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Course Number	IND 605
Course Title	Experimental Design & Quality Assurance
Semester/Year	Semester 5/Year 3
Section Number	Section 1
Group Number	Group 5

Factors Affecting Quality of a Co-op Placement in Engineering at TMU

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Abstract

This project investigates the factors influencing the quality of co-op placements for engineering students at Toronto Metropolitan University. The study focuses on two quality characteristics: annual salary and the number of students returned to the same company. Using data from the last three co-op cycles for three engineering disciplines (Industrial, Mechanical, Computer), we will analyze how CGPA and field of study correlate with the perceived quality of placements. The findings show that, while CGPA and field of study have no significant impact on the likelihood of returning to the same company, they do influence annual salary. Computer and Industrial Engineering disciplines emerged as leading fields for securing higher salaries, and students with medium CGPAs (2.56-3.44) were found to achieve better pay than High and Low CGPAs. These results suggest that while academic performance and discipline selection influence pay outcomes, students should also prioritize personal and professional development outside the classroom. This research intends to guide first-year students and inform TMU's co-op office in fostering better co-op experiences and outcomes.

Terminology

QC: Quality Characteristic

Configuration: Combination of factors and levels

Introduction

One of the most critical parts for any Engineering student during their Undergraduate education is the co-op job placement which takes place at the end of third year. Co-op is considered a crucial part of a student's education. It guides the students in the program to success by giving them real-world experience that will help them succeed once they graduate. In first year many undergraduate students are in the undeclared stream, this means they have not selected their engineering discipline. For some students it's very difficult to choose an engineering discipline. Many students have the goal of achieving a high quality co-op placement and are faced with such a tough choice selecting an engineering discipline. The following analysis will help to guide first year students in that decision. After completing first year engineering students have not necessarily developed enough technical or softs skills and don't have enough experience making it hard to analyze many of the factors in the cause and effect diagram. However what a student does know is their CGPA. The analysis aims to help students understand based on their current CGPA along with the engineering discipline, what they should choose to have the best opportunity to get a high quality co-op.

The data used in the statistical analysis was retrieved from the TMU FEAS Co-op Office; it included student co-op information from 2023. The choice to select data from only the past year is because of the impact of COVID-19 on the job market and students. Data from years previous to 2023 would be biased or skewed and not represent a close relationship to the current state of engineering education at TMU and the job market.

The data set from the Co-op Office comprises data for 111 students across 3 engineering disciplines, it also includes the students CGPA the company they worked at and the number of students who have returned to the company after completing a co-op placement in the last 5 years.

Approach

This project aims to define and analyze the factors that influence the quality of co-op placements for engineering students specifically in industrial engineering, mechanical engineering, and computer engineering at Toronto Metropolitan University. The analysis will provide insight that can help first-year students in engineering in preparing for co-op. Understanding how Engineering Discipline and their CGPA contribute to a high-quality co-op

placement can greatly assist students and the TMU co-op office. The main body of this paper presents the findings and analysis derived from collected data. This process follows a normal distribution, ensuring the data can be effectively analyzed using statistical techniques outlined in the report. Statistical quality control was assessed through the use of control charts, while design of experiments (DOE) and ANOVA were used to determine the statistical significance of the factors. Microsoft Excel was used for organizing the data, while Minitab software facilitated the execution of statistical tests, including the Design of Experiments (DOE) and Analysis of Variance (ANOVA).

The quality of co-op placement will be assessed based on two characteristics: Salary per year and the number of students who return to the same company. Salary per year, which is a continuous characteristic, provides a quantitative measure of the monetary value associated with each co-op placement. The number of students who return to the same company is an attribute characteristic, offering a qualitative indicator of student satisfaction and the perceived quality of the placement experience.

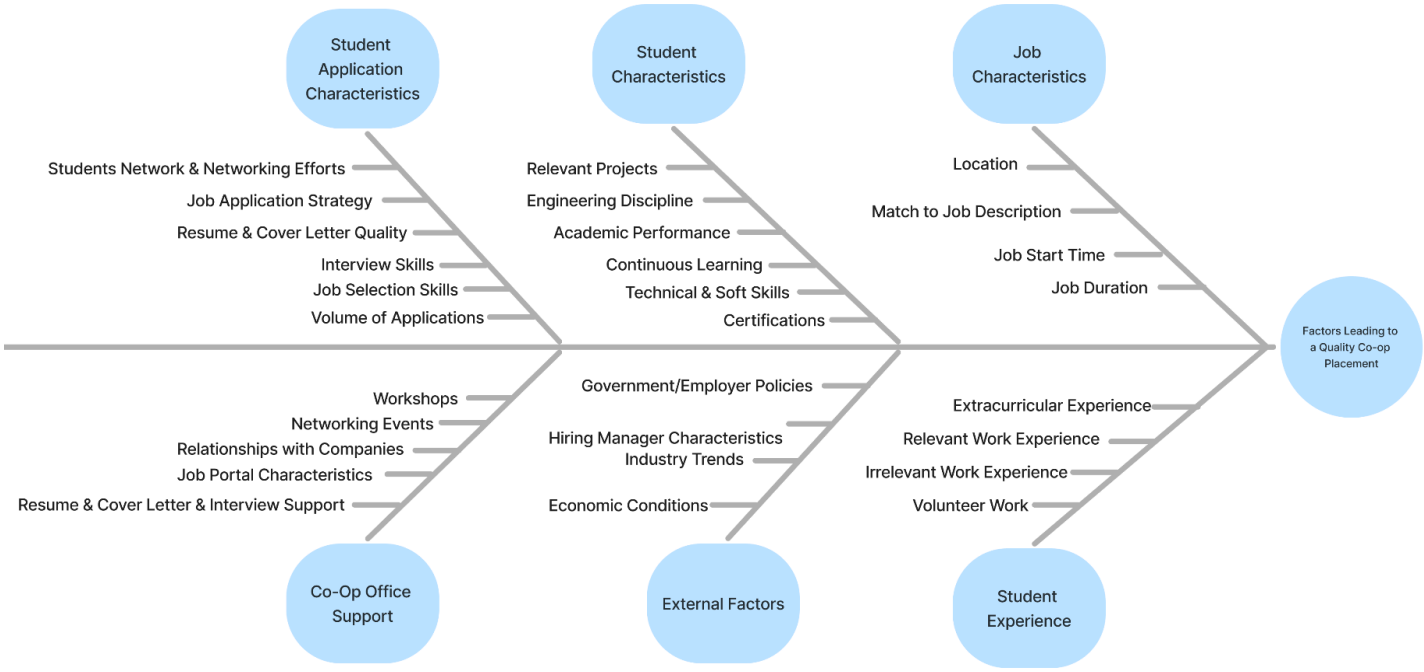
Assumptions made:

- Co-op placements are uniformly available across all engineering disciplines (Industrial, Mechanical, Computer)
- Students honestly and accurately report their earnings, satisfaction, and other relevant data to the co-op office.
- Individual factors such as the number of applications submitted, the effort invested by each student, and the development of job application skills vary and are not controlled in this study as we aim to provide information to first year students that are choosing between
- GPA ranges and engineering disciplines are significant predictors of placement quality and will yield meaningful patterns for analysis.

Main Body

Cause And Effect Diagram:

The initiation of the project was based on the creation of a Cause and Effect Diagram, this was used to breakdown the topic of the project and define the factors that contribute to getting a high quality co-op placement.



The cause and effect diagram has a lot of different factors below you will find a short summary of each branch:

Student Application Characteristics: A large part of achieving a high quality co-op placement is a students ability to succeed during the application process these factors are captured here.

Student Characteristics: These are qualities unique to each student that reflect skills and abilities relevant to potential co-op placements.

Job Characteristics: These are specific factors that change from job to job and may influence whether or not a student can get a co-op placement.

Co-op Office Support: These factors encompass the support that a co-op office can provide to students during their job search.

External Factors: These are factors that are outside of the students control that may influence their ability to get a co-op placement.

Student Experience: Every student has unique experiences and employers rely heavily on students previous experiences to evaluate whether or not they are good candidates.

Data Summary

The data set collected for our project focuses on factors influencing the quality of co-op placements for engineering students at TMU, as outlined in the project scope. The key variables

in the data set include the Student ID, Engineering Discipline, CGPA, CGPA Levels (categorized into Low, Medium, and High), Company, Annual Salary, and the Number of Students Who Returned to the Company in the Last 5 Years. The quality characteristics used to measure the quality of a co-op placement are the Annual Salary and the Number of Students Who Returned to the Company in the Last 5 Years. The factors chosen for analysis are the engineering discipline of the student and their CGPA Level. It is also important to note that the Student ID represents the timeline of each student accepting their co-op placement with number 1 being the first person.

Data Variables Description

1. **Engineering Discipline (Factor):** The dataset contains data from Industrial, Mechanical and Computer Engineering students, allowing us to draw preliminary insights into these specific disciplines. Expanding the data set to other disciplines will provide further comparative insights as per the project approach.
2. **CGPA and CGPA Level (Factor):** Students are grouped into three performance categories: **Low** (1.67 - 2.55), **Medium** (2.56 - 3.44), and **High** (3.45 - 4.33). This classification helps analyze the relationship between academic performance and co-op quality.
3. **Annual Salary (Quality Characteristic #1) :** Compensation data, expressed as annual salary, provides a direct measure of the quality of placements. Salaries range from approximately $49,400 to $64,200 in this sample.
4. **Return Rate/Number of Students Who Returned (Quality Characteristic #2):** The number of students who have returned to the company within the last five years serves as an indirect measure for employee satisfaction, opportunities for development, networking opportunities, employee benefits and much more.

Establishing Statistical Control Configurations

The selected factors each have 3 levels, this means that there are 9 factor configurations for each quality characteristic. For Engineering Discipline the levels analyzed in this report are Industrial (Indy), Mechanical (Mech) and Computer (Comp) Engineering, the CGPA of each student also has 3 levels which are Low, Medium (Med) and High. For reference of the CGPA intervals that correspond to each level please see the Data Description above. To assist in understanding the configurations for the DOE the structure is visually summarized below. It is important to note that these configurations will be applied twice once for each Quality Characteristic.

Configuration	Engineering Discipline	CGPA Level
Config 1	Indy	Low
Config 2	Indy	Med
Config 3	Indy	High
Config 4	Mech	Low
Config 5	Mech	Med
Config 6	Mech	High
Config 7	Comp	Low
Config 8	Comp	Med
Config 9	Comp	High

Table 1: Factor Configurations For DOE

Achieving Statistical Control

The initial analysis of the QC data determined that the process was out of statistical control. (Appendix C: Figures 2, 6, 8). The initial analysis was conducted using an IM-R Chart for the Salary/Year of each student because it is a continuous data type and the sample size is 1. A C-Chart was used to analyze the Number of Students Who Returned because the data represented the number of students and the sample size remained constant. The data points that were out of control in each instance are all a result of a Students Salary/Year being above the upper control limit. In these instances these students were working for tier-1 companies (Microsoft, Tesla) that have extremely high revenues are known to pay significantly more than other companies. The students that were outliers were removed from the dataset pushing the data into statistical control (Appendix C: Figures 10, 11, 12).

The data is subjected to normality tests to ensure that the data was fit for further analysis. First the data was formed into 2 histograms to assist in visualizing the normal distribution of the

data (Appendix B: Figures 5, 6). Then the data was plotted in Probability Plots to calculate the P-Value of the data (See Below)

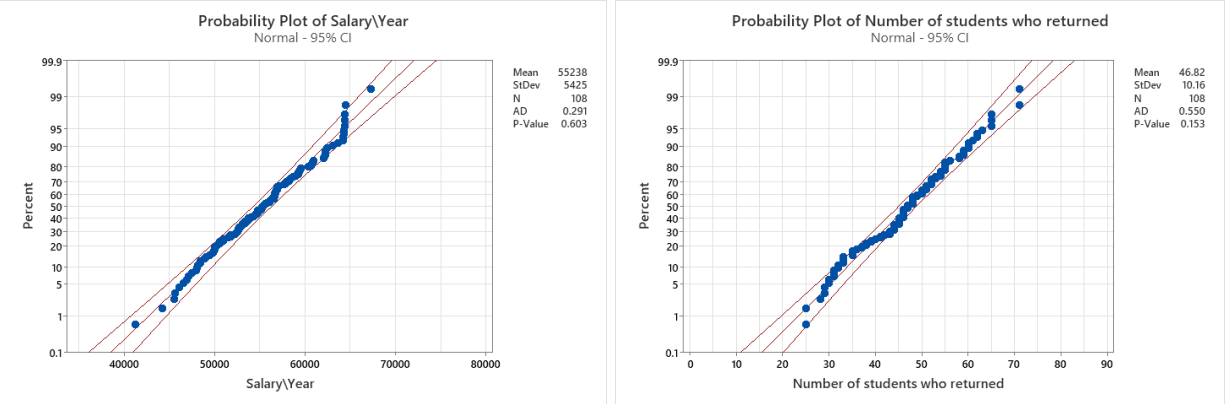


Figure 2: Probability Plots For QC# 1 and #2

It is important to note the P-Values in each plot as it is used to assess the distribution of the data. The P-Value in each plot is greater than 0.005 this means it fails to reject the null hypothesis meaning that the data does not significantly deviate from the normal distribution.

Design of Experiment (DOE) and ANOVA

To determine the influence of the factors and their combination a two factor factorial analysis or a 3^2 design, the analysis includes 2 factors and 3 levels for each factor. A significance level of $\alpha = 0.05$ was used as the standard when evaluating the factors. The figure below shows the design schematic for a 3^2 design (Appendix F: DOE Schematics).

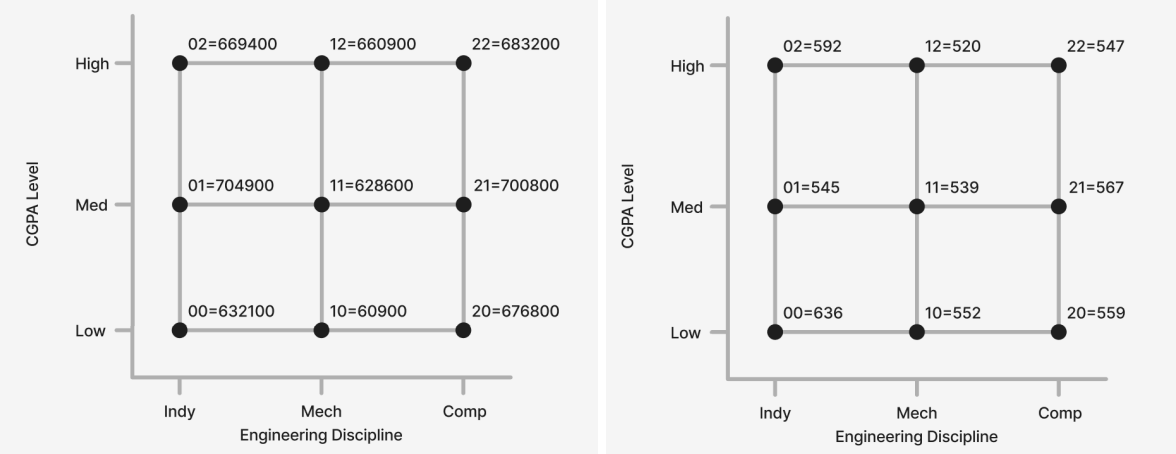


Figure 3: Doe Schematic for Salary/Year QC #1 (Left) for Number of Students Who Returned QC #2 (Right)

The ANOVA test results shown below determined the statistical significance of the factors or their combination. The sample calculations for the ANOVA table for Quality Characteristic #1 Salary/Year can be found in Appendix G: ANOVA Calculations. The results from the ANOVA are represented in the figure below (Appendix D).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	740190185	92523773	3.80	0.001
Linear	4	593185370	148296343	6.09	0.000
Engineering Discipline	2	379102407	189551204	7.79	0.001
CGPA Level	2	214082963	107041481	4.40	0.015
2-Way Interactions	4	147004815	36751204	1.51	0.205
Engineering Discipline*CGPA Level	4	147004815	36751204	1.51	0.205
Error	99	2408764167	24330951		
Total	107	3148954352			

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	776.4	97.05	0.94	0.491
Linear	4	528.8	132.20	1.27	0.285
Engineering Discipline	2	371.2	185.59	1.79	0.173
CGPA Level	2	157.6	78.81	0.76	0.471
2-Way Interactions	4	247.6	61.90	0.60	0.666
Engineering Discipline*CGPA Level	4	247.6	61.90	0.60	0.666
Error	99	10271.2	103.75		
Total	107	11047.7			

Figure 4: ANOVA Tables for Salary/Year QC #1 (Left) for Number of Students Who Returned QC #2 (Right)

Before analyzing the ANOVA tables the critical F-value must be calculated, this will be used to determine if the factors or their combination are statistically significant. Using Minitab the calculated critical F-values are as follows:

Critical F-value for independent factors:

$$F_{0.05,2,99} = 3.09$$

Critical F-value for interaction of factors:

$$F_{0.05,4,99} = 2.46$$

The result of the ANOVA test for Quality Characteristic #2 concluded that the factors and their interaction were not statistically significant. Firstly the calculated F-values for Engineering Discipline (1.79) and CGPA Level (0.76) were both less than the critical value for independent factors (3.09) which means they do not cause significant differences in the group response mean. The F-value for the interaction of the factors (0.6) was also less than the critical F-value (2.46) thus it also does not cause significant difference in the group response mean. The level of significance for this experiment is (0.05) and the p-value for factors and their combination is greater than 0.05 so the results are not statistically significant.

The ANOVA test for Quality Characteristic #1 did show an effect and statistical significance. The interaction of the factors (1.51) had an F-value less than the critical value (2.46) and a

p-value (0.205) greater than 0.05 therefore the interaction of the factors did not result in a large difference in the group mean and the result was not statistically significant. However the F-values for the factors, Engineering Discipline (7.79) and CGPA Level (4.40) were both greater than the critical value (3.09) thus each of the factors causes a large difference in the group response mean. Engineering discipline has a larger effect due to its higher F-value compared to the CGPA Level. The P-values for both of the factors are less than 0.05 meaning that difference in the group mean is statistically significant and can be considered for further analysis.

Mean Affect & Plots

The results of the ANOVA can be further investigated to determine the influence of the levels of each factor on the Salary/Year. To understand the individual effects of each level on the response the mean effect for each factor level is calculated. The results are summarized in the table below and the calculations can be found in Appendix G: Main Effect Calculations.

Factor	**Level**	**Mean Effect**
Engineering Discipline	Industrial Engineering	495.37
	Mechanical Engineering	-2501.85
	Computer Engineering	2006.48
CGPA Level	Low	-1962.96
	Med	1270.37
	High	692.59

Table 2: Mean Effect Data Summary

Based on the main effect calculations independently Computer Engineering and Med CGPA Level contributes to respectively about a $2006.8 and $1270.37 increase compared to the mean Salary/Year. Industrial Engineering and High CGPA Level also contribute to a Salary/Year higher than the average but less than that of Computer Engineering or a Med CPGA Level. Once again independently, Mechanical Engineering and Low CGPA level have a negative impact on the average Salary/Year. The results of these calculations can also be visualized in the figure below the gray dotted line represents the average Salary/Year.

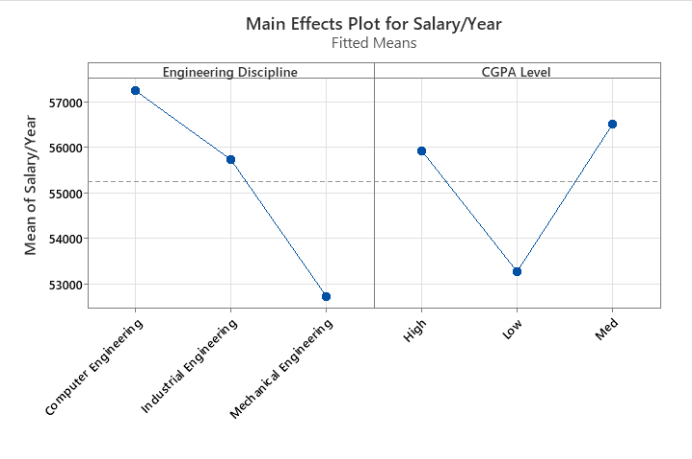


Figure 5: Main Effect Plot for Salary/Year

Discussion & Conclusion

The conclusion of the statistical analysis in this report did not have the expected result, it was expected that the statistical analysis would reveal the combinations of engineering disciplines with a certain level of CGPA that lead to the highest quality co-op placement. The result of the analysis determined that the combination of CGPA Level and Engineering Discipline had no effect on the Salary/Year or working at a company where a large number of students return after their co-op term is complete. First, the analysis of Number of Students Who Returned showed no statistical significance between our factors or our levels. This conclusion could have a variety of different meanings however it is most important to acknowledge that this result reveals that there are other factors that are more influential and significant to working at a company where a large number of students return and thus a high quality co-op placement. This indicates that students should not worry about their CGPA Level or Engineering Discipline but rather spend time learning and developing themselves outside the classroom by developing different skills for example soft skills.

The result of the statistical analysis related to the Annual Salary revealed that independently a students Engineering Discipline or CGPA Level are significant. With this in mind it is important to look at the levels of each factor to determine the best Engineering Discipline and CGPA Level when it comes to earning a high salary. The experiment revealed that Computer and Industrial Engineering provide the best opportunity for students to achieve a high salary and thus a quality co-op placement, this is a useful piece of insight as it gives students a

general insight into the current engineering job market and which engineering disciplines make the most and are in highest demand. Notably, Industrial Engineering offers less competition due to lower enrollment in the stream, resulting in high demand and nearly all the Industrial Engineering students enrolled into the CO-OP program secure an internship, highlighting a surplus of opportunities compared to supply of students.

Perhaps our deduction above explains why those in the Medium Range for CGPA (2.56-3.44) are able to secure co-op placements with the largest salary. This verdict once again enables the inference that a student should not spend all of their time working towards a high CGPA Level but rather spend time developing in other aspects of their life and also choose the stream with the highest demand.

Overall the analysis did not provide the expected conclusion and aside from the statistical conclusion that the hierarchy for Annual Salary goes by Computer, Industrial, then Mechanical and that the students with a Medium CGPA Level have the highest Annual Salary. However it did provide the opportunity for an important inference for students and that is they should develop themselves inside of the classroom as well as outside of the classroom by participating in student clubs,workshops, while also networking and developing technical skills independently, will enhance their readiness for their future career.

References

Jila, A. (2024). *TMU FEAS Co-op Office.* Student Co-op Data. Retrieved September 27, 2024,.

Montgomery, D. C. (2020). Introduction to statistical quality control. John Wiley & Sons, Inc.

Graham, H. (2005). *University of Sussex.* F-Ratio Table. Retrieved from: https://users.sussex.ac.uk/~grahamh/RM1web/F-ratio%20table%202005.pdf

National Institute of Standards and Technology. (n.d.). *US Department of Commerce.* Three-level full factorial designs. https://www.itl.nist.gov/div898/handbook/pri/section3/pri339.htm

Appendix

Appendix A: Datasets

Table A.1: Initial Dataset

Student ID	Engineering Discipline	CGPA	Company	Salary\Year	Number of students who returned to the company in the last 5 years	CGPA Levels
1	Computer Engineering	2.22	Honda	56600	45	Low
2	Mechanical Engineering	2.38	Toyota	46100	54	Low
3	Computer Engineering	3.61	Ericsson	54500	59	High
4	Industrial Engineering	2.5	Celestica	46900	65	Low
5	Computer Engineering	2.1	Ericsson	50600	59	Low
6	Computer Engineering	2.52	Honda	55200	45	Low
7	Mechanical Engineering	3.74	Boeing	52200	48	High
8	Mechanical Engineering	2.31	Manulife	48400	42	Low
9	Computer Engineering	3.39	Apple	67300	28	Med
10	Computer Engineering	4.03	Wealthsimple	64300	47	High
11	Industrial Engineering	2.86	Coca-Cola	63600	55	Med

12	Mechanical Engineering	2.25	Toyota	50000	54	Low
13	Mechanical Engineering	3.31	Rockwell Automation	60400	47	Med
14	Computer Engineering	3.15	SAP	56900	55	Med
15	Computer Engineering	2.15	Ericsson	47500	59	Low
16	Industrial Engineering	3.71	Kraft Heinz	49400	40	High
17	Computer Engineering	3.91	Scotiabank	64400	35	High
18	Industrial Engineering	2.91	Pratt & Whitney	56200	55	Med
19	Industrial Engineering	3.54	Sobeys	53700	39	High
20	Computer Engineering	3.75	Honeywell Aerospace	62200	33	High
21	Mechanical Engineering	3.69	Amazon	54800	33	High
22	Mechanical Engineering	2.64	Nokia	56100	38	Med
23	Mechanical Engineering	3.33	L3 Harris	45600	58	Med
24	Industrial Engineering	2.44	Deloitte	44200	71	Low
25	Computer Engineering	1.98	Bombardier Aerospace	59200	45	Low
26	Industrial Engineering	3.81	Amazon	55100	33	High
27	Industrial Engineering	2.34	Bombardier Transportation	41200	41	Low

28	Industrial Engineering	2.08	Loblaws	55200	44	Low
29	Mechanical Engineering	2.31	De Havilland Aircraft	50300	40	Low
30	Mechanical Engineering	3.32	HP	45500	61	Med
31	Mechanical Engineering	3.46	SAP	54800	55	High
32	Computer Engineering	3.44	SOTI	53100	46	Med
33	Industrial Engineering	1.83	Bombardier Transportation	59400	41	Low
34	Industrial Engineering	2.83	Microsoft	84400	34	Med
35	Computer Engineering	4.07	Intel	56300	31	High
36	Mechanical Engineering	2.98	Toyota	47100	54	Med
37	Mechanical Engineering	2.54	Amazon	48100	33	Low
38	Industrial Engineering	2.94	Coca-Cola	60700	55	Med
39	Mechanical Engineering	2.2	Thales	51500	52	Low
40	Industrial Engineering	2.24	Deloitte	52500	71	Low
41	Mechanical Engineering	3.79	Siemens	56500	25	High
42	Mechanical Engineering	2.78	CIBC	51800	51	Med
43	Mechanical Engineering	4.24	Unilever	52600	56	High

44	Industrial Engineering	2.39	EllisDon	54000	68	Low
45	Mechanical Engineering	2.51	Bell	54300	52	Low
46	Computer Engineering	3.85	Ford	48900	28	High
47	Industrial Engineering	4.25	Google	56500	44	High
48	Industrial Engineering	3.13	General Motors	63100	62	Med
49	Computer Engineering	3.14	Spin Master Ltd.	53600	44	Med
50	Mechanical Engineering	3.25	CAE Inc.	49100	34	Med
51	Computer Engineering	3.41	Coca-Cola	64500	55	Med
52	Industrial Engineering	3.57	Nestlé	53100	54	High
53	Industrial Engineering	4.27	Maple Leaf Foods	49900	37	High
54	Computer Engineering	3.21	Bombardier Aerospace	47900	45	Med
55	Mechanical Engineering	3.54	Bombardier Aerospace	51000	45	High
56	Computer Engineering	4.31	TD	62200	53	High
57	Industrial Engineering	2.12	Nestlé	60900	54	Low
58	Mechanical Engineering	2.18	General Motors	48000	62	Low
59	Computer Engineering	1.89	SOTI	50000	46	Low

60	Industrial Engineering	3.53	Unilever	53400	56	High
61	Mechanical Engineering	1.99	Boeing	52900	48	Low
62	Computer Engineering	4.07	Toyota	48400	54	High
63	Computer Engineering	3.15	Nokia	64300	38	Med
64	Mechanical Engineering	2.47	MDA Space	56700	38	Low
65	Industrial Engineering	3.44	Canada Goose	62400	29	Med
66	Mechanical Engineering	2.67	OpenText	49800	28	Med
67	Industrial Engineering	3.08	Toyota	50600	54	Med
68	Computer Engineering	2.45	CGI Inc.	58200	36	Low
69	Computer Engineering	2.07	MDA Space	59200	38	Low
70	Mechanical Engineering	3.14	MDA (MacDonald, Dettwiler & Assoc.)	56900	52	Med
71	Computer Engineering	1.94	Safran	57700	65	Low
72	Industrial Engineering	2.27	Canadian Pacific Railway	52700	60	Low
73	Computer Engineering	3.74	Bell	60600	52	High
74	Industrial Engineering	3.49	Linamar Corporation	55300	47	High
75	Industrial Engineering	3.16	FGF Brands	62200	30	Med

76	Industrial Engineering	3.68	Celestica	62000	65	High
77	Mechanical Engineering	3.94	Palantir Technologies	64400	23	High
78	Mechanical Engineering	2.22	L3 Harris	50900	58	Low
79	Mechanical Engineering	4.05	Nokia	52400	38	High
80	Mechanical Engineering	3.07	Intel	58300	31	Med
81	Industrial Engineering	3.69	Accenture	64200	61	High
82	Computer Engineering	3.25	MDA (MacDonald, Dettwiler & Assoc.)	64200	52	Med
83	Computer Engineering	3.67	OpenText	59300	28	High
84	Computer Engineering	2.27	AMD (Advanced Micro Devices)	59500	54	Low
85	Industrial Engineering	2.31	CIBC	50100	51	Low
86	Industrial Engineering	4.12	Purolator	54700	63	High
87	Computer Engineering	3.14	Tesla	60800	27	Med
88	Industrial Engineering	4.07	Canadian Pacific Railway	62100	60	High
89	Computer Engineering	3.11	Microsoft	96300	34	Med
90	Industrial Engineering	3.07	Coca-Cola	59000	55	Med
91	Industrial Engineering	2.16	Suncor Energy	58400	48	Low

92	Mechanical Engineering	3.56	Tesla	78500	27	High
93	Industrial Engineering	2.34	Loblaws	56600	44	Low
94	Industrial Engineering	3.25	Canadian National Railway (CN)	56800	56	Med
95	Industrial Engineering	3.34	Thermo Fisher Scientific	56600	32	Med
96	Mechanical Engineering	3.34	Kinaxis	55400	29	Med
97	Computer Engineering	3.39	AMD (Advanced Micro Devices)	56700	54	Med
98	Computer Engineering	4.02	Procter & Gamble	55600	53	High
99	Mechanical Engineering	3.76	Rockwell Automation	57100	47	High
100	Computer Engineering	2.46	Scotiabank	64400	35	Low
101	Industrial Engineering	3.44	FGF Brands	57900	30	Med
102	Mechanical Engineering	3.82	Maple Leaf Foods	53400	37	High
103	Mechanical Engineering	4.09	OpenText	54800	28	High
104	Computer Engineering	3.18	GE Aviation	53700	56	Med
105	Mechanical Engineering	3.22	Siemens	52600	25	Med
106	Computer Engineering	3.91	Unilever	46500	56	High
107	Mechanical Engineering	2.17	Scotiabank	51800	35	Low

108	Computer Engineering	1.99	Sunlife	58700	32	Low
109	Mechanical Engineering	3.79	Unilever	56900	56	High
110	Computer Engineering	3.22	Canadian Pacific Railway	57800	60	Med
111	Industrial Engineering	3.44	Loblaws	55800	44	Med

Table A.2 Controlled Dataset

Student ID	Engineering Discipline	CGPA	Company	Salary\Year	Number of students who returned to the company in the last 5 years	CGPA Levels
1	Computer Engineering	2.22	Honda	56600	45	Low
2	Mechanical Engineering	2.38	Toyota	46100	54	Low
3	Computer Engineering	3.61	Ericsson	54500	59	High
4	Industrial Engineering	2.5	Celestica	46900	65	Low
5	Computer Engineering	2.1	Ericsson	50600	59	Low
6	Computer Engineering	2.52	Honda	55200	45	Low
7	Mechanical Engineering	3.74	Boeing	52200	48	High
8	Mechanical Engineering	2.31	Manulife	48400	42	Low

9	Computer Engineering	3.39	Apple	67300	28	Med
10	Computer Engineering	4.03	Wealthsimple	64300	47	High
11	Industrial Engineering	2.86	Coca-Cola	63600	55	Med
12	Mechanical Engineering	2.25	Toyota	50000	54	Low
13	Mechanical Engineering	3.31	Rockwell Automation	60400	47	Med
14	Computer Engineering	3.15	SAP	56900	55	Med
15	Computer Engineering	2.15	Ericsson	47500	59	Low
16	Industrial Engineering	3.71	Kraft Heinz	49400	40	High
17	Computer Engineering	3.91	Scotiabank	64400	35	High
18	Industrial Engineering	2.91	Pratt & Whitney	56200	55	Med
19	Industrial Engineering	3.54	Sobeys	53700	39	High
20	Computer Engineering	3.75	Honeywell Aerospace	62200	33	High
21	Mechanical Engineering	3.69	Amazon	54800	33	High
22	Mechanical Engineering	2.64	Nokia	56100	38	Med
23	Mechanical Engineering	3.33	L3 Harris	45600	58	Med
24	Industrial Engineering	2.44	Deloitte	44200	71	Low

25	Computer Engineering	1.98	Bombardier Aerospace	59200	45	Low
26	Industrial Engineering	3.81	Amazon	55100	33	High
27	Industrial Engineering	2.34	Bombardier Transportation	41200	41	Low
28	Industrial Engineering	2.08	Loblaws	55200	44	Low
29	Mechanical Engineering	2.31	De Havilland Aircraft	50300	40	Low
30	Mechanical Engineering	3.32	HP	45500	61	Med
31	Mechanical Engineering	3.46	SAP	54800	55	High
32	Computer Engineering	3.44	SOTI	53100	46	Med
33	Industrial Engineering	1.83	Bombardier Transportation	59400	41	Low
35	Computer Engineering	4.07	Intel	56300	31	High
36	Mechanical Engineering	2.98	Toyota	47100	54	Med
37	Mechanical Engineering	2.54	Amazon	48100	33	Low
38	Industrial Engineering	2.94	Coca-Cola	60700	55	Med
39	Mechanical Engineering	2.2	Thales	51500	52	Low
40	Industrial Engineering	2.24	Deloitte	52500	71	Low
41	Mechanical Engineering	3.79	Siemens	56500	25	High

42	Mechanical Engineering	2.78	CIBC	51800	51	Med
43	Mechanical Engineering	4.24	Unilever	52600	56	High
44	Industrial Engineering	2.39	EllisDon	54000	68	Low
45	Mechanical Engineering	2.51	Bell	54300	52	Low
46	Computer Engineering	3.85	Ford	48900	28	High
47	Industrial Engineering	4.25	Google	56500	44	High
48	Industrial Engineering	3.13	General Motors	63100	62	Med
49	Computer Engineering	3.14	Spin Master Ltd.	53600	44	Med
50	Mechanical Engineering	3.25	CAE Inc.	49100	34	Med
51	Computer Engineering	3.41	Coca-Cola	64500	55	Med
52	Industrial Engineering	3.57	Nestlé	53100	54	High
53	Industrial Engineering	4.27	Maple Leaf Foods	49900	37	High
54	Computer Engineering	3.21	Bombardier Aerospace	47900	45	Med
55	Mechanical Engineering	3.54	Bombardier Aerospace	51000	45	High
56	Computer Engineering	4.31	TD	62200	53	High
57	Industrial Engineering	2.12	Nestlé	60900	54	Low

58	Mechanical Engineering	2.18	General Motors	48000	62	Low
59	Computer Engineering	1.89	SOTI	50000	46	Low
60	Industrial Engineering	3.53	Unilever	53400	56	High
61	Mechanical Engineering	1.99	Boeing	52900	48	Low
62	Computer Engineering	4.07	Toyota	48400	54	High
63	Computer Engineering	3.15	Nokia	64300	38	Med
64	Mechanical Engineering	2.47	MDA Space	56700	38	Low
65	Industrial Engineering	3.44	Canada Goose	62400	29	Med
66	Mechanical Engineering	2.67	OpenText	49800	28	Med
67	Industrial Engineering	3.08	Toyota	50600	54	Med
68	Computer Engineering	2.45	CGI Inc.	58200	36	Low
69	Computer Engineering	2.07	MDA Space	59200	38	Low
70	Mechanical Engineering	3.14	MDA (MacDonald, Dettwiler & Assoc.)	56900	52	Med
71	Computer Engineering	1.94	Safran	57700	65	Low
72	Industrial Engineering	2.27	Canadian Pacific Railway	52700	60	Low
73	Computer Engineering	3.74	Bell	60600	52	High

74	Industrial Engineering	3.49	Linamar Corporation	55300	47	High
75	Industrial Engineering	3.16	FGF Brands	62200	30	Med
76	Industrial Engineering	3.68	Celestica	62000	65	High
77	Mechanical Engineering	3.94	Palantir Technologies	64400	23	High
78	Mechanical Engineering	2.22	L3 Harris	50900	58	Low
79	Mechanical Engineering	4.05	Nokia	52400	38	High
80	Mechanical Engineering	3.07	Intel	58300	31	Med
81	Industrial Engineering	3.69	Accenture	64200	61	High
82	Computer Engineering	3.25	MDA (MacDonald, Dettwiler & Assoc.)	64200	52	Med
83	Computer Engineering	3.67	OpenText	59300	28	High
84	Computer Engineering	2.27	AMD (Advanced Micro Devices)	59500	54	Low
85	Industrial Engineering	2.31	CIBC	50100	51	Low
86	Industrial Engineering	4.12	Purolator	54700	63	High
87	Computer Engineering	3.14	Tesla	60800	27	Med
88	Industrial Engineering	4.07	Canadian Pacific Railway	62100	60	High
90	Industrial Engineering	3.07	Coca-Cola	59000	55	Med

91	Industrial Engineering	2.16	Suncor Energy	58400	48	Low
93	Industrial Engineering	2.34	Loblaws	56600	44	Low
94	Industrial Engineering	3.25	Canadian National Railway (CN)	56800	56	Med
95	Industrial Engineering	3.34	Thermo Fisher Scientific	56600	32	Med
96	Mechanical Engineering	3.34	Kinaxis	55400	29	Med
97	Computer Engineering	3.39	AMD (Advanced Micro Devices)	56700	54	Med
98	Computer Engineering	4.02	Procter & Gamble	55600	53	High
99	Mechanical Engineering	3.76	Rockwell Automation	57100	47	High
100	Computer Engineering	2.46	Scotiabank	64400	35	Low
101	Industrial Engineering	3.44	FGF Brands	57900	30	Med
102	Mechanical Engineering	3.82	Maple Leaf Foods	53400	37	High
103	Mechanical Engineering	4.09	OpenText	54800	28	High
104	Computer Engineering	3.18	GE Aviation	53700	56	Med
105	Mechanical Engineering	3.22	Siemens	52600	25	Med
106	Computer Engineering	3.91	Unilever	46500	56	High
107	Mechanical Engineering	2.17	Scotiabank	51800	35	Low

108	Computer Engineering	1.99	Sunlife	58700	32	Low
109	Mechanical Engineering	3.79	Unilever	56900	56	High
110	Computer Engineering	3.22	Canadian Pacific Railway	57800	60	Med
111	Industrial Engineering	3.44	Loblaws	55800	44	Med

Appendix B: Normality Tests

Initial Normality Tests

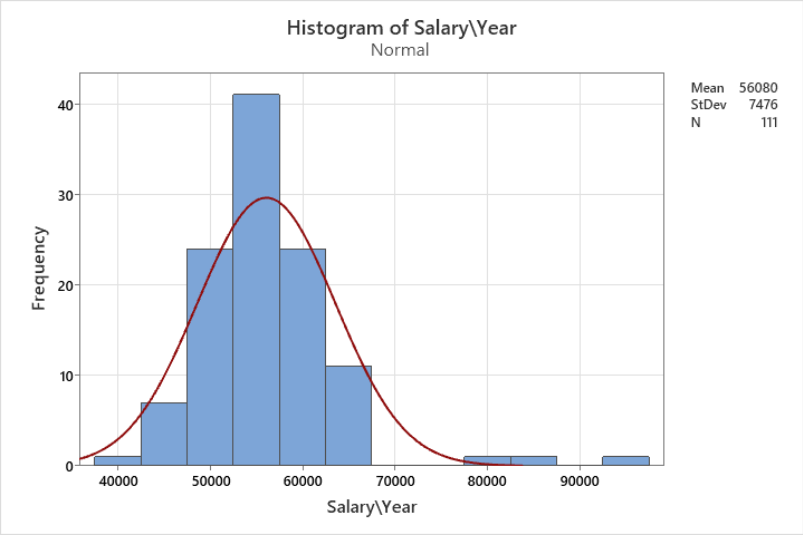


Figure B.1: *Histogram for QC #1 Salary/Year*

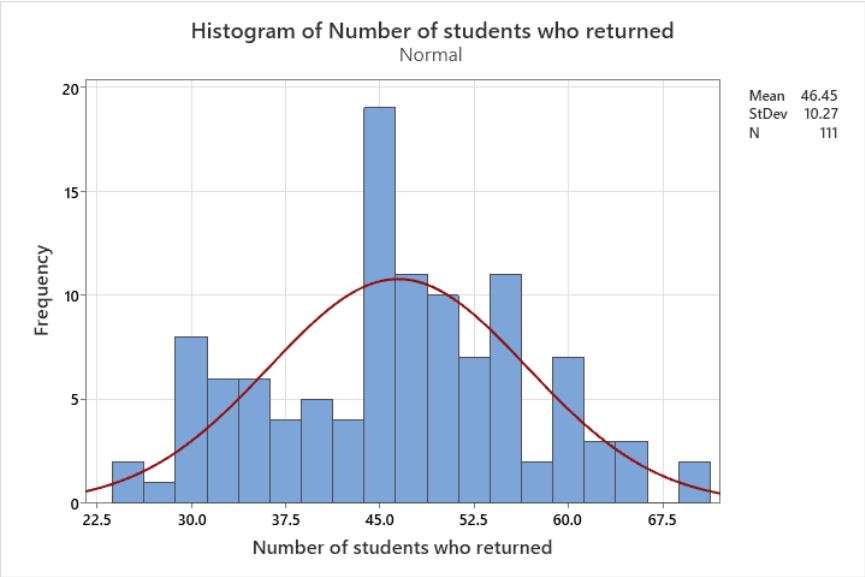


Figure B.2: *Histogram for QC #2 Number of Students Who Returned*

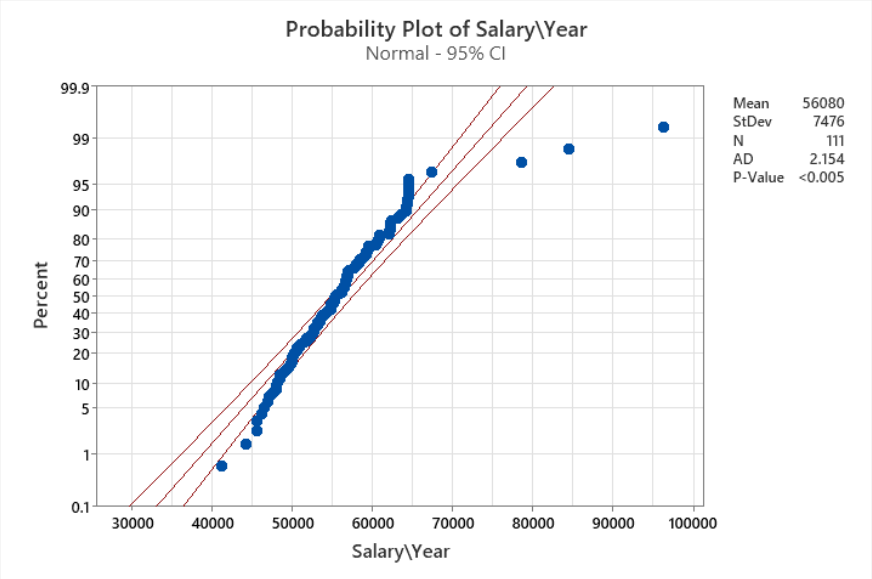


Figure B.3: *Probability Plot for QC #1 Salary/Year*

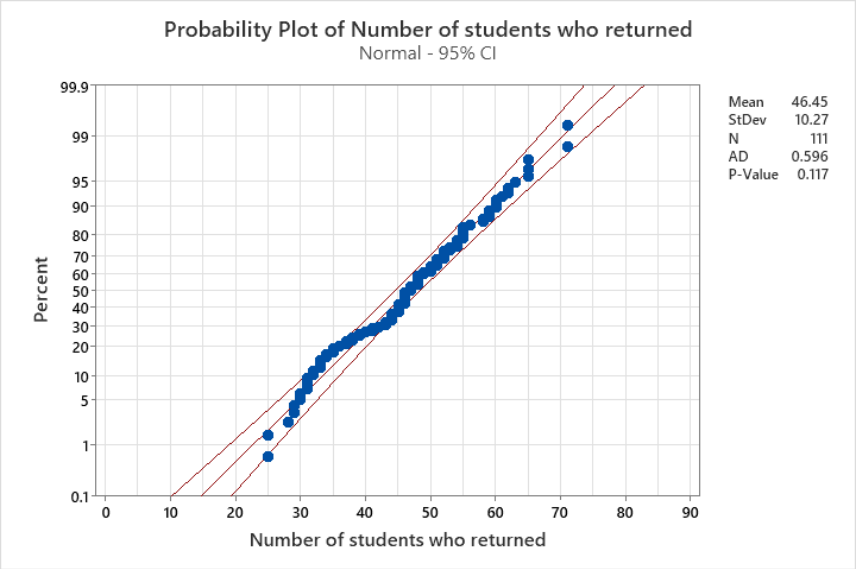


Figure B.4: *Probability Plot for QC #2 Number of Students Who Returned*

Controlled Normality Tests

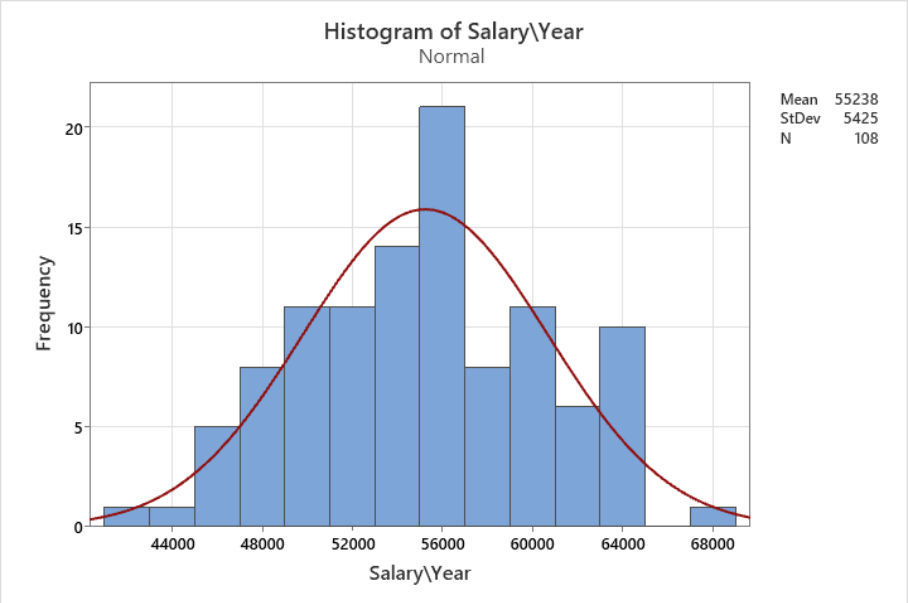


Figure B.5: *Histogram for QC #1 Salary/Year*

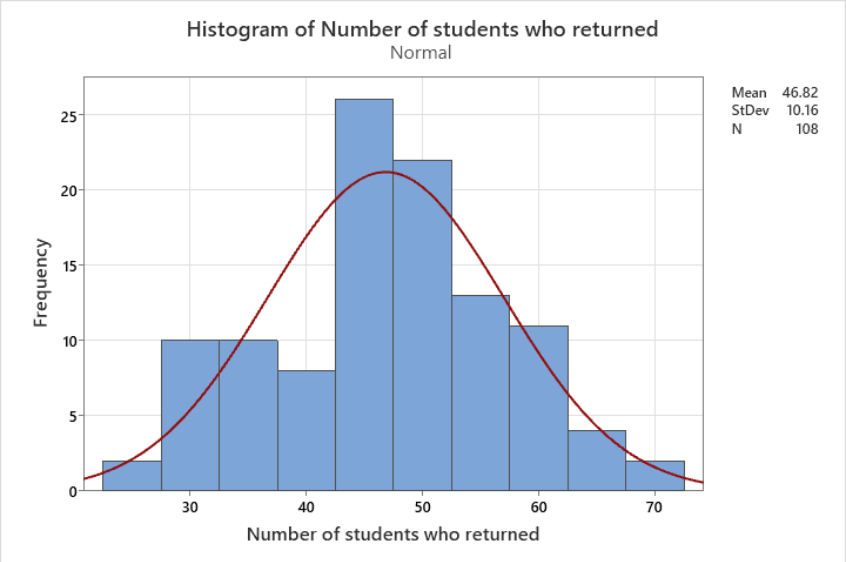


Figure B.6: *Histogram for QC #2 Number of Students Who Returned*

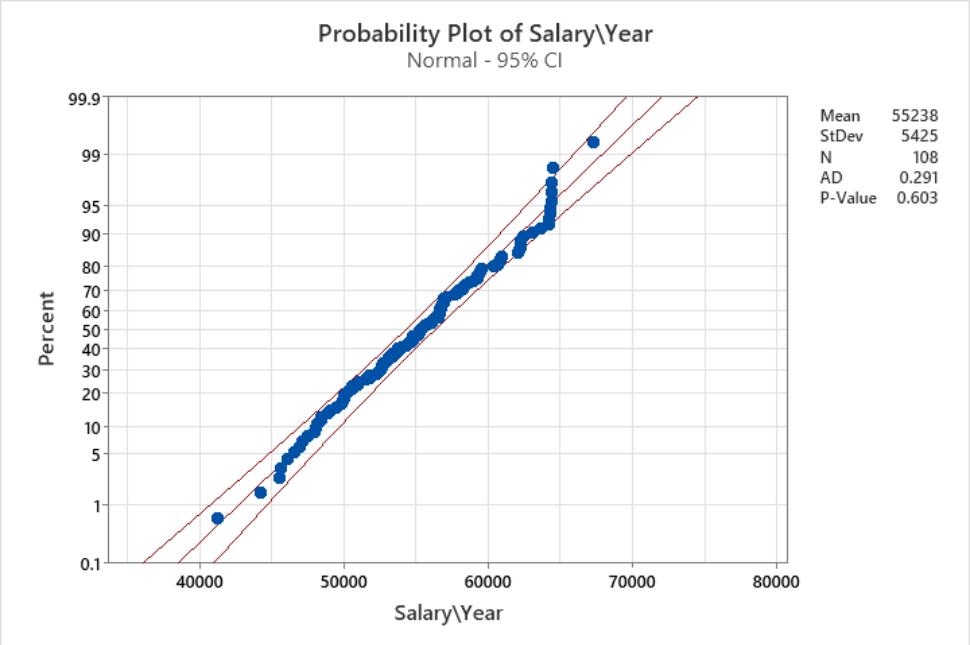


Figure B.7: *Probability Plot for QC #1 Salary/Year*

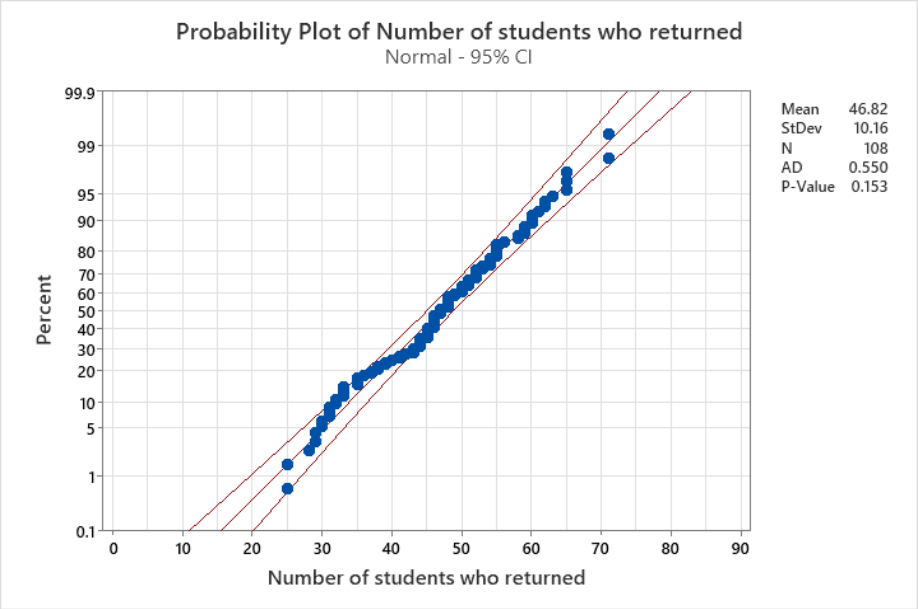


Figure B.8: *Probability Plot for QC #2 Number of Students Who Returned*

Appendix C: Control Charts

Initial Control Charts

Configuration 1

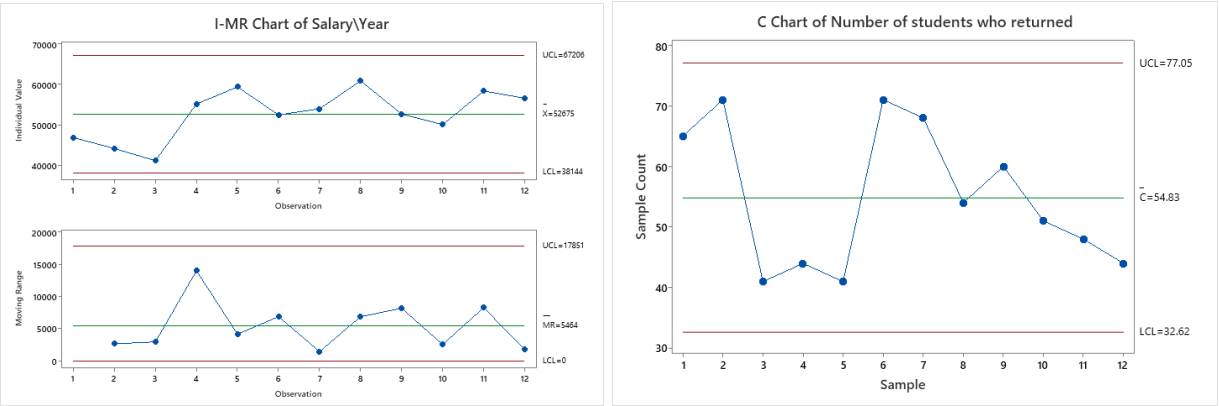


Figure C.1: *Config #1 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 2

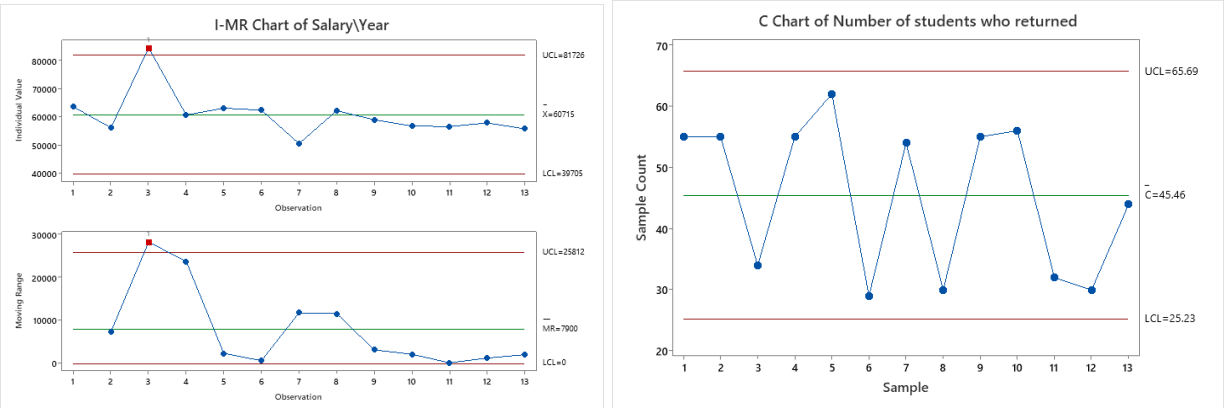


Figure C.2: *Config #2 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 3

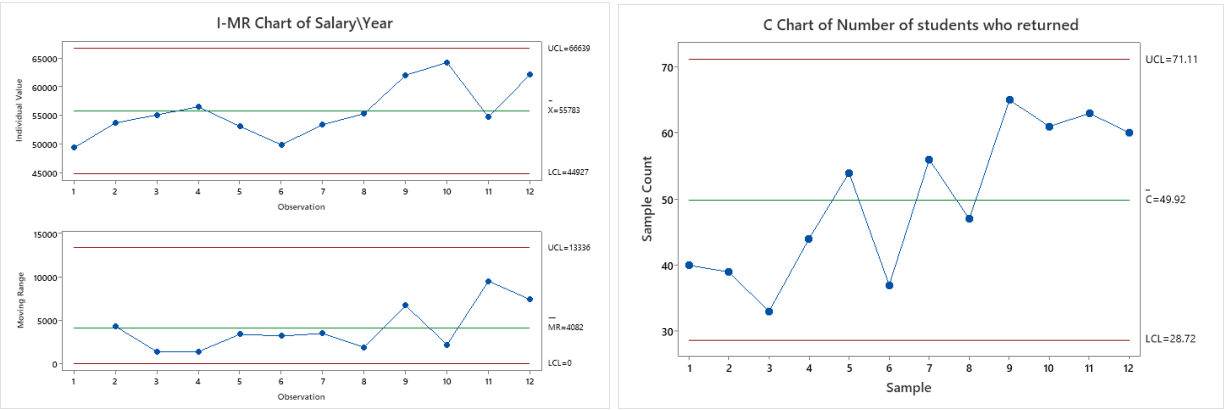


Figure C.3: *Config #3 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 4

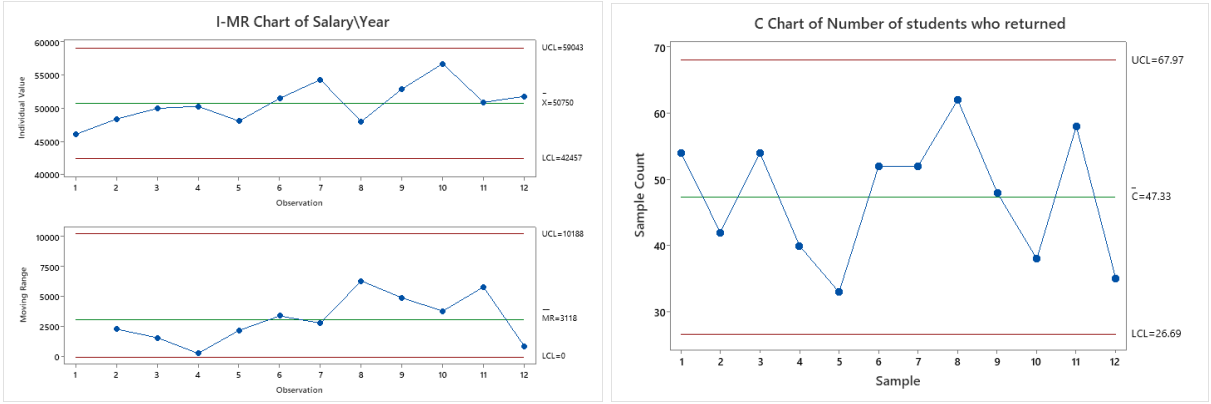


Figure C.4: *Config #4 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 5

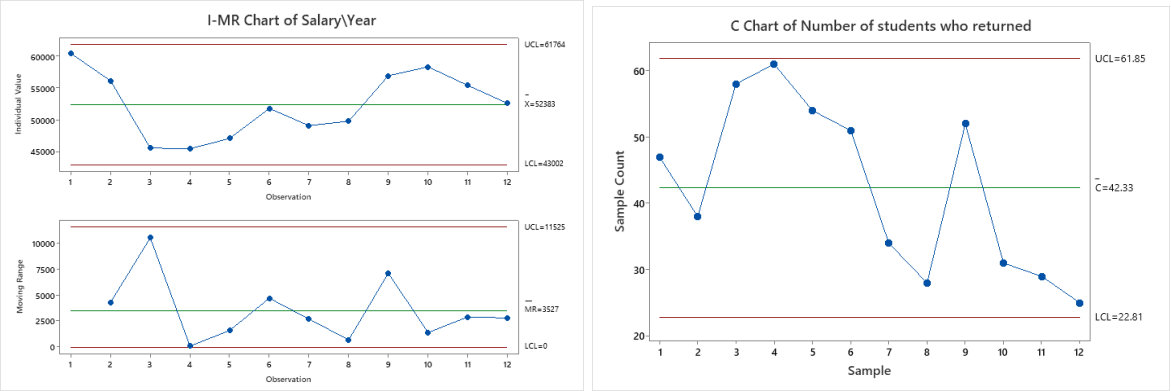


Figure C.5: *Config #5 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 6

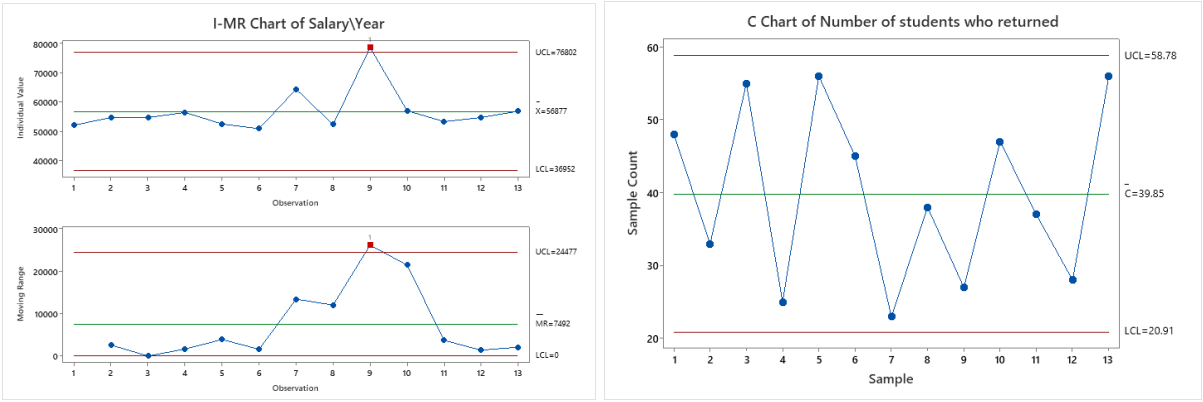


Figure C.6: *Config #6 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 7

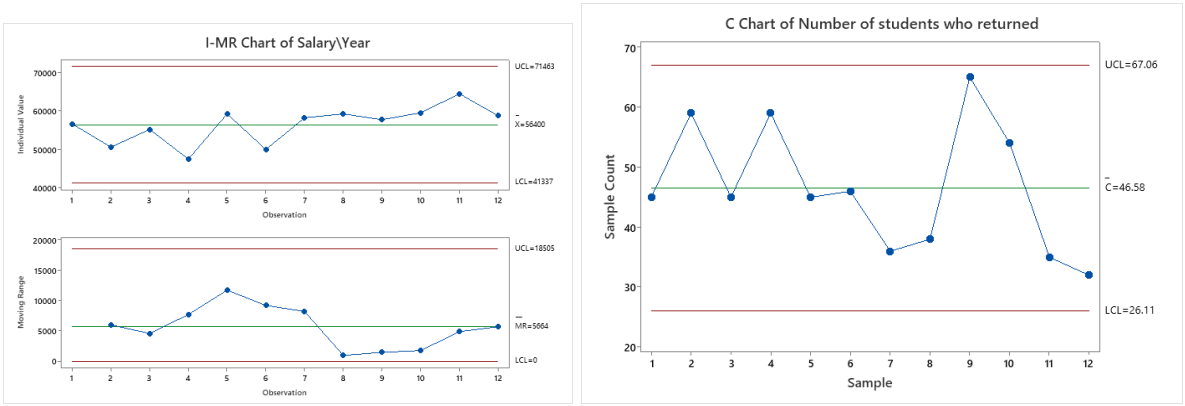


Figure C.7: *Config #7 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 8

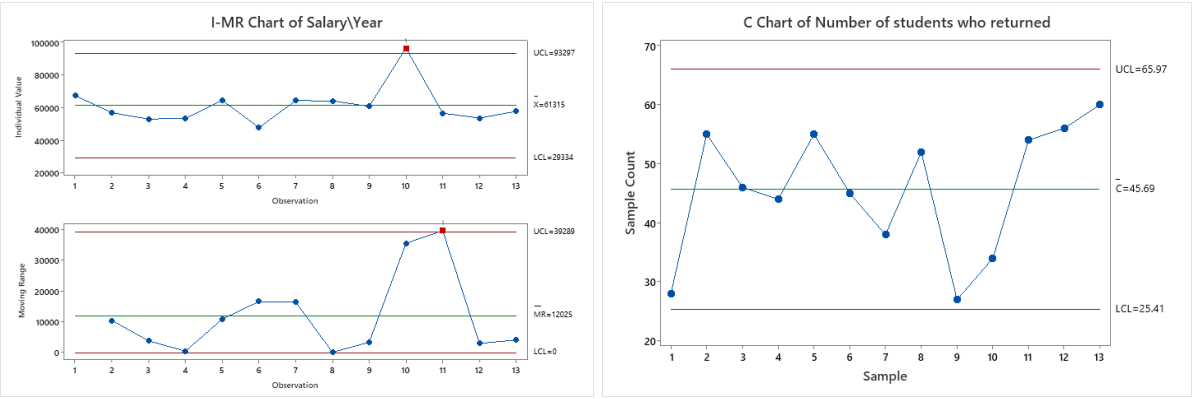


Figure C.8: *Config #8 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 9

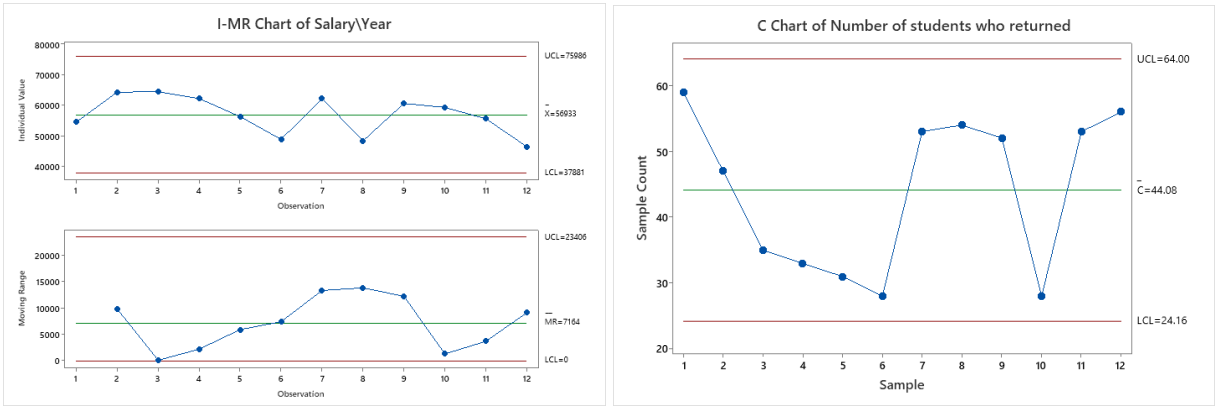


Figure C.9: *Config #9 - IM-R Chart for QC #1 and C Chart for QC #2*

Revised Control Charts

Configuration 2

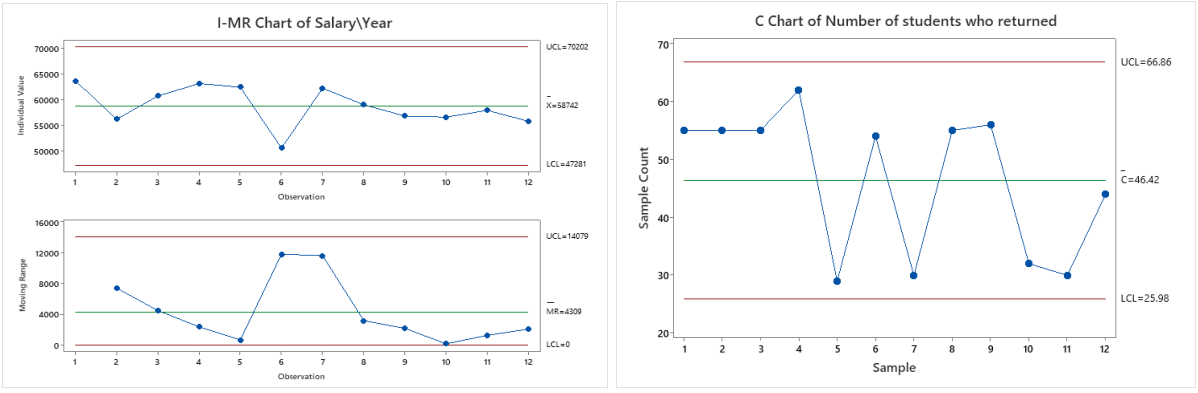


Figure C.10: *Revised Config #2 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 6

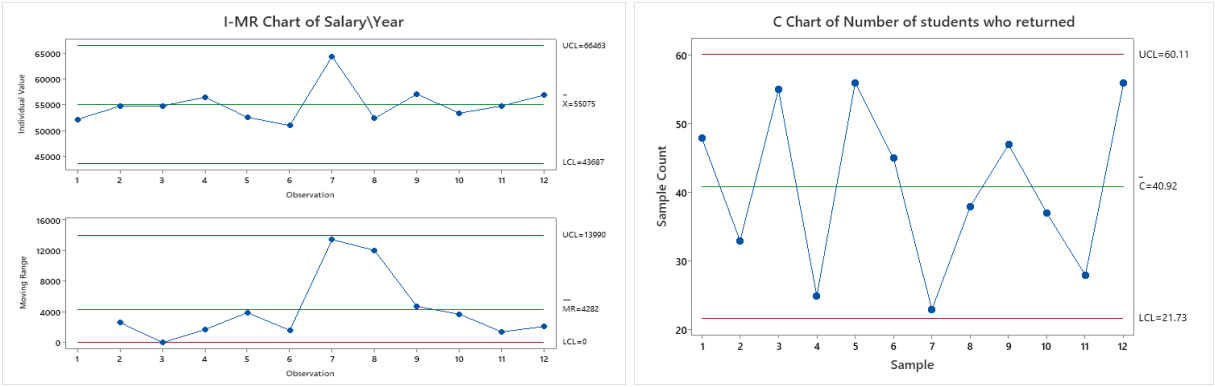


Figure C.11: *Revised Config #6 - IM-R Chart for QC #1 and C Chart for QC #2*

Configuration 8

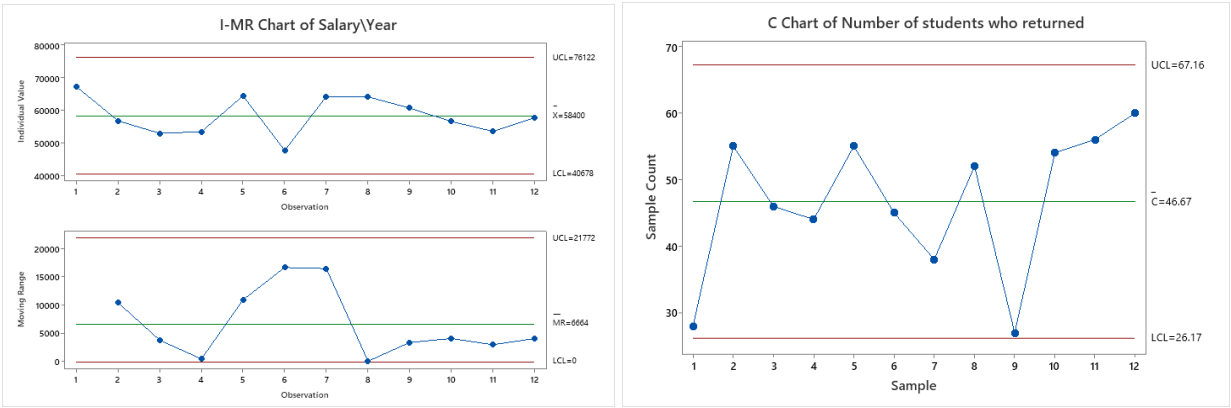


Figure C.12: *Revised Config #8 - IM-R Chart for QC #1 and C Chart for QC #2*

Appendix D: DOE and ANOVA Results

Salary/Year Quality Characteristic #1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	740190185	92523773	3.80	0.001
Linear	4	593185370	148296343	6.09	0.000
Engineering Discipline	2	379102407	189551204	7.79	0.001
CGPA Level	2	214082963	107041481	4.40	0.015
2-Way Interactions	4	147004815	36751204	1.51	0.205
Engineering Discipline*CGPA Level	4	147004815	36751204	1.51	0.205
Error	99	2408764167	24330951		
Total	107	3148954352			

Figure D.1: *ANOVA Table for QC #1*

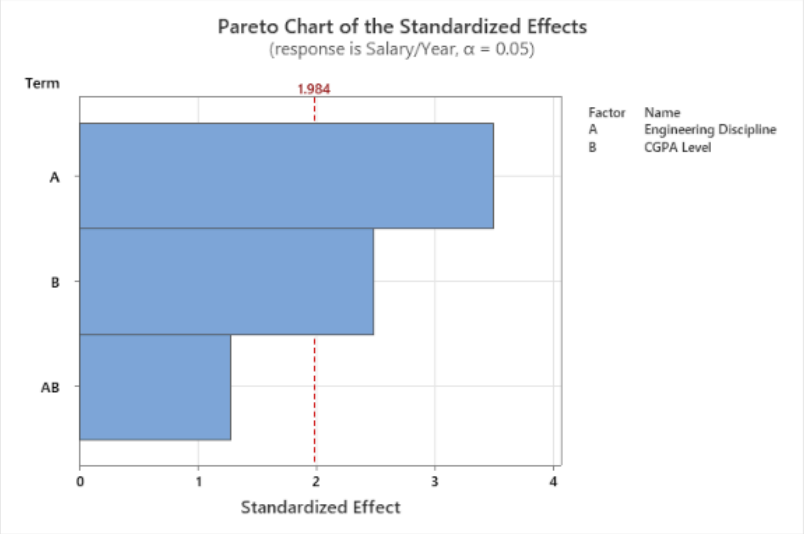


Figure D.2: *Pareto Chart for QC #1*

Number of Students Who Returned Quality Characteristic #2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	776.4	97.05	0.94	0.491
Linear	4	528.8	132.20	1.27	0.285
Engineering Discipline	2	371.2	185.59	1.79	0.173
CGPA Level	2	157.6	78.81	0.76	0.471
2-Way Interactions	4	247.6	61.90	0.60	0.666
Engineering Discipline*CGPA Level	4	247.6	61.90	0.60	0.666
Error	99	10271.2	103.75		
Total	107	11047.7			

Figure D.3: *ANOVA Table for QC #2*

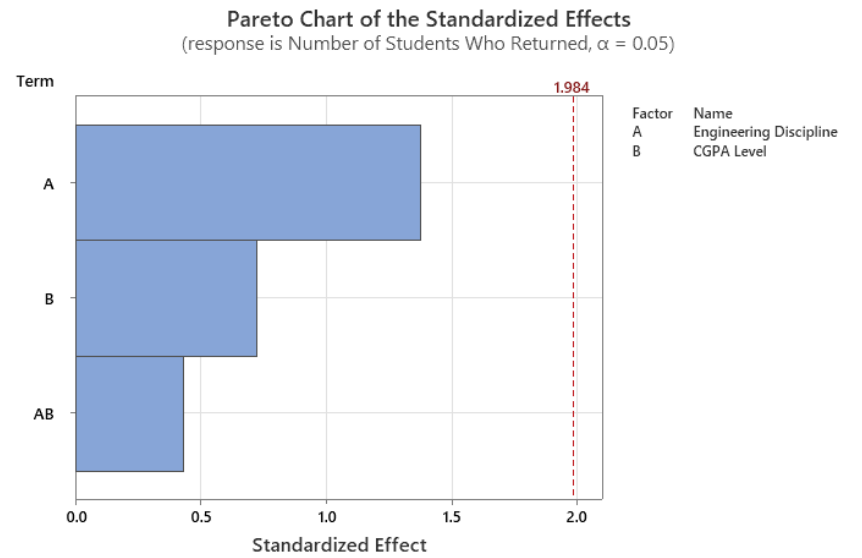


Figure D.4: *Pareto Chart for QC #2*

Appendix E: Interaction & Main Effect Plots

Salary/Year Quality Characteristic #1

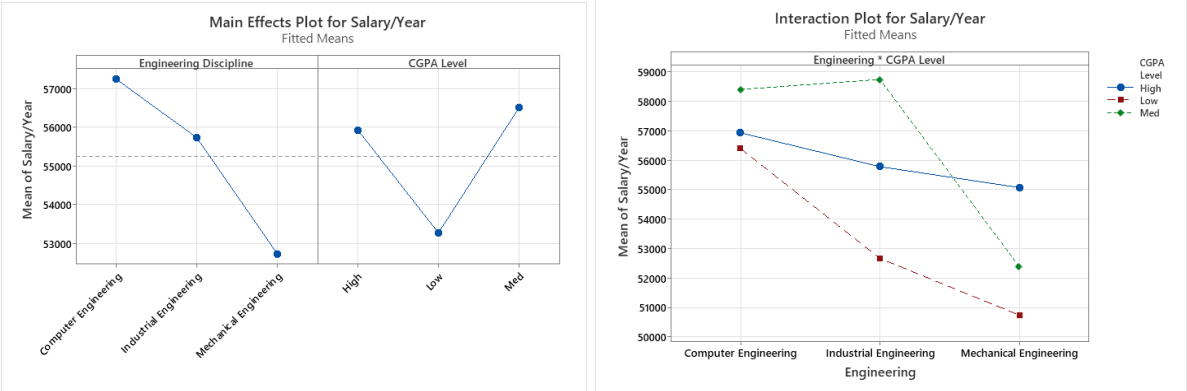


Figure E.1: *Plots for QC #1*

Number of Students Who Returned Quality Characteristic #2

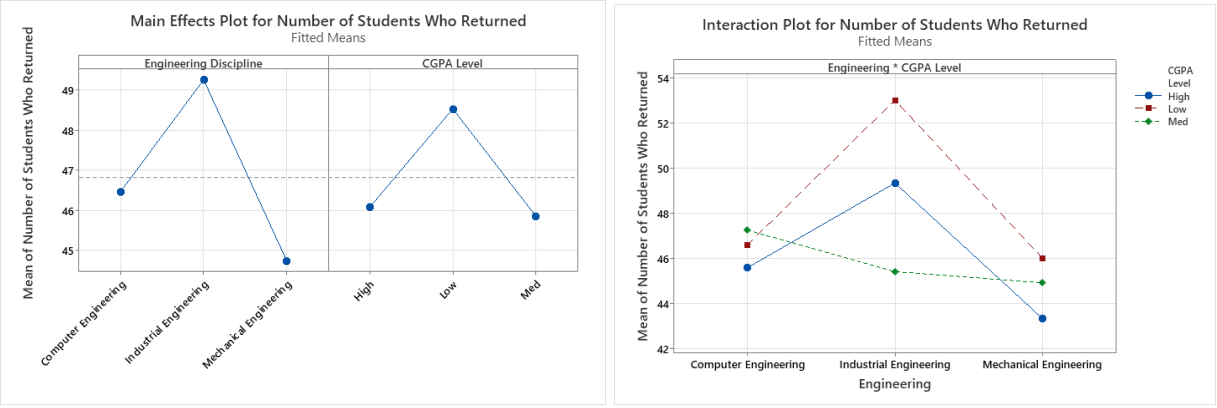


Figure E.2: *Plots for QC #2*

Appendix F: DOE Schematic and Filtered Treatment Data

Doe Schematics

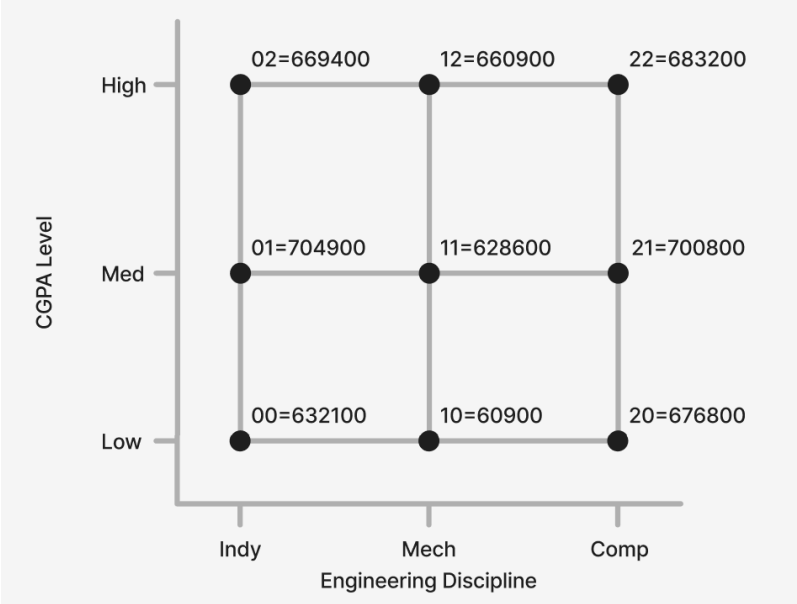


Figure F.1: *Design Schematic for QC #1 Salary/Year*

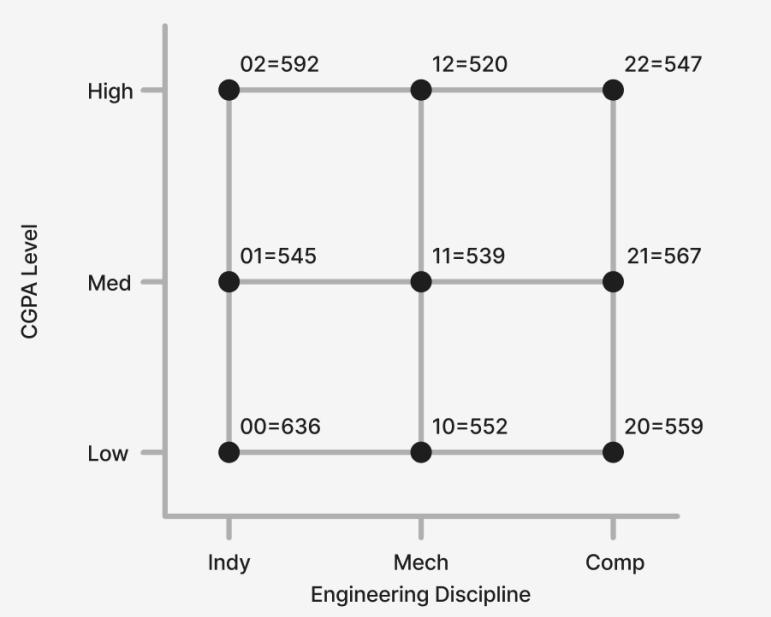


Figure F.2: *Design Schematic for QC #2 Number of Students Who Returned*

Factor Level Coding Chart

CGPA Level	**Coded Factors**
Low	0
Med	1
High	2
Engineering Discipline	**Coded Factors**
Indy	0
Mech	1
Comp	2

Table F.1: **Factor Level Coding**

DOE Data Setup

Factors			**Salary/Year - Replications**											
Engineering Discipline	**CGPA Level**	**Treatment Combinations**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Totals**
0	0	00	46900	44200	41200	55200	59400	52500	54000	60900	52700	50100	58400	56600	632100

1	0	10	46100	48400	50000	50300	48100	51500	54300	48000	52900	56700	50900	51800	609000
2	0	20	56600	50600	55200	47500	59200	50000	58200	59200	57700	59500	64400	58700	676800
0	1	01	63600	56200	60700	63100	62400	50600	62200	59000	56800	56600	57900	55800	704900
1	1	11	60400	56100	45600	45500	47100	51800	49100	49800	56900	58300	55400	52600	628600
2	1	21	67300	56900	53100	53600	64500	47900	64300	64200	60800	56700	53700	57800	700800
0	2	02	49400	53700	55100	56500	53100	49900	53400	55300	62000	64200	54700	62100	669400
1	2	12	52200	54800	54800	56500	52600	51000	64400	52400	57100	53400	54800	56900	660900
2	2	22	54500	64300	64400	62200	56300	48900	62200	48400	60600	59300	55600	46500	683200
		Totals	497000	485200	480100	490400	502700	454100	522100	497200	517500	514800	505800	498800	5965700

Table F.2: *DOE Data Setup for QC #1 Salary/Year*

Factors			**Number of Students Who Returned - Replications**												
Engineering Discipline	**CGPA Level**	**Treatment Combinations**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Totals**
0	0	00	65	71	41	44	41	71	46	54	60	51	48	44	636
1	0	10	46	42	46	40	33	52	52	62	48	38	58	35	552
2	0	20	45	59	45	59	45	46	36	38	65	54	35	32	559
0	1	01	55	51	55	62	29	46	30	55	56	32	30	44	545
1	1	11	47	48	58	61	46	51	48	43	52	31	29	25	539
2	1	21	28	55	46	44	55	45	48	52	31	54	49	60	567
0	2	02	51	39	33	44	54	37	50	47	65	49	63	60	592
1	2	12	48	33	55	25	50	45	39	48	47	37	43	50	520
2	2	22	59	47	35	33	31	45	53	46	52	43	53	50	547
		Totals	444	445	414	412	384	438	402	445	476	389	408	400	5057

Table F.3: *DOE Data Setup for QC #2 Number of Students Who Returned*

Appendix G: Calculations

Main Effect Calculations Salary/Year QC #1

$Grand\ Mean = \bar{y}_{..} = \frac{Total\ Sum}{Total\ Count} = \frac{5965700}{108} = 55237.96$

Industrial Engineering Mean = $\frac{Total\ Sum}{Total\ Count} = \frac{632100+704900+669400}{36} = 55733.33$

Mechanical Engineering Mean = $\frac{Total\ Sum}{Total\ Count} = \frac{609000+62860+660900}{36} = 52736.11$

Computer Engineering Mean = $\frac{Total\ Sum}{Total\ Count} = \frac{676800+700800+683200}{36} = 57244.44$

CGPA Low Mean = $\frac{Total\ Sum}{Total\ Count} = \frac{632100+609000+676800}{36} = 53275$

CGPA Med Mean = $\frac{Total\ Sum}{Total\ Count} = \frac{704900+628600+700800}{36} = 56508.33$

CGPA High Mean = $\frac{Total\ Sum}{Total\ Count} = \frac{669400+660900+683200}{36} = 55930.55$

Main Effect Industrial Engineering = Industrial Engineering Mean - Grand Mean = 55733.33 - 55237.96 = 495.37

Main Effect Mechanical Engineering = Mechanical Engineering Mean - Grand Mean = 52736.11 - 55237.96 = -2501.85

Main Effect Computer Engineering = Computer Engineering Mean - Grand Mean = 57244.44 - 55237.96 = 2006.48

Main Effect CGPA Low = CGPA Low Mean - Grand Mean = 53275 - 55237.96 = -1962.96

Main Effect CGPA Med = CGPA Med Mean - Grand Mean = 56508.33 - 55237.96 = 1270.37

Main Effect CGPA High = CGPA High Mean - Grand Mean = 55930.55 - 55237.96 = 692.59

Sample ANOVA Calculations for Salary/Year QC #1

Sum of Squares for Total and Error:

$SS_{Total} = \Sigma(Y_i - \overline{y})^2$

$SS_{Total} = 3148954352$

$$SS_{Engineering\ Discipline} = \frac{(Engineering\ Discipline)^2}{3^3\ x\ n}$$

$$SS_{Engineering\ Discipline} = 379102407$$

$$SS_{CGPA\ level} = \frac{(Contrast\ CGPA\ level)^2}{3^k\ x\ n}$$

$$SS_{CGPA\ level} = 214082963$$

$$SS_{Error} = SS_{Total} - (SS_{Engineering\ Discipline} + SS_{CGPA\ level} + SS_{Engineering\ Disciple*CGPA\ level})$$

$$SS_{Error} = 3148954352 - 740190185$$

$$SS_{Error} = 2408764167$$

$$SS_{Interaction} = SS_{Total} - (SS_{Engineering\ Discipline} + SS_{CGPA\ level} + SS_{Error})$$

$$SS_{Interaction} = 3148954352 - (379102407 + 214082963 + 2408764167)$$

$$SS_{Interaction} = 147004815$$

$$Df_{Total} = n - 1$$

$$Df_{Total} = 108 - 1$$

$$Df_{Total} = 107$$

$$Df_{Error} = Df_{Total} - (Df_{Engineering\ Discipline} + Df_{CGPA\ level} + Df_{Engineering\ Disciple*CGPA\ level})$$

$$Df_{Error} = 107 - (2 + 2 + 4)$$

$$Df_{Error} = 99$$

$$Df_{Engineering\ Discipline} = 2$$

$$Df_{CGPA\ Level} = 2$$

$$Df_{Interaction} = (a - 1)(b - 1) = (3 - 1)(3 - 1) = 4$$

$$MS_{Engineering\ Discipline} = \frac{SS_{Engineering\ Discipline}}{Df}$$

$$MS_{Engineering\ Discipline} = \frac{379102407}{2}$$

$$Ms_{Engineering\ Discipline} = 189551204$$

$$MS_{CGPA\ level} = \frac{SS_{CGPA\ level}}{Df}$$

$$MS_{CGPA\ level} = \frac{214082963}{2}$$

$$MS_{CGPA\ level} = 107041481$$

$$MS_{Error} = \frac{SS_{Error}}{Df_{Error}}$$

$$MS_{Error} = \frac{2408764167}{99}$$

$$MS_{Error} = 24330951.18$$

$$MS_{Interaction} = \frac{SS_{Interaction}}{df_{Interaction}} = \frac{147004815}{4} = 36751203.75$$

F-value Calculations:

$$F_{Engineering\ Discipline} = \frac{MS_{Engineering\ Discipline}}{MS_E}$$

$$F_{Engineering\ Discipline} = \frac{189551204}{24330951.18}$$

$$F_{Engineering\ Discipline} = 7.79$$

$$F_{CGPA\ Level} = \frac{MS_{CGPA\ level}}{MS_E}$$

$$F_{CGPA\ Level} = \frac{107041481}{24330951.18}$$

$$F_{CGPA\ Level} = 4.4$$

$$F_{Interaction} = \frac{MS_{Interaction}}{MS_E} = 1.51$$

$$F_{Interaction} = \frac{36751203.75}{24330951.18}$$

$$F_{Interaction} = 1.51$$