Minitab®

SPC

LESSON: *c* charts

Instructions: Solve the following problems and show your work. Make sure the requested Minitab graphics and work are with the problem they go with. The data for this set is in the file: **Hmwk7DATA_AttributeCharts.Hmwk8DATA_WhichChart.**

Open your bag of M&M's and (1) count the total # of M&M's and (2) count the # of those M&M's that are "defective." Before you start counting, we need to create an ***operational definition*** for defective; e.g., M off-center, bad coloring, not a "nice" oval shape, can't clearly read the M, not the whole shape, … others?

Lesson 20: Constructing c charts

- ***c* charts-**
  - **Number of defects per unit**, where "unit" is an object, item, region, such as "per day" or "per square foot"
  - A defect is a quality characteristic that does not meet some specification, such as:
    - Paint blemishes per car, Snags per square foot of carpeting, Bruises on an apple
  - These charts are based on **Poisson distribution**

Assumptions with *c* charts

- Poisson distribution assumptions
  - Area of opportunity is large enough to experience a defect
  - Average number of defects per unit area is small
  - Occurrence of defects are independent of each other
  - Each area of opportunity has an equally likely chance of having the same number of defects

Construction of the *c* chart:

Let the random variable X represent the **number of defects** on an **item** (e.g., number of bruises on an apple), and let the **mean number of defects** on such an item be ***c***, which we had been calling λ.

The **Poisson distribution** yields the **probability of x defects** per item as:

$$p(x) = P(X = x) = \frac{e^{-c}c^{x}}{x!} \text{ for } x = 0, 1, 2, 3, \ldots \quad \textbf{Mean} = c, \textbf{Variance} = c$$

For example, suppose there are, on average, 2 bruises per apple received from a supplier. Then the probability of a randomly selected apple with 5 bruises is:

$$p(5) = P(X = 5) = \frac{e^{-2}2^{5}}{5!} \cong 0.036.$$

Fill in the following blanks:

1. Let the random variable X represent the **number of defects on an item** and let the **mean number of defects on such an item be 4**. Thus, X is a Poisson random variable with parameter c = 4. Determine the following.

E(X) = **Mean(*X*)** = _____, **Variance(*X*)** = _____, **StdDev(*X*)** = _____.

2. What is the probability that there will be ***at most*** 3 (meaning 0, 1, 2, or 3) defects on an item with mean c = 4? You can use Minitab or your calculator to determine this. Remember that Poisson is a **discrete random variable** (i.e. determine probabilities with sums and not integrals). Report your answer correct to 4 decimal places.

In Minitab desktop (20 or higher):

1. Choose **Graph** > **Probability Distribution Plot** > **View Probability**.
2. In **Distribution,** choose **Poisson**. In **Mean**, enter 4.
3. Choose **Shaded Area.** Select **X Value** and **Left Tail**. In **X Value**, enter **3.**
4. Click **OK** in each dialog box.

In Minitab web app:

1. Choose **Graph > Probability Distribution Plot > View Probability**.
2. In **Distribution**, choose **Poisson**. In **Mean**, enter 4.
3. Click **Options**. Select **A specified x value** and select **Left Tail**. In **X value**, enter 3.
4. Click **OK** in each dialog box.

Constructing c-charts

- Assume there are k **inspection units** (e.g. 100 apples) and c_i **is the number of defects on the** i^{th} **sample.**
  - c_3 = 1 means the number of defects (bruises) on the 3rd apple in the lot is 1,
  - c_{51} = 2 means the number of defects on the 51st apple in the lot is 2.
- The **mean number of defects per the entire lot of inspection units** is found by averaging the number of defects per unit, where c_i is the number of defects on item i. Thus, the mean number of defects on all units in the lot, where k is the number of lots, is determined as:

$$\bar{c} = \sum_{i=1}^{k} \frac{c_i}{k}$$

- The control chart limits for the c chart are then:

Control Limits for c chart; Construction of Limits from Past Data

$$CLc = \bar{c} \qquad UCLc = \bar{c} + 3\sqrt{(\bar{c})} \qquad LCLc = \max(0, \bar{c} - 3\sqrt{(\bar{c})})$$

3. A basic *c* chart example: Snags per 1 square foot block of carpeting for k = 10 samples:

2, 3, 3, 2, 1, 0, 4, 2, 1, 0

Determine the **center line, upper control limit**, and **lower control limit** for this *c* chart by-hand or in Minitab. Report decimal values to 3 decimal places.

CLc =

UCLc = LCLc =

4. Data for k = 25 samples of fabric from a textile mill, each 100 m^2, are selected and the number of flaws per sample is counted. Data for the 25 samples are in the **worksheet HomeworkSet7_AttributeCharts_DATA.**

(a) Determine the center line and control chart limits for the number of nonconformities per 100 m^2 of the fabric. Report decimal values to 2 decimal places.

CLc =

UCLc = LCLc =

Construct a control chart in Minitab for the number of defects per sample. Make sure your center lines and limits match up with what you computed above.

Stat > Control Charts > Attribute Charts > C

(b) As a comparison, imagine that you thought this data was measurement data and constructed an I-MR chart. What's the only difference between the c chart and I chart?

Solution: The only difference is the values of the control limits (UCL and LCL) for the two different graphs (*c and I*). You will notice that the I chart has tighter control limits and the c chart has wider control limits

For the *c* chart, the standard deviation is computed as $\sqrt{(\bar{c}} = \sqrt{7.56} \cong \mathbf{2.75}$. The I chart has LCL, UCL as: 1.13 and 13.99, respectively. The standard deviation is computed as $\hat{\sigma} = \overline{(MR)} / d_2 \cong 2.42/1.128 \cong \mathbf{2.15}$. This would imply that the order in which the data is collected matters, which technically it probably doesn't – the defects are likely independent of order number.

(c) True or False. In general, using an I chart instead of a c chart could affect the number of Type I or Type II Errors reported. Note: Since Poisson charts aren't normally distributed, Type I Error is no longer 0.0027, though it could be close.

True False

5. Go to the following website, and answer as many questions as you can before you reach 3 strikes. You can have only 1 practice round. On the front board, record your number of correct answers ***on your second try***. **Construct and attach a c chart** of the number of correct answers per person (after everyone has recorded their answers on the board). ***Make sure to title your graph***. If you've taken this quiz before, your score will most likely be an out-of-control point!

http://www.notdoppler.com/theimpossiblequiz.php

6. The number of typographical errors is counted over chapters in a textbook. The data for k = 25 chapters is in the file Hmwk7DATA_AttributeCharts.

(a) Determine the center line and control chart limits for the number of errors per chapter.

CLc =

UCLc = LCLc =

(b) There is a more appropriate chart for this data – it's called a u chart. To construct a u chart, we need a piece of additional information. For this example, what additional piece of information would help to build a mor e useful chart? That is, what information should we take into consideration (if it is available)?

7. In a **Health Information Center, telephone counselors** are available to provide up-to-date information about health-related issues to callers. When calls are received at the main switchboard, they are transferred to one of four groups of counselors, based on the classification of the caller's question. The **four classifications for callers' questions** are:

(1) General Health, (2) Pediatrics, (3) Infectious Diseases, and (4) Oncology/Hematology.

Even though the counselors have extensive training as well as many sources of medical information, questions do arise for which adequate information or knowledge is not readily available. In such cases, the counselors research the question and, later, telephone the original caller with accurate and detailed information concerning the caller's questions. Because of the amount of time lost for each caller's question that must be researched, it is desired to **determine the health area where these questions most frequently occur**. The data in columns C9-C13 in Hmwk7DATA_AttributeCharts contains the number of calls received per day for which the answer is not readily available (assume a good operational definition exists for this concept!).

Number of "Unanswerable Calls"
Classification of Questions Asked

Days	General Health	Pediatrics	Infectious Diseases	Oncology
1	5	7	10	14
2	7	9	11	13
3	6	13	15	14
4	9	10	8	16
5	4	12	14	17
6	7	8	11	9
7	9	5	13	14
8	3	8	15	13
9	7	7	14	16
10	8	13	13	11
11	9	13	14	18
12	9	10	10	13
13	3	8	12	16
14	6	7	9	13

7. (a) In Minitab, plot the appropriate control charts for classifications 1, 2, 3, and 4. Record the center lines for each plot. You do not need to attach the plots.

Classification 1: **Classification 2:** **Classification 3:** **Classification 4:**

(b) Let's look at the **Classification 4: Oncology** control chart. If the process is in control, what's the probability of committing a Type I Error, Rule #1 (point beyond LCL or UCL) on this chart? Note: It is appropriate to use a Poisson distribution to calculate this probability, although you can *approximate* this probability with a normal distribution. Also, you can only input positive integers into a Poisson distribution. Give your answer correct to 4 decimal places.

(c) Assume that the number of unanswerable calls per day in Oncology shifts to mean 20. What is the probability that you will commit a Type II Error given the mean has shifted to 20? Note: It is appropriate to use a Poisson distribution, although you can *approximate* this probability with a normal distribution. Give your answer correct to 4 decimal places.

(d) In order to directly compare the number of unanswerable calls for each classification, what additional data would be helpful to have? If you had this information, what type of control chart would be preferable for monitoring the number of unanswerable per day?

8. At the front board, write down your total number of M&M’s and the number of defective ones. Construct the appropriate control chart for tracking the ***proportion of defective M&M’s per bag***. Attach the control chart, ***appropriately labeled***, at the end of this assignment.