the Average Quality Scores for Bikes having Serious Complaints is less than those Bikes having Moderate Complaints, meaning Serious Complaints degrade the Quality Score extremely.

5.2.5 Testing if the Average Absent Hours of Employees are distributed equally for both the Gender

H0: There is no difference; the Average Absent Hours is identical across Males and Females
H1: The Average Absent Hours for Females is less than that for Males

Gender	Average of AbsentHours	Count of AbsentHours	StdDev of AbsentHours
F	39.97250235	69	46.17876775
M	53.87028131	75	56.42523952
Grand Total	47.21092889	144	52.05910951

test statistic	-1.622657355	
z critical	-1.96	for 95% confidence level (two-tailed test)
Since test statistic is negative and test statistic > z critical (-1.62 > -1.96)		H0 cannot be rejected

Hence it cannot be concluded that the Average Absent for Females is less than that of Males

Figure 40: z-test 5

Even though the data when summarised gave insights into Average Absent Hours of Male being more than those of Females, the hypothesis failed, and it cannot be taken into consideration. However, this test was on the distribution and not on total absence time.

5.3 Chi-square test (non-parametric test)

5.3.1 Testing if the Serious and Moderate Complaints are equally distributed for all the four Bike Models

Using chi-squared test it was tested whether the Nature of Complaints are equally distributed across all the four bike models.

H0: Serious and Moderate Complaints are equally distributed for all the four Bike Models
H1: Number of Serious and Moderate Complaints vary across all the four Bike Models

Figure 41: Null Hypothesis and Alternate Hypothesis for Chi-Square test 1

Table 10: Observed Values for Chi-Square test 1

Observed Values					
OBSERVED	1	2	3	4	Total
Moderate	72	87	26	79	264
Serious	21	21	4	9	55
Total	93	108	30	88	319

Table 11: Expected Values for Chi-Square test 1

Expected Values					
EXPECTED	1	2	3	4	Total
Moderate	76.965517	89.37931	24.828	72.8276	264
Serious	16.034483	18.62069	5.1724	15.1724	55
Total	93	108	30	88	319

Table 12: Contingency Table for Chi-Square test 1

Contingency Table			
Observed	Expected	(O-E)	((O-E)^2)/E
72	76.96551724	-4.96551724	0.320355951
21	16.03448276	4.96551724	1.537708564
87	89.37931034	-2.37931034	0.063338122
21	18.62068966	2.37931034	0.304022987
26	24.82758621	1.17241379	0.055363984
4	5.172413793	-1.172413793	0.265747126
79	72.82758621	6.17241379	0.523135449
9	15.17241379	-6.17241379	2.511050155
		Total	5.580722339

Test Observations	
test statistic	5.58
degrees of freedom	3
critical value	7.81
test statistic < critical value	H0 cannot be rejected

Hence, H0 is not rejected and it is concluded that the proportion of Moderate and Serious Complaints are equally distributed across the four Bike Models.

Figure 42: Chi-Square test 1

It is proved that the Nature of Complaints are unequally distributed across the four Bike Models.

5.3.2 Testing if the Serious and Moderate Complaints are equally distributed for both the Power Systems

H0: Serious and Moderate Complaints are equally distributed across both the Power Systems
H1: Number of Serious and Moderate Complaints vary across both the Power Systems

Figure 43: Null Hypothesis and Alternate Hypothesis for Chi-Square test 2

Table 13: Observed Values for Chi-Square test 2

	Observed Values		
OBSERVED	Power System 1	Power System 2	Total
Moderate	159	105	264
Serious	42	13	55
Total	201	118	319

Table 14: Expected Values for Chi-Square test 2

	Expected Values		
EXPECTED	Power System 1	Power System 2	Total
Moderate	166.3448276	97.65517241	264
Serious	34.65517241	20.34482759	55
Total	201	118	319

Table 15: Contingency Table for Chi-Square test 2

	Contingency Table		
Observed	Expected	(O-E)	((O-E)^2)/E
159	166.3448276	-7.3448276	0.324305199
42	34.65517241	7.34482759	1.556664953
105	97.65517241	7.34482759	0.552418177
13	20.34482759	-7.34482759	2.651607249
		Total	**5.084995579**

Test Observations	
test statistic	5.08
degrees of freedom	1
critical value	3.84
test statistic > critical value	H0 can be rejected

Hence, H0 is rejected, i.e., Power System 1 has a higher % of Serious Complaints which can be a differentiating factor in terms of Overall Production Quality

Figure 44: Chi Square test 2

It is proved that the Nature of Complaints are unequally distributed across the two Power Systems, and since Power System 1 has higher % of Serious Complaints, it can affect the Production more.

6. CONCLUSIONS AND RECOMMENDATIONS FOR MANAGEMENT

6.1 Key Findings

6.1.1 Bike Model

- Model with the highest Average Quality Score is Model 3 (Rossi) and one with lowest is Model 2 (Delgard)
- Model 4 takes the most Production Time but also has considerably high Quality Score
- Out of total complaints received, Model 2 has the highest % of complaints and Model 3 has the lowest %
- Out of the total bikes dispatched per model, Model 4 has the highest % of complaints (both Serious and Moderate) followed by Model 2

6.1.2 Power System

- Power System 1 has low Average Quality Score but also takes less production time
- Power System 1 account for 63% of the total complaints received

6.1.3 Individual Processes

- Installing Power Systems takes the maximum time, whereas Quality Checks take the least time in the Production Process.

6.1.4 Absent Hours

- Quality and Refit workers account for the highest % of Absent Hours
- Quality and Refit workers are least experienced terms of minimum Length of Service, have highest Average Age, and stay most nearby to work location, still they are absent the most
- Workers belonging to the Weekend Night Shift are absent the most
- Male workers belonging to Weekend Swing Shift and Female workers belonging to Weekday Night Shift are Absent the most
- Male workers belonging to Weekday Night Shift and Female workers belonging to Weekend Swing Shift are Absent the least

6.2 Recommendations

6.2.1 Objective 1 – Analysis of Quality Problems

(a) Bike Model

- Production of Model 2 (Delgard) should be stopped as it has least Quality Score and also has maximum % of Total Complaints, instead focus should be made on Model 3 that has the highest Quality Score and least % of Complaints
- Since Model 4 (Torre) has high expectations from customer, it is expected to have high Complaints, and it takes highest Production Time. On the contrary, it has High Quality Score. Balancing all of these factors, its production cannot be stopped, however, steps must be taken to reduce the % of Complaints per dispatched bike

(b) Power System

- Use of Power System 1 should be paused for production since it has low Quality Score and high % of Complaints and Power System 2 should be fully released into production for a duration of 6 months, during which the feedback can be monitored to observe how well it performs alone. This practical experiment can prove the theoretical hypothesis correct

6.2.2 Objective 2 – Analysis of Employee Absenteeism and improve manufacturing conditions

- Absent Hours of Quality and Refit workers is questionably high, despite it being the most important process. This is an area HR department should look seriously into. Since Power System 1 has experienced workers, and Power System 1 can be paused meanwhile for production, those workers can be shifted to Quality and Refit department to balance the workload and enhance the Quality process
- Weekend Night shift has the highest Absent Hours. The HR department can check in on the productivity of these workers and have meetings with the head of departments to know how to solve such issues. A solution might be to rotate the night shift amongst all workers and provide additional incentives to those working on Weekend Night Shifts to decrease the Absent Hours.
- Male workers belonging to Weekend Swing Shift and Female workers belonging to Weekday Night Shift are Absent the most, and Male workers belonging to Weekday Night Shift and Female workers belonging to Weekend Swing Shift are Absent the

least. These shifts can be interchanged among the two Genders and results may be observed.

- There is no provision at present to monitor staff performance on individual stages. Employee performance should be monitored by a Performance Management System in a predictable and quantifiable way. This will ensure that all workers accomplish the tasks at individual processes, and overall 15% reduction in activity timings is expected.
- These recommendations when implemented can help company achieve yearly expected production of 4500 motorcycles, and also reduce the costs and delivery time

6.2.3 Objective 3 – Addressing the increasing demand for the future

- The hypothesis test proved that the Training has improved the Quality Score of Employees, therefore, it can be efficient to train more employees on individual processes to increase Production Quality in upcoming years
- Additionally, since the Quality Process has the most Absenteeism, and gets least process time, four new workstations can be build and staff can be recruited as a capacity investment plan. This can incorporate more Quality Checks taking 30 extra minutes at each stage, but this can reduce rework to 1% to help increase effective capacity in future

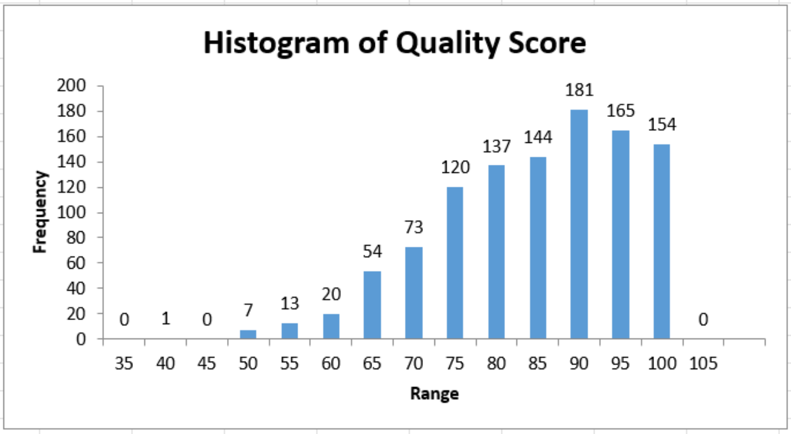
6.3 Suggestions for Further Work

- More data needs to be gathered to test the hypothesis about how Production Time affects the Quality Score. This can create many causal relationships which can help to undertake more detailed analysis
- More information may be provided to study the impact of Serious Complaints on rework
- Probability data can be gathered to understand the risk of a Bike having Serious or Moderate Complaint
- Revenue and Profit data may be provided to analyse the company’s financials on sales of motorcycles and whether the expected target is achieved

APPENDIX A

1. Histograms and Descriptive Statistics of Quality Scores for different Models

1.1 Quality Score (Overall)

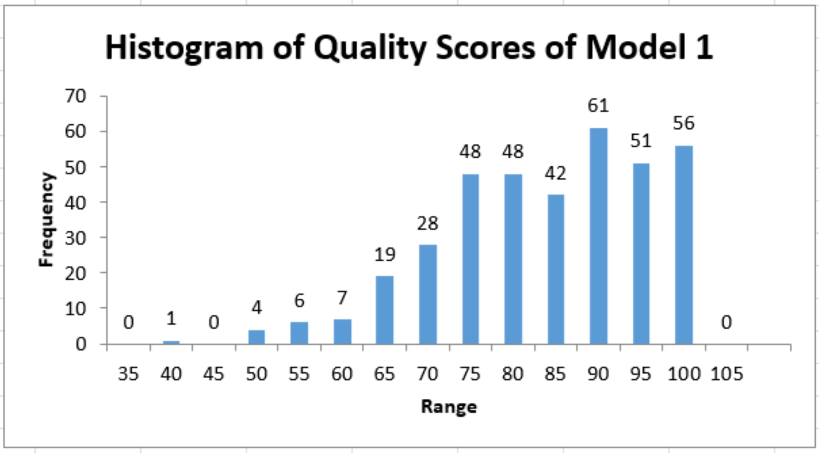


Descriptive Statistics of Quality Score	
Mean	82.58746492
Standard Error	0.353181054
Median	84
Mode	86
Standard Deviation	11.54745428
Sample Variance	133.3437004
Kurtosis	-0.127965847
Skewness	-0.617346114
Range	62
Minimum	38
Maximum	100
Sum	88286
Count	1069

Figure 45: Histogram of Quality Score

- The Histogram is skewed towards the left (Negatively Skewed)
- Mean Quality Score: 82.59
- Standard Deviation: 11.55

1.2 Quality Score (Model 1 - Comici)

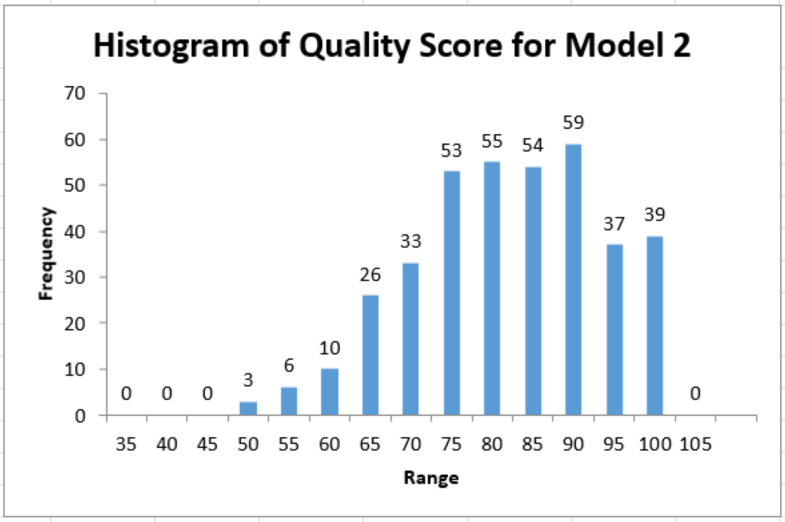


Descriptive Statistics of Quality Score	
Mean	81.7493
Standard Error	0.63439
Median	83
Mode	96
Standard Deviation	12.2191
Sample Variance	149.307
Kurtosis	-0.03897
Skewness	-0.61035
Range	62
Minimum	38
Maximum	100
Sum	30329
Count	371

Figure 46: Histogram of Quality Score of Model 1

- Mean Quality Score: 81.75 (Less than Overall Mean Quality Score)
- Standard Deviation: 12.22 (More than Overall)

1.3 Quality Score (Model 2 - Delgard)

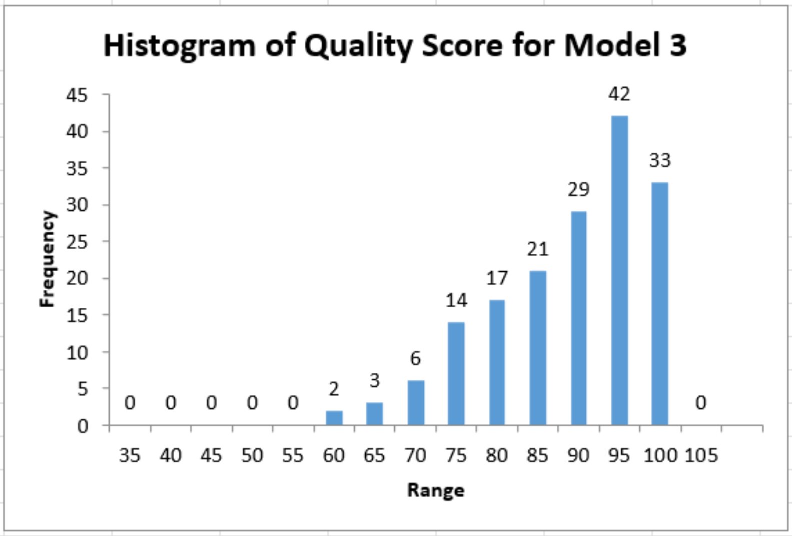


Descriptive Statistics for Quality Score	
Mean	80.0133
Standard Error	0.59109
Median	81
Mode	86
Standard Deviation	11.4463
Sample Variance	131.019
Kurtosis	-0.48956
Skewness	-0.34251
Range	52
Minimum	48
Maximum	100
Sum	30005
Count	375

Figure 47: Histogram of Quality Score of Model 2

- Mean Quality Score: 80.01 (Less than Overall Mean Quality Score)
- Standard Deviation: 11.45 (Slightly Less than Overall)

1.4 Quality Score (Model 3 - Rossi)

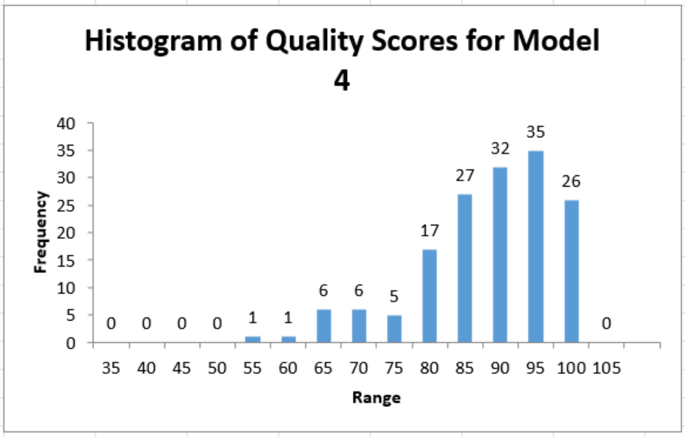


Descriptive Statistics of Quality Score	
Mean	86.8024
Standard Error	0.73849
Median	90
Mode	91
Standard Deviation	9.54333
Sample Variance	91.0752
Kurtosis	-0.00708
Skewness	-0.80061
Range	41
Minimum	59
Maximum	100
Sum	14496
Count	167

Figure 48: Histogram of Quality Score of Model 3

- Mean Quality Score: 86.80 (More than Overall Mean Quality Score)
- Standard Deviation: 9.54 (Less than Overall)

1.5 Quality Score (Model 4 - Torre)



Descriptive Statistics of Quality Score	
Mean	86.2564
Standard Error	0.79379
Median	88
Mode	99
Standard Deviation	9.91439
Sample Variance	98.2951
Kurtosis	0.97845
Skewness	-1.02922
Range	49
Minimum	51
Maximum	100
Sum	13456
Count	156

Figure 49: Histogram of Quality Score of Model 4

- Mean Quality Score: 86.26 (More than Overall Mean Quality Score)
- Standard Deviation: 9.91 (Less than Overall)

Observations:

The best-performing models are Model 3 and Model 4 in terms of:

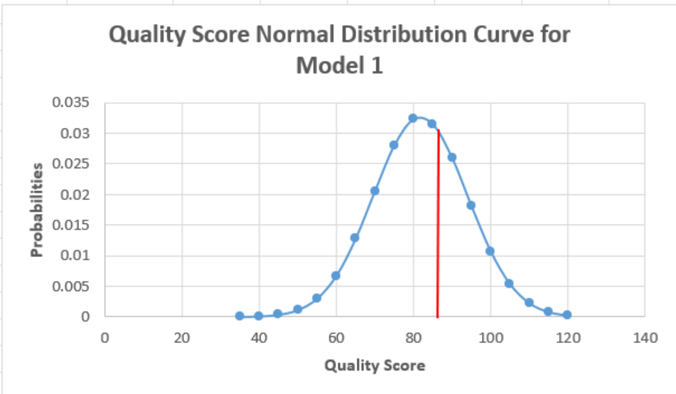
- Mean Quality Score
- Less Standard Deviation between the Quality Scores

2. Calculating Probabilities of Mean Quality Score for different Models

As per the case study (Section 4), the Mean Quality Score is 86 and it is assumed to stay the same in future. The Probabilities that each model will yield a Quality Score of 86% has been calculated:

2.1 Model 1

Quality Score Bin Size	Probabilities
35	2.16612E-05
40	9.53123E-05
45	0.000354737
50	0.001116749
55	0.0029737
60	0.006697778
65	0.012760167
70	0.020562411
75	0.02802746
80	0.032313611
85	0.031512242
90	0.025993524
95	0.018136065
100	0.010703185
105	0.005342875
110	0.002255948
115	0.000805703
120	0.000243396



Mean Quality Score	81.75
Standard Deviation	12.22

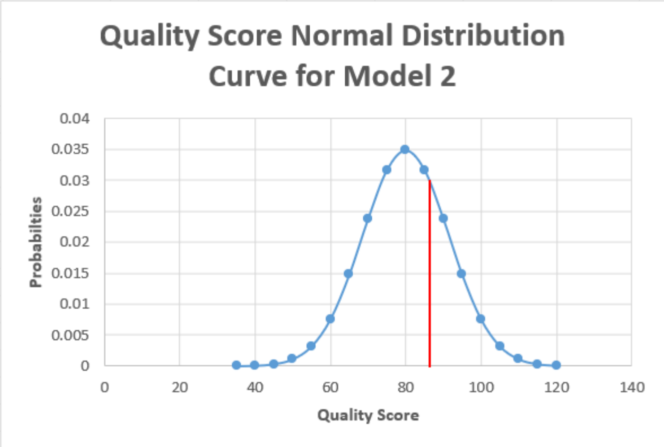
Probability of Quality Score being greater than 86	P(x>86)
z value	0.34779
P(z>0.35)	0.3632
Probability of Quality Score Greater than 86	36.32%

Figure 50: Probability Calculation of Mean Quality Score for Model 1

There is a 36.32% probability that Model 1 will exceed the Mean Quality Score of 86.

2.2 Model 2

Quality Score Bin Size	Probabilities
35	1.53664E-05
40	7.77451E-05
45	0.000325055
50	0.001123119
55	0.003206848
60	0.007566852
65	0.014754901
70	0.023776148
75	0.031661455
80	0.034842107
85	0.031685614
90	0.023812447
95	0.014788703
100	0.007589975
105	0.003219102
110	0.001128271
115	0.000326795
120	7.82209E-05



Mean Quality Score	**80.01**
Standard Deviation	**11.45**

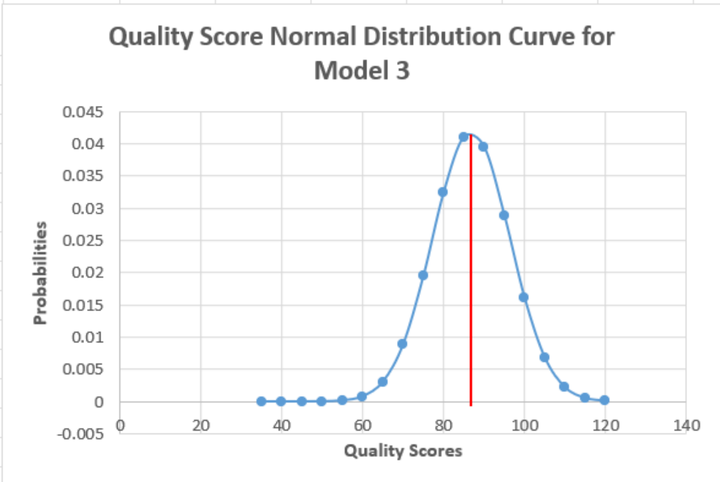
Probability of Quality Score being greater than 86	P(x>86)
z value	0.52314
P(z>0.52)	0.3015
Probability of Quality Score Greater than 86	30.15%

Figure 51: Probability Calculation of Mean Quality Score for Model 2

There is a 30.15% probability that Model 2 will exceed the Mean Quality Score of 86.

2.3 Model 3

Quality Score Bin Size	Probabilities
35	1.65707E-08
40	2.48659E-07
45	2.83511E-06
50	2.45607E-05
55	0.000161664
60	0.000808522
65	0.003072364
70	0.008870682
75	0.019460092
80	0.032436674
85	0.04108008
90	0.03953027
95	0.02890226
100	0.016056001
105	0.00677714
110	0.002173497
115	0.000529633
120	9.80607E-05



Mean Quality Score	**86.8**
Standard Deviation	**9.54**

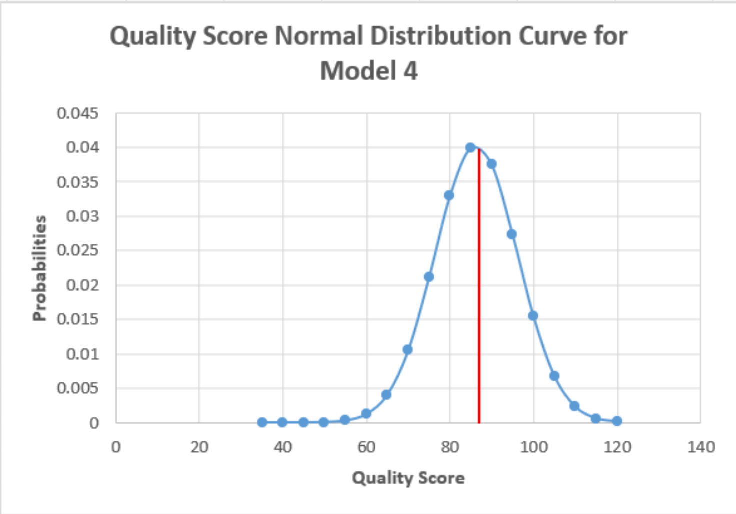
Probability of Quality Score being greater than 86	P(x>86)
z value	-0.08386
P(z<-0.08)	0.4681
Probability of Quality Score Greater than 86	46.81%

Figure 52: Probability Calculation of Mean Quality Score for Model 3

There is a 46.81% probability that Model 3 will exceed the Mean Quality Score of 86.

2.4 Model 4

Quality Score Bin Size	Probabilities
35	6.23729E-08
40	7.46663E-07
45	6.92946E-06
50	4.98562E-05
55	0.000278089
60	0.001202525
65	0.004031343
70	0.010477335
75	0.021110438
80	0.032975317
85	0.039932461
90	0.037489403
95	0.027285777
100	0.015396056
105	0.006734851
110	0.002283978
115	0.000600483
120	0.000122393



Mean Quality Score	**86.25**
Standard Deviation	**9.91**

Probability of Quality Score being greater than 86	P(x>86)
z value	-0.02624
P(z<-0.03)	0.3821
Probability of Quality Score Greater than 86	38.21%

Figure 53: Probability Calculation of Mean Quality Score for Model 4

There is a 38.21% probability that Model 3 will exceed the Mean Quality Score of 86.

Observations:

Model 3 has a maximum probability of exceeding the Mean Quality Score of 86 and Model 2 has least probability.