INSE 6210: Assignment 1 Solutions
(Winter, 2012-2013)

CHAPTER 1

Things to do (Q5)

Q5. Find a company that has implemented a Six Sigma process. What changes have they made in the organization in order to develop their Six Sigma approach?

Ans: Look at the "Ford's drive to six sigma quality" case study present in Chapter 1 of the textbook. The changes that the organization made in order to develop their Six Sigma approach are:

- Development of operating systems to define standards and processes
- Quality leadership to engage all employees
- Consumer driven six sigma
- Value creation and waste prevention during six sigma deployment
- Strengthen ties with suppliers
- Integration of six sigma tools, methods and mindset for delivering results to fulfill the corporate objective "Quality is Job 1".

Practice exercise from Lecture 1 slides (page 44, Q2, Q3)

Q2. Apply DMAIC to resolve the following quality issues. - Long Check-in times for Flight Companies

Ans: The five phases of DMAIC are described as follows:

DEFINE: The problem can be defined as Long check-in times for flight companies

MEASURE: Measure check-in times over weekdays and weekends, for different periods of the day, for different flight types at the airport.

ANALYZE: Analyze the collected data on check-in times to see which days, time periods or flight types are incurring delays and hence the problematic ones

IMPROVE: Suggest improvements to fix delays observed for analyzed days, time periods or flight types. For example, staff training, automated check-ins, increasing the number of check-in counters.

CONTROL: Perform regular audits to ensure that the suggested improvements are effective in bringing reported delays under control.

Q3. Apply DMAIC to resolve the following quality issues - Long Service times in Restaurants

Answer: The five phases of DMAIC are described as follows:

DEFINE: The problem can be defined as Long service time in restaurants

MEASURE: Measure service times in restaurants. This involves collecting data on various service elements such as seating time, food preparation time, service times, billing times for weekdays and weekends, different periods of the day, for different server types etc.

ANALYZE: Analyze the collected data to see which service element(s) is causing delays, for which days or time periods, which server etc.

IMPROVE: Suggest improvements to reduce delay by improvising the analyzed service elements. For example, server training, automated billing system, better organization of restaurant facilities.

CONTROL: Perform regular audits to ensure that the suggested improvements are effective in bringing service time delays under control.

CHAPTER 2

Review Questions (Q3, Q4)

Q3. Explain the concept of a system. Why is systems thinking important to Six Sigma?

Ans. A system is the set of functions or activities within an organization that work together for the aim of the organization. Systems thinking is critical to the application of Six Sigma and quality, in general, because it supplies organizational linkages that help to align various functions, in order to meet the needs of customers and other stakeholders.

Q4. Briefly summarize the Six Sigma Body of Knowledge.

Ans. Six Sigma encompasses a vast collection of concepts, tools, and techniques that are drawn from many areas of business, statistics, engineering, and practical experience. Many of these subjects are technical; others deal with management and organizational issues. Practitioners need a balanced set of both the “hard” and the “soft” disciplines in order to apply and implement Six Sigma effectively. (See list in the body of the chapter for more details.)

Problems (Q3, Q4, Q5, Q6)

Q3. Over the last year 1054 injections were administered at a clinic. Quality is measured by the proper amount of dosage as well as the correct drug. In two instances, the incorrect amount was given, and in one case, the wrong drug was given. At what sigma level is this process?

Ans.

Defect = 2+1 = 3

Opportunities = 1054

Sigma level = NORMSINV (1- Number of Defects/Number of Opportunities) + SHIFT

Sigma level = NORMSINV (1- 3/1054) + SHIFT

= 2.764 +1.5 = 4.264

Q4. The *Wall Street Journal* reported on February 15, 2000 that about 750,000 airplane components are manufactured, machined, or assembled for Boeing Co. by workers from the Seattle Lighthouse for the Blind. A Boeing spokeswoman noted that the parts have an "exceptionally low" rejection rate of one per thousand. At what sigma level is this process operating?

Ans.

Defects = 750,000 *1/1000= 750

Opportunities = 750,000

Sigma level = NORMSINV (1- 750/750,000) + SHIFT

Sigma level = 3.0902 + 1.5 = 4.5902

Q5. An electronics firm manufactures 500,000 circuit boards per month. A random sample of 5,000 boards is inspected every week for 5 characteristics. During a recent week, 2 defects were found for one characteristic, and one defect, each, was found for the other four characteristics. If these inspections produced defect counts that were representative of the population, what is the overall sigma level for the process? What is the sigma level for the characteristic that showed 2 defects?

Ans.

Case1 :

Number of defects = 2+1+1+1+1 = 6

Case2:

Number of defects = 2

Number of opportunities for both cases= 5000

We know,

Sigma-level = NORMSINV (1- number of defects/number of opportunities) + SHIFT

We can consider SHIFT = 1.5

Therefore

Case1:

Sigma level = NORMSINV (1 – 6/5,000) + 1.5 = 4.534 sigma level.

Case2:

Sigma level = NORMSINV (1 – 2/5,000) + 1.5 = 4.852 sigma level

Q6. As noted in the text, a typical hospital has 225 medication errors per year. Approximately 35 percent of these are a result of the prescription, 30 percent from dispensing, and the remaining from administration. Suppose that a hospital has 9000 annual admissions, and that the average patient receives 5 prescriptions during a hospital stay. Patients stay an average of 5.3 days, and each ordered medication is dispensed daily. The average patient receives 12 medications per day. Compute the average dpmo for each of the three categories of medication errors. To what sigma levels do these values correspond? Use Table 2.4 to find additional information for your analysis.

Ans.

Here, the dpmo is calculated in each category. But this is considered as the average dpmo for each case.

For Prescription:

No of Errors=225x0.35=78.75

No of opportunities=9000x5 = 45000

dpmo= (No of defects x1000000)/no of opportunities

=(78.75x1000000)/45000 = 1750 dpmo

We know

Sigma level = NORMSINV(1- dpmo/1000000) + SHIFT

We can consider SHIFT = 1.5

Sigma-level = NORMSINV (1 – 1750/1000000) + 1.5 = 4.420028 sigma level

For Medication:

No of Errors=225x0.30=67.5

No of opportunities=9000x5.3x12 = 572400

dpmo= (No of defectsx1000000)/no of opportunities

=(67.5x1000000)/572400

= 117.92 dpmo

We know

Sigma level = NORMSINV(1- dpmo/1000000) + SHIFT

We can consider SHIFT = 1.5

Sigma level = NORMSINV (1 – 117.92/1000000) + 1.5 = 3.6777+1.5=5.1777 sigma level

For Administration

No of Errors=225x0.35=78.75

No of opportunities=9000

dpmo= (No of defectsx1000000)/no of opportunities

=(78.75x1000000)/9000

= 8750 dpmo

We know

Sigma level = NORMSINV(1- dpmo/1000000) + SHIFT

Using the above equation the sigma level can be easily calculated on an Excel Sheet

If the SHIFT values is not given, we can consider SHIFT = 1.5

Sigma level = NORMSINV (1 – 8750/1000000) + 1.5 = 3.876031 sigma level

CHAPTER 3

Review Questions (Q12, Q15)

Q12. What factors should be considered when selecting Six Sigma projects?

Ans. Factors that should be considered when selecting Six Sigma projects include the following:

- Impacts on customers and organizational effectiveness
- Probability of success
- Impact on employees
- Fit to strategy and competitive advantage
- Financial return, as measured by costs associated with quality and process performance, and impacts on revenues and market share

Q15. How do quality costs differ between service and manufacturing organizations?

Ans. In manufacturing, quality costs are primarily product-oriented; for services, they are generally labor-dependent, with labor often accounting for up to 75 percent of total costs. Traditional external failure costs such as warranty and field support are less relevant to services than to manufacturing. Process-related costs, such as customer-service and complaint-handling staff and lost customers are more critical. Internal failure costs might not be as evident in services as in manufacturing.

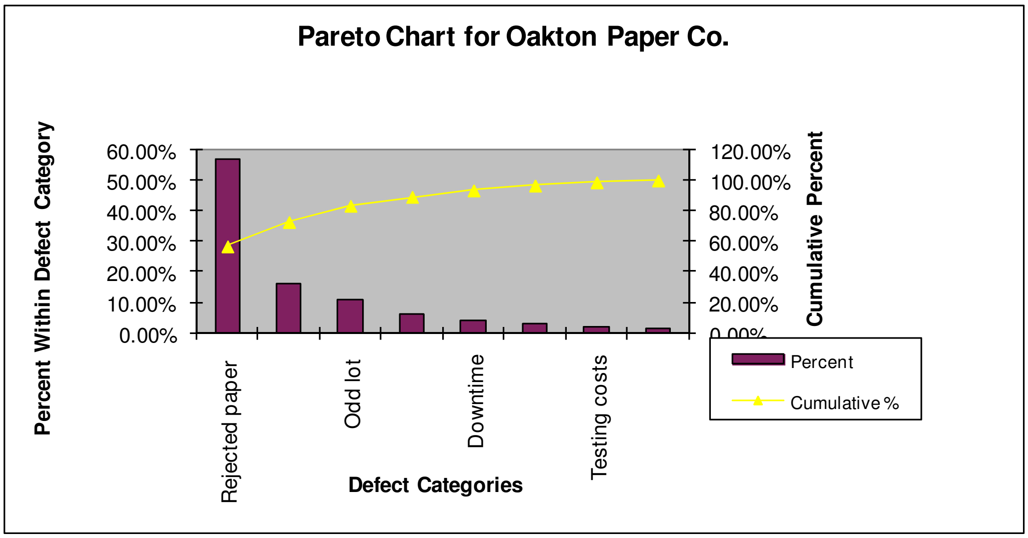
Problems (Q5, Q7)

Q5. Use Pareto analysis to investigate the quality losses at Oakton Paper Mill, using data in the worksheet *Prob.3-5* in the Excel workbook *Ch3Dataset* on the student CD-ROM. What conclusions do you reach?

Ans. See the following table and figure for Pareto analysis for Oakton Paper Company.

	OAKTON PAPER COMPANY		
	QUALITY COSTS AND PERCENTAGES		
	Percent	Cumulative %	Cost
Rejected paper	56.82	56.82	375000
Customer complaints	15.91	72.73	105000
Odd lot	10.61	83.33	70000
High material costs	5.91	89.24	39000
Downtime	4.24	93.48	28000
Excess inspection	3.18	96.67	21000
Testing costs	2.12	98.79	14000
Quality Imprv. Trng.	1.21	100.00	8000
Total Costs			660000

Conclusion: Oakton Paper Co. is experiencing problems in two major categories: rejected paper and customer complaints. These categories, which could be related to each other, account for 72.7 percent of their quality costs. Rejected paper suggests a possible technical problem in the chemistry of the materials or paper machine adjustments. If customers perceive that the paper does not meet their requirements then the causes need to be determined, as well. Thus, it may be recommended that two improvement teams be formed, but that they coordinate closely to work on these areas. After these problems have been eliminated, then work could begin on addressing the next two defect areas.



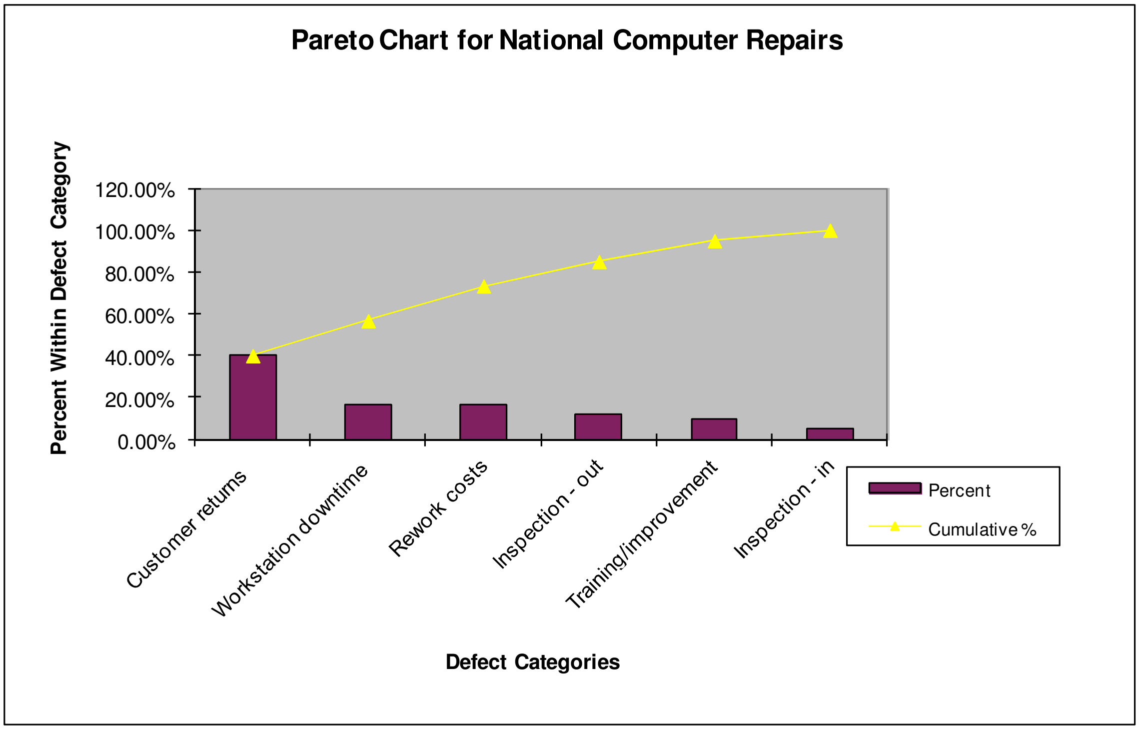
Q7. National Computer Repairs, Inc. has a thriving business repairing and upgrading computers. The data in the worksheet *Prob.3-7* in the Excel workbook *Ch3Dataset* on the student CD-ROM represent costs of quality that they have collected over the past year. Use Pareto analysis to investigate their quality losses and to suggest which areas they should address first in an effort to improve their quality.

Ans. Spreadsheet data and the Pareto chart (see C3Pr07.xls for details) for National Computer Repairs, Inc. are shown.

NATIONAL COMPUTER REPAIRS, INC.

QUALITY COSTS AND PERCENTAGES

	Percent	Cumulative %	Cost
Customer returns	40.00	40.00	$120,000
Workstation downtime	16.67	56.67	50,000
Rework costs	16.67	73.33	50,000
Inspection - out	11.67	85.00	35,000
Training/improvement	10.00	95.00	30,000
Inspection - in	5.00	100.00	15,000
Total Costs			300000



The data show that two categories of customer returns and workstation downtime total 56.7 percent of the defects. These two are possibly related, and may indicate "short staffing," and lack of training of setup personnel. Only 10% of total quality cost is allocated to prevention (training/improvement). Steps should be taken to analyze root causes for these problem areas in order to correct them as quickly as possible.

Practice exercise from Lecture 2 slides (page 29,39)

Practice Question (Lecture 2 slides, Page 29): Apply simple scoring model to improve quality of service at a fast food restaurant. List Customer issues, List projects.

Ans:

PROJECT SELECTION MATRIX

Customer Issues	Fast Service	High Quality Food	Low Price
Customer Importance	6	10	8

Project ranking based on correlation to customer issues

Project				**Ranking metric**
Train Staff	8	9	4	170 (=6*8+10*9+8*4)
Standardize Menu	6	9	6	174 (=6*6+10*9+8*6)
IT Upgrade	8	3	4	110 (=6*8+10*3+8*4)
Change layout	8	5	3	122 (=6*8+10*5+8*3)
Hire staff	9	7	5	164 (=6*9+10*7+8*5)

The project “Standardize Menu” (Highest score) is finally chosen.

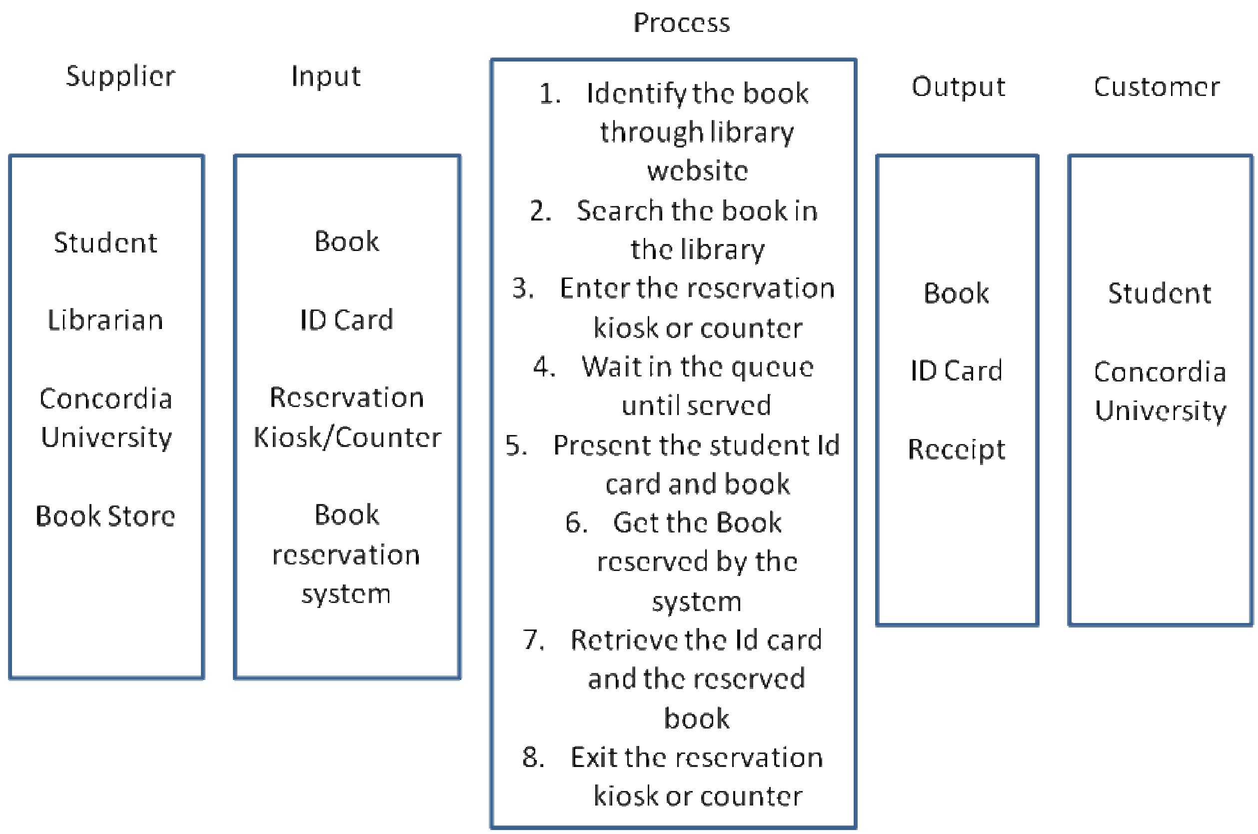
Customer importance	Relationship to customer importance
0	Not important
3	Slightly important
5	Important
8	Very important
10	Critical

Project rank	Relationship to customer issue
0	No correlation
3	Very little correlation
5	Some correlation
8	High correlation
10	Complete correlation

Source: William Michael Kelly, “Three Steps to Project Selection,” *Six Sigma Forum Magazine* 2, no. 1 (November 2002), 29–32. © 2002. American Society for Quality. Reprinted with permission.

Practice Question (Lecture 2 slides, page 39): Develop a SIPOC diagram to analyze and improve quality of book borrowing services at Concordia Library.

Ans:



CHAPTER 4

Review Questions (Q7, Q11, Q14)

Q7. Describe the different methods of sample selection and provide an example in which each would be most appropriate.

Ans. Methods of sample selection, include: simple random sampling, stratified sampling, systematic sampling, cluster sampling and judgment sampling. Simple random sampling is useful where one needs to gather information from a moderately large, homogeneous population of items. For example, if a MBA director wished to find out the attitudes of 300 MBA students toward various policies, procedures, and services provided to the students, s(he) might use a simple random sample to determine whom the survey should be sent to. An automobile insurance company could use a stratified sample to determine accident rates of customers, stratified according to their ages. An auditor might use a systematic sampling to sample accounts receivable records by choosing every 50th record out of a file cabinet. Cluster sampling could be used by management analysts within city government to determine satisfaction levels of residents on a neighborhood by neighborhood (cluster) basis. Judgment sampling should be avoided, except as a way to gather preliminary, impressionistic data before beginning a true sampling study.

Q11. What is the difference between accuracy, precision, and reproducibility?
Ans. *Accuracy* is defined as the closeness of agreement between an observed value and an accepted reference value or standard. Accuracy is measured as the amount of error in a measurement in proportion to the total size of the measurement. One measurement is more accurate than another if it has a smaller relative error.

Precision is defined as the closeness of agreement between randomly selected individual measurements or results. Precision, therefore, relates to the variance of repeated measurements. A measuring instrument having a low variance is said to be more precise than another having a higher variance.

Reproducibility is the variation in the same measuring instrument when it is used by different individuals to measure the same parts. Causes of poor reproducibility include poor training of the operators in the use of the instrument or unclear calibrations on the gauge dial.

Q14. Define the process capability indexes, C_p, C_{pl}, and C_{pu}, and explain how they may be used to establish or improve quality policies in operating areas or with suppliers.

Ans. The following are brief definitions of the various process capability indexes:

C_p is the ratio of the specification width to the natural tolerance of the process

C_{pl} is the lower one-sided index that relates the distance from the process mean to the lower tolerance limit to its 3 σ natural spread

C_{pu} is the upper one-sided index that relates the distance from the process mean to the upper tolerance limit to its 3 σ natural spread

These indexes are calculated to determine the ability of a process to meet or exceed design specifications and are only meaningful when a process is known to be under control. General a process is considered to be capable if its index is 1.0 or above. These indexes may be used to establish quality policy in operating areas or with a supplier by stating an acceptable standard, such as: all capability indexes must be at 2.0 (called 6 σ quality) or above if the process is to be considered acceptable for elimination of inspection processes by customers.

Problems (Q3, Q4, Q9)

Q3. You are asked by a motel owner to develop a customer satisfaction survey to determine the percentage of customers who are dissatisfied with service. The motel serviced 20,000 customers in the past year. The manager desires a 95 percent level of confidence with an allowable statistical error of ± 0.02. From past estimates, the manager believes that about 7 percent of customers have expressed dissatisfaction. What sample size should you use for this survey?

Ans. The size of the population is irrelevant to this customer satisfaction survey, although it is good to know that it is sizable. Therefore, make the following calculations:

$$n = (z_{\alpha/2})^2 p(1-p) / E^2 = (1.96)^2 (0.07)(0.93) / (0.02)^2 = 625.22, \text{ use } 626$$

Q4. A utility requires service operators to answer telephone calls from customers in an average time of 0.1 minute or less, and either respond to them or refer the customer to the proper department within 0.5 minute. The manager is interested in estimating the actual overall time for both components, in total. A pilot study sample of 30 actual operator times was drawn, and the results are given in the following table. If the service manager wants to be 95 percent confident that the overall time is correctly estimated, with a 3 percent probability of error, what size sample should be taken?

Component	Mean Time	Standard Deviation
Answer	0.1023	0.0183
Service	0.5290	0.0902

Ans. Using the formula: $n = (z_{\alpha/2})^2 \sigma^2 / E^2$, the manager can solve for the sample size, n, as follows:

The variance for both measures, together, can be found by using the following relationship for combining variances:

$$\sigma_{total}^2 = \sigma_1^2 + \sigma_2^2 = (0.0183)^2 + (0.0902)^2 = 0.00847$$

So:

$$n = (1.96)^2 (0.00847) / (0.03)^2 = 36.16 \text{ or } 37$$

From the Standard Normal Distribution table, Appendix A, we found a probability of 0.475 and located z = 1.96 to use for $z_{\alpha/2}$ in the formula. Thus, the utility manager can be 95% confident of the results based on this sample size. 7 more observations would be required, above the 30 samples already gathered.

Q9. Suppose that a process with a normally distributed output has a mean of 55.0 and a variance of 4.0.

a. If the specifications are 55.0 ± 4.00, compute C_p, C_{pk}, and C_{pm}.

b. Suppose the mean shifts to 53.0 but the variance remains unchanged. Recompute and interpret these process capability indexes.

c. If the variance can be reduced to 40 percent of its original value, how do the process capability indices change (using the original mean of 55.0)?

Ans. (a) For $\bar{x} = 55.0$; $\sigma = 2.0$

$$C_p = \frac{UTL - LTL}{6\sigma} = \frac{59.0 - 51.0}{6(2.0)} = 0.667$$

$$C_m = C_p / \sqrt{1 + (\text{mean} - \text{target})^2 / \sigma^2} = 0.667 / \sqrt{1 + (55.0 - 55.0)^2 / 2^2} = 0.667$$

$$C_{pu} = \frac{UTL - \bar{x}}{3\sigma} = \frac{59.0 - 55.0}{3(2.0)} = 0.667$$

$$C_{pl} = \frac{\bar{x} - LTL}{3\sigma} = \frac{55.0 - 51.0}{3(2.0)} = 0.667$$

Conclusion: The process is centered on the mean, but it does not have adequate capability at this time.

(b) $\bar{x} = 53$; $\sigma = 2.0$

$$C_p = \frac{UTL - LTL}{6\sigma} = \frac{59.0 - 51.0}{6(2.0)} = 0.667$$

This result has not changed.

$$C_m = C_p / \sqrt{1 + (\text{mean} - \text{target})^2 / \sigma^2} = 0.667 / \sqrt{1 + (53.0 - 55.0)^2 / 2^2} = 0.471$$

Because of the shift away from the target, capability is lower.

$$C_{pu} = \frac{UTL - \bar{x}}{3\sigma} = \frac{59.0 - 53.0}{3(2.0)} = 1.0$$

$$C_{pl} = \frac{\bar{x} - LTL}{3\sigma} = \frac{53.0 - 51.0}{3(2.0)} = 0.333$$

Conclusion: The process <u>still</u> does not have adequate capability at this time.

(c) $\sigma^2_{new} = 0.4\ (4) = 1.6 \quad \therefore \sigma_{new} = 1.265$

$$C_p = \frac{59.0 - 51.0}{6\ (1.265)} = 1.054$$

$$C_m = C_p / \sqrt{1 + (\text{mean} - \text{target})^2 / \sigma^2} = 1.054 / \sqrt{1 + (55.0 - 55.0)^2 / 1.265^2} = 1.054$$

If there is no shift away from the target, capability is equal to C_p.

$$C_{pu} = \frac{59.0 - 55.0}{3\ (1.265)} = 1.054$$

$$C_{pl} = \frac{55.0 - 51.0}{3\ (1.265)} = 1.054;$$ Reducing the variance brings the C_p and C_{pu} to the point of minimal adequacy, provided the process can remain centered.

Practice exercise from Lecture 3 slides (page 27)

Question: A gauge repeatability and reproducibility study at Jeena Parts collected the following data. What should be done? The specification for the parts is 10±1 mm.

	Operator 1			Operator 2			Operator 3		
Part	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
A	9	10	9	9	9	9	10	10	9
B	10	9	9	9	9	10	9	9	10
C	10	9	9	9	9	9	10	10	10
D	10	10	10	10	9	9	9	9	9
E	10	10	9	10	9	10	9	10	10

$\bar{x}_1 =$

$\bar{x}_2 =$

$\bar{x}_3 =$

$D_4 =$

$\bar{\bar{R}} =$

Control Limit = $D_4\bar{\bar{R}}$

$EV = K_1\bar{\bar{R}}$

$AV = \sqrt{(K_2\bar{x}_D)^2 - (EV^2 / nr)}$

$R \,\&\, R = \sqrt{(EV)^2 + (AV)^2}$

Number of Trials	2	3	4	5
K1	4.56	3.05	2.5	2.21

Number of Operators	2	3	4	5
K2	3.65	2.7	2.3	2.08

Ans: *m* (operators)=3, *n* (parts) = 5, *r* (trials) =3, K_1=3.05, K_2= 2.7,
D_4(number of trials = 3)=2.574

$\bar{x}_1 = 9.5333$

$\bar{x}_2 = 9.2667$

$\bar{x}_3 = 9.5333$

$\bar{x}_D = 9.5333 - 9.2667 = 0.2666$

$\bar{\bar{R}} = (\bar{R}_1 + \bar{R}_2 + \bar{R}_3)/3 = (0.8 + 0.6 + 0.6)/3 = 0.6667$

Control Limit $= D_4\bar{\bar{R}}$ =2.574*0.6667= 1.716

EV $= K_1\bar{\bar{R}}$ =3.05*0.6667=2.0334

AV= $= \sqrt{(K_2\bar{x}_D)^2 - (EV^2/nr)} = \sqrt{(2.7 * 0.2666)^2 - (2.0334 * 2.0334/5*3)}$
$= \sqrt{0.51814 - 0.27565} = \sqrt{0.24248} = 0.4924$

R&R=$\sqrt{AV^2 + EV^2} = \sqrt{2.0334^2 + 0.4924^2} = \sqrt{4.13471 + 0.24245} = 2.092$

Tolerance = USL-LSL = 11-9 = 2

EV% = 100*2.0334/2= 101.67%> 30%, hence, this rate is not acceptable
AV% = 100*0.4924/2=24.62%, which lies between 10-30%, hence, this rate may be acceptable.
R&R% =100*2.092/2= 104.6 % > 30%, hence, this rate is not acceptable

Based on the above results, Jeena Parts should investigate the reasons for high Equipment variation and work towards improving it.

CHAPTER 5

Chapter 5: Review Questions (Q2, Q10, Q13, Q16),

Q2. Discuss the differences between the three major components of statistical methodology (descriptive statistics, statistical inference, and predictive statistics). Why might this distinction be important to a manager?

Ans. The methods for the efficient collection, organization, and description of data are called *descriptive statistics*. *Statistical inference* is the process of drawing conclusions about unknown characteristics of a population from which the data were taken. *Predictive statistics* is used to develop predictions of future values based on historical data. The three differ in approach, purpose, and outcomes. Descriptive statistics simply summarize and report on existing conditions, inference helps to make decisions about population characteristics based on sample data. Predictive statistics attempt to look into the future and state what will be the results, if certain assumptions hold. All three of these can be important to a manager who is trying to describe the current characteristics of a process, or make inferences about whether a process is in control, or predict future values of instrument readings in order to determine whether it is properly calibrated.

Q10. Explain the differences between correlation and regression. How are they related?

Ans. **Regression analysis** is a tool for building statistical models that characterize relationships between a dependent variable and one or more independent variables, all of which are numerical. The relationship may be linear, one of many types of nonlinear forms, or there may be no relationship at all. To develop a regression model, you first must specify the type of function that best describes the data. This step is important, because using a linear model for data that are clearly nonlinear, for instance, would probably lead to poor business decisions and results.

Correlation is a measure of a linear relationship between two variables, *X* and *Y,* and is measured by the (population) correlation coefficient. Correlation coefficients will range from –1 to +1. A correlation of 0 indicates that the two variables have no linear relationship to each other. Thus, if one changes, we cannot reasonably predict what the other variable might do using a linear equation (we might, however, have a well-defined nonlinear relationship). A correlation coefficient of +1 indicates a perfect positive linear relationship; as one variable increases, the other will also increase. A correlation coefficient of –1 also shows a perfect linear relationship, except that as one variable increases, the other decreases. The square of the correlation coefficient is the regression coefficient, which indicates the percentage of variation in the dependent variable that is explained by the independent variable(s).

Q13. Contrast the differences between an ordinary process map and a value stream map.

Ans. A special type of process map is a **value stream map**. The value stream refers to all activities involved in designing, producing, and delivering goods and services to customers. These include the flow of materials throughout the supply chain, transformation activities in the manufacturing or service delivery process, and the flow of information needed to support these activities. A value stream map shows the process flows in a manner similar to an ordinary process map; however, the difference lies in that value stream maps highlight value-added versus non-value-added activities, and include times that activities take. This allows one to measure the impact of value-added and non-value-added activities on the total lead time of the process, and compare this to the **takt time** – which is the ratio of the available work time to the required production volume necessary to meet customer demand.

Q16. Explain the difference between common and special causes of variation.

Ans. Common causes of variation occur as a natural part of the process and are difficult to change without making a major change in the system of which they are a part. Special causes of variation arise from sources outside the system and can generally be traced back to a specific change that has occurred and needs correction. For example, a process may be stable and running well until the supplier of a critical material is changed. The new vendor's material causes the process to go out of control (becomes unstable), so the "solution" to the special cause is to have the vendor correct the deficiency, or return to the previous supplier for materials.

Probles (Q2, Q5, Q8, Q10)

Q2. Outback Beer bottles have been found to have a standard deviation of 5 ml. If 5 percent of the bottles contain less than 535 ml, what is the average filling volume of the bottles?

Ans. Given that the standard deviation for OutBack Beer, as $\sigma = 5$ ml.

$$z = -1.64 = \frac{535 - \mu}{5} ; \therefore \mu = 543.2 \text{ ml.}$$

(Results are based on the Standard Normal Distribution Table, Appendix A)

Q5. A utility requires service operators to answer telephone calls from customers in an average time of 0.1 minute or less. A sample of 30 actual operator times was drawn, and the results are given in the following table. In addition, operators are expected to determine customer needs and either respond to them or refer the customer to the proper department within 0.5 minute. Another sample of 30 times was taken for this job component and is also given in the table. If these variables can be considered to be independent, is the average time taken to perform each component statistically different from the standard?

Component	Mean Time	Standard Deviation
Answer	0.1023	0.0183
Service	0.5290	0.0902

Ans. Specification for answer time for the utility is :

H_0: Mean response time: $\mu_1 \leq 0.10$

H_1: Mean response time: $\mu_1 > 0.10$

$\bar{x}_1 = 0.1023$, $s_1 = 0.0183$

and the t-test is:

$$t_1 = \frac{\bar{x} - 0.10}{s/\sqrt{n}} = \frac{0.1023 - 0.10}{0.0183/\sqrt{30}} = \frac{0.0023}{0.0033} = 0.697, \quad t_{29,\ .05} = 1.699$$

Specification for service time is:

H_0: Mean service time: $\mu_2 \leq 0.50$

H_1: Mean service time: $\mu_2 > 0.50$

$\bar{x}_2 = 0.5290$, $s_2 = 0.0902$

and the t-test is:

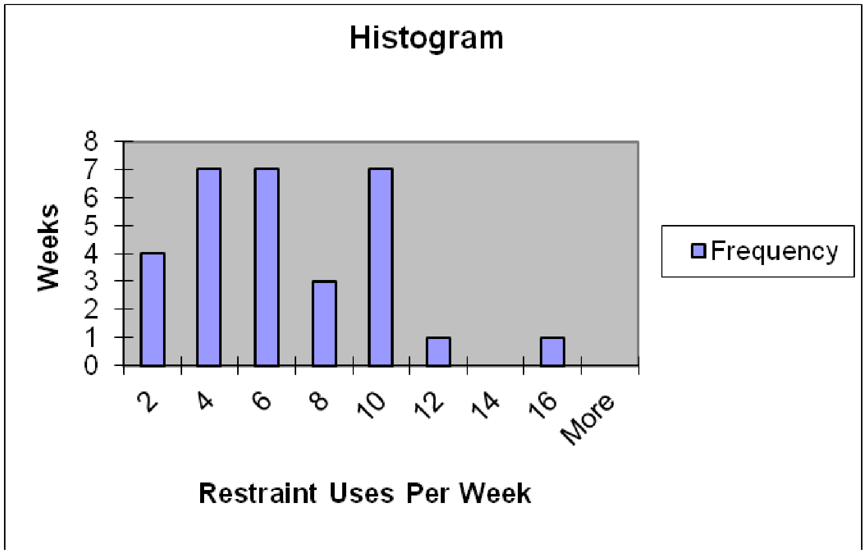
$$t_2 = \frac{\bar{x} - 0.50}{s/\sqrt{n}} = \frac{0.529 - 0.50}{0.0902/\sqrt{30}} = \frac{0.029}{0.0165} = 1.761, \quad t_{29,\ .05} = 1.699$$

Because $t_{29,\ .05} = 1.699$, we cannot reject the null hypothesis for t_1, but we can reject the hypothesis for t_2 . Therefore, there is no statistical evidence that the mean response time exceeds 0.10 for the answer component, but the statistical evidence does support the service component.

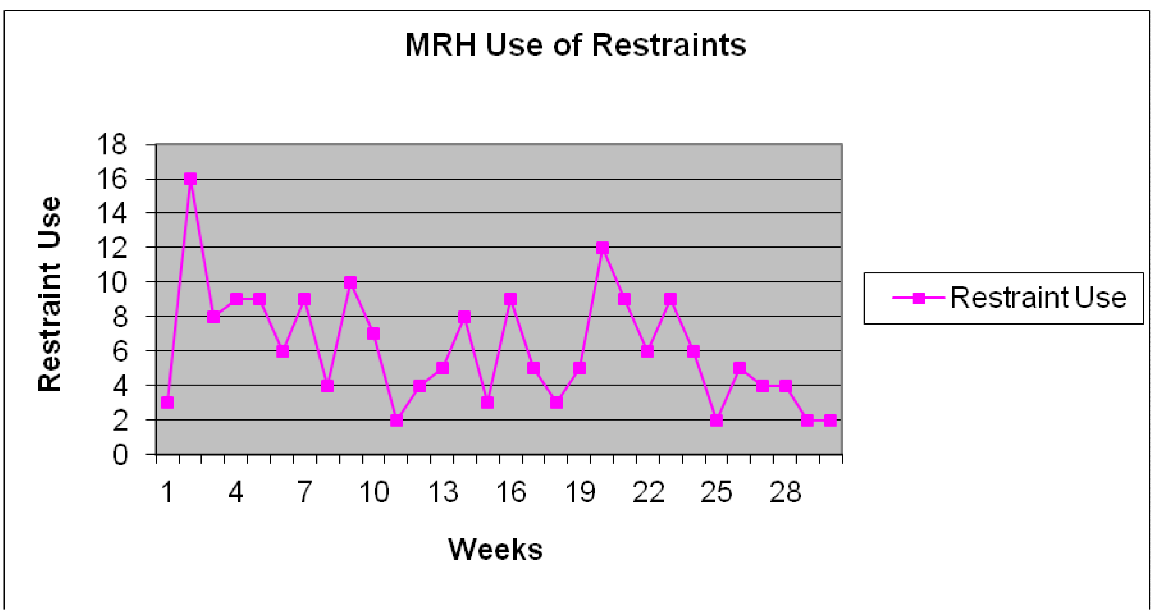
Q8. Apply the descriptive statistics tools and construct a scatter diagram using the hypothetical data for the use of patient restraints in the Psychiatric Nursing Unit at Middletown Hospital (see Middletown Regional Hospital case in Chapter 4 for background) shown in the *Ch5Dataset* file for *Prob. 5-8* on the student CD-ROM. What can you conclude ?
Ans.

Descriptive Statistics	
Mean	6.2000
Standard Error	0.6110
Median	5.5000
Mode	9.0000
Standard Deviation	3.3466
Sample Variance	11.2000
Kurtosis	0.9287
Skewness	0.8781
Range	14.0000
Minimum	2.0000
Maximum	16.0000
Sum	186.0000
Count	30.0000
Confidence Level(95.0%)	1.2497

The Frequency histogram forms no recognizable pattern for the values of restraint use versus weeks:



However, the scatter diagram (line chart) reveals that the use of restraints shows a steady decline since about week 20. This indicates that use is being monitored, and efforts are being made to reduce their use. See spreadsheet C5Pr08.xls for details



Q10. A process engineer at Sival Electronics was trying to determine whether three suppliers would be equally capable of supplying the mounting boards for the new "gold plated" components that she was testing. The *Ch5Dataset* file for *Prob. 5-10* on the student CD-

ROM shows the coded defect levels for the suppliers, according to the finishes that were tested. Lower defect levels are preferable to larger levels. Using one-way ANOVA, analyze these results. What conclusion can be reached, based on these data?

Ans.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Supplier 1	5	54.6	10.92	4.762		
Supplier 2	5	35.6	7.12	0.697		
Supplier 3	5	64.1	12.82	1.812		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	84.233	2	42.117	17.377	0.00029	3.885
Within Groups	29.084	12	2.424			
Total	113.317	14				

According to the F-test and probability of $< .05$, there is a significant difference between suppliers

Practice questions from Lecture 4 slide (page 24, 32, 35)

Question (page 24): The diameters of aluminium alloy rods produced on an extrusion machine are known to have a standard deviation of 0.0001 inches. A random sample of 25 rods has an average diameter of 0.5046 inches. Construct a 95% two-sided confidence interval on the mean rod diameter.
Ans:$\sigma = 0.0001$, $n = 25$, $\bar{x} = 0.5046$

Using the formula for calculating confidence interval under the condition mean known, standard deviation unknown, for a given sample size n, we get

Confidence Interval
$= \bar{x} \pm z_{\alpha/2}(\sigma/\sqrt{n}) = 0.5046 \pm z_{0.025}*(0.0001/\sqrt{25}) = 0.5046 \pm 1.96*(0.0001/5) = 0.5046 \pm 0.0004$ or [0.5042,0.5050]

Question (page 32): The diameters of aluminium alloy rods produced on an extrusion machine are known to have a standard deviation of 0.0001 inches. A random sample of 25 rods has an average diameter of 0.5046 inches. Test the hypothesis that the mean rod diameter is 0.5025 inches. Assume a two-sided alternative and use $\alpha = 0.05$. Construct a 95% two-sided confidence interval on the mean rod diameter.
Ans: The hypothesis is two-sided (variance known).

H_0: μ=0.5025
H_1:μ≠0.5025

$$z_{\alpha/2} = z_{0.025} = 1.96$$
$$z_0 = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{0.5046 - 0.5025}{0.0001 / \sqrt{25}} = \frac{0.0021}{0.0001 / 5} = 21 * 5 = 105$$

Since, $z_0 > z_{\alpha/2}$, the null hypothesis is rejected and we can conclude that the mean rod diameter is not 0.5025 inches.

Question (page 35): A machine is used to fill containers with a liquid product. Fill volume can be assumed to be normally distributed. A random sample of 10 containers is selected, and the net contents (oz) are as follows:

12.03, 12.01, 12.04, 12.02, 12.05, 11.98, 11.96, 12.02, 12.05, 11.99

Suppose that the manufacturer wants to be sure that the mean content exceeds 12 oz. What conclusions can be drawn from the data. Use α = 0.01

Ans: The hypothesis is one-sided (variance unknown).
H_0: μ>12
H_1:μ<= 12

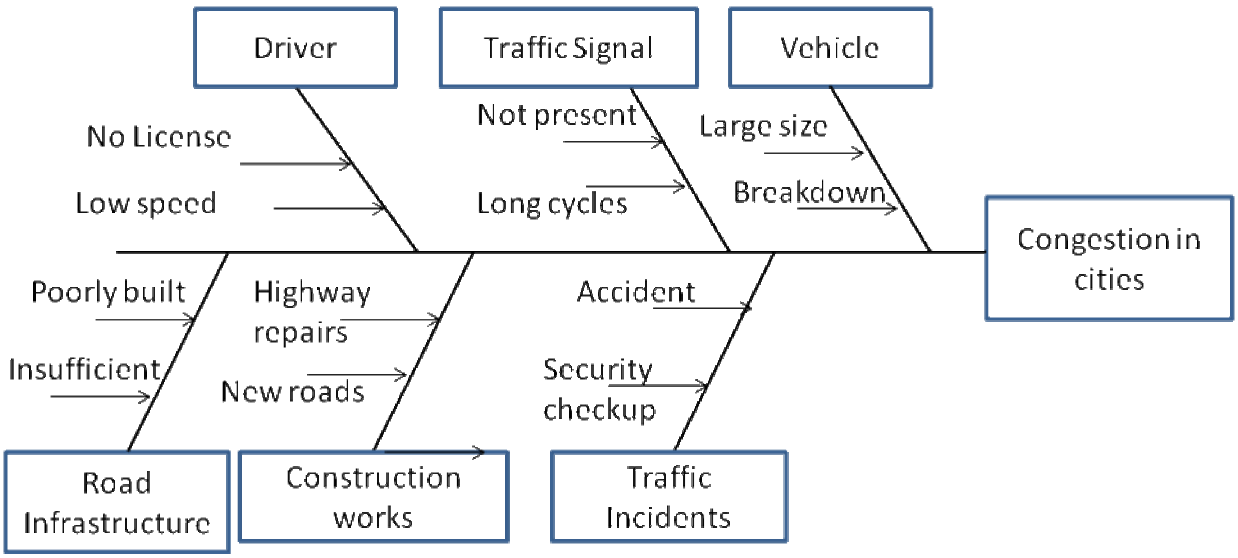
The sample mean and standard deviation using the 10 container data is:
$\bar{x}$ = 12.015, s=0.030277

$$t_{\alpha/2,n-1} = z_{0.005,9} = 3.25$$
$$t_{\alpha,n-1} = t_{0.01,9} = 2.821$$
$$t_0 = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{12.015 - 12}{0.030277 / \sqrt{10}} = 1.5655$$

Since, $t_0 < t_{\alpha,n-1}$, the null hypothesis is not rejected and is accepted, therefore, we can conclude that the mean content exceeds 12 oz.

Practice questions from Lecture 5 slide (page 24, Q2, Q3)

Question: Develop a cause effect diagram for congestion in cities.
Ans:



Question: Develop a cause effect diagram for low productivity in manufacturing industries.
Ans: