Minitab®

SPC

LESSON: “Which Chart Am I?”

Problem 0.

1. *Average bolt torque for 4 bolts* on a transmission coming off an assembly line – ***torque is a measurement***

Xbar-R I-MR *p or np* *c or u*

Solution: Torque is continuous (measurement) data, and we are averaging 4 measurements. Horizontal axis is transmission number, and vertical axis is average bolt torque measurement.

2. Number or proportion of missing bolts per 8 on an engine – ***we have a sample size n = 8***

Xbar-R I-MR ***p or np*** *c or u*

Solution: Number of missing bolts is count data, and we are counting missing bolts per 8, where at most there could be is 8. Since the sample size is constant, an p or np chart will work. Horizontal axis is engine number, and vertical axis is number or proportion of missing bolts.

3. Number of typos per sales contract – ***sales contract is an object, could have infinite typos***

Xbar-R I-MR *p or np* ***c or u***

Solution: Number of typos is count data, and we counting typos on identical contracts. Although we cannot realistically have an infinite number of typos, there is no upper bound on the sample size. Horizontal axis is contract number, and vertical axis is number of typos. A u chart is technically correct as well, since a c chart is the same as a u chart with a constant sampling unit.

4. Number of defects on an engine – ***an engine is an object, could have infinite defects***

Xbar-R I-MR *p or np* ***c or u***

Solution: Number of defects on an engine is count data. Although we cannot realistically have an infinite number of defects, there is no upper bound on the sample size. Horizontal axis is engine number and vertical axis is number of defects per engine. A u chart is technically correct as well, since a c chart is the same as a u chart with a constant sampling unit.

5. Amount of time it takes to build an engine – ***time is a measurement***

Xbar-R **I-MR** *p or np* *c or u*

Solution: Time is measurement data, and we are measuring time to build an engine. Horizontal axis is engine number, and vertical axis is time measurement.

6. Number or proportion of defective engines made per month given that we know how many engines are produced ***– since we know the # produced, then we have the sample size n for each month***

Xbar-R I-MR ***p or np*** *c or u*

Solution: Number of defective engines is count data. Since we know the total number of engines produced in a month (which may be different from month to month), we can determine the proportion of those engines that are defective. So, we are counting the proportion of defective engines made in a month out of the total number of engines made. Horizontal axis is month (e.g., January, February, March, etc.) and vertical axis is proportion of defective engines (e.g., 2%, 5%, 3%, etc.). Since the number of engines made each month differs from month to month, then an np chart is inappropriate.

7. Number of engine recalls per month – ***month is a unit of time, could have infinite # of recalls***

Xbar-R I-MR *p or np* ***c or u***

Solution: Number of engine recalls per month is count data. Although we cannot realistically have an infinite number of recalls, there is no upper bound on the sample size. Horizontal axis is month (e.g., January, February, March, etc.) and vertical axis is number of engine recalls.

8. Amount of time it takes to close a sales account – ***time is measurement data***

Xbar-R **I-MR** *p or np* *c or u*

Solution: Time is measurement data, and we are measuring time to close a sales account. Horizontal axis is sales account number, and vertical axis is time measurement.

9. The number of customer complaints in a week – ***week is a unit of time, could have infinite # of complaints***

Xbar-R I-MR *p or np* ***c or u***

Solution: Number of customer complaints is count data, and we are counting the number of complaints per week. Although we cannot realistically have an infinite number of complaints, there is no upper bound on the sample size. Horizontal axis is week number and vertical axis is number of customer complaints. A u chart is technically correct as well, since a c chart is the same as a u chart with a constant sampling unit.

10. The number or proportion of defective bolts in a 64-pack – ***we know the total # in the pack, so n = 64***

Xbar-R I-MR ***p or np*** *c or u*

Solution: We are counting the number of defective bolts out of the total number of bolts in a pack, which I'm assuming is the same per pack. Horizontal axis is pack number and vertical axis is proportion of defective bolts (e.g., 2%, 5%, 3%, etc.). Since we can most likely assume that the same number of bolts is in a pack, we'll say np chart is appropriate as well.

11. The average weight of four engines coming off an assembly line – ***weight is a measurement, and we're averaging 4 engines***

Xbar-R I-MR *p or np* *c or u*

Solution: Weight is measurement data, and we are averaging the weight of four engines. Horizontal axis is group number of 4 engines, and vertical axis is average weight.

12. The number of plant accidents in a month – ***month is a unit of time, there could be an infinite # of accidents***

Xbar-R I-MR *p or np* ***c or u***

Solution: Number of plant accidents is count data, and we are counting the number of plant accidents in a month. Although we cannot realistically have an infinite number of accidents, there is no upper bound on the sample size. Horizontal axis is month (e.g., January, February, March, etc.) and vertical axis is number of accidents. A u chart is technically correct as well, since a c chart is the same as a u chart with a constant sampling unit.

13. The time is takes to tour an engine assembly plant – ***time is a measurement***

Xbar-R **I-MR** *p or np* *c or u*

Solution: Time is measurement data, and we are measuring time to tour an assembly plant. Horizontal axis is tour number, and vertical axis is time.

14. The number or proportion of daily workers taking a sick day given we know how many daily workers there are – since we know the # of daily workers, then we know n (though n may vary)

Xbar-R I-MR ***p or np*** *c or u*

Solution: We know the total number of daily workers and the number of those workers who take a day off for sickness. So, we are counting the total number of sick workers out of the total number of workers on a given day. Horizontal axis is day of the work week, and vertical axis is proportion of workers taking a sick day. If the company doesn't fluctuate in its total number of workers (unlikely), then it could be an np chart.

Problems 1-7: For the following problems, some of them have data provided in Minitab that will help you make a choice as to the correct control chart to use. The Minitab worksheet is called Hmwk8DATA_WhichChart.

Problem 1. Piston Ring Nonconformance Rates: A manufacturer of piston rings wants to reduce the number of nonconforming rings that are produced each day.

Data Collection: Each day, the team inspects every piston ring that is produced and records the total number of nonconforming rings along with the total number or rings produced.

Each piston ring is rated as a:

- Success, if it meets specifications
- Failure, if it does not meet specifications

Please refer to the Minitab worksheet of data before making your choice.

Data Set: Description of variables and data contained in the Minitab worksheet for Homework 8:

Variable	Description
C1: Date	Date the piston rings were manufactured
C2: Defective Units	Number of defective rings for each date
C3: Sample Size	Number of rings produced and inspected for each date

Circle the correct chart to use: ***we have the sample size and the sample size varies – so np is not possible***

Xbar-R I-MR ***p*** *np* *c* *u*

Solution: Data is "count" or attribute data, and we are counting the number of defective rings per total number of rings produced -> Binomial and track with a p chart since sample size n is changing with each date of collection. Knowing the sample size gives us additional information to form a p chart rather than a c chart (defects per day). If we collected exactly 1200 samples every day, then we could construct either a p or np chart.

Date	Defective Units	Sample Size
3/03	99	1195
3/04	99	1197
3/05	93	1272
3/06	92	1250
3/07	105	1217
3/08	103	1246 …

If we ***didn't*** know the sample sizes, then we would do a c chart for the "number of defective rings" per day (single time unit).

Problem 2. Bad Bills: A study was undertaken on the billing process at an electric company which had been experiencing complaints from customers about their quarterly billing system (such as incorrect amounts, no bill included, wrong address, damaged envelopes). Samples of 500 bills were examined and the number of "bad" bills was recorded.

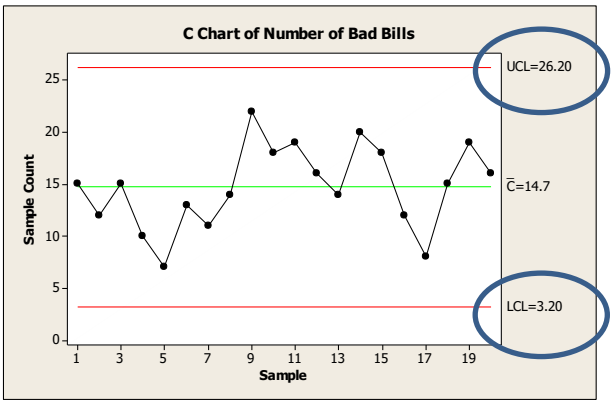
The results of 20 such samples (in column C5) were:

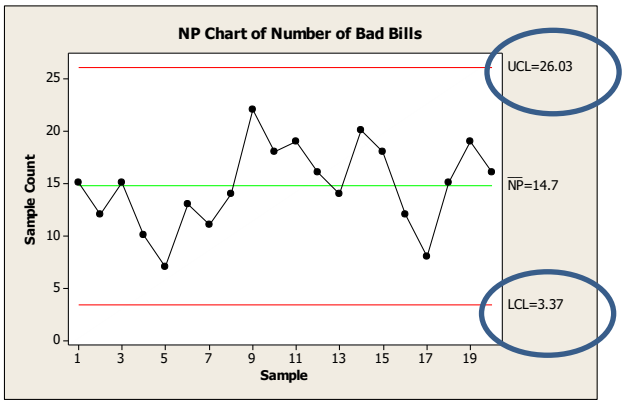
15	12	15	10	7	13	11	14	22	18	19	16	14
20	18	12	8	15	19	16						

Let *X* be a random variable that represents the **number of bad bills out of 500**. I would use an np chart (number of defective items per lot), but you could use a c chart (number of defects per unit, where "unit" is a batch of 500 bills). It is "more" correct to use the np (or p) chart since you know the TOTAL number of bills.

Comment: The data is "count" or attribute data, and we are counting number of defective bills per sample of 500 bills -> Binomial and track with a p chart or np chart since sample size n is the same for each sample. If you were using a c chart, you could be "throwing" away the information that we have a finite number of bills each time, 500. The number of bad bills per day or per lot doesn't take the number in the lot into consideration. The more information that you can use to build a chart – USE IT. Construct both the np and c charts. Which chart would give the company less of a chance of a Type I Error, but more of a chance of a Type II Error? You do not need to attach your charts.

Solution: The ***c* chart** because the 3 sigma UCL and LCL are larger than those for the *np* chart. Why? In the *c* chart they are located at $\bar{c} \pm 3\sqrt{\bar{c}} = 14.7 \pm 3\sqrt{14.7}$, which is **LCL ≈ 3.20 bills** and **UCL ≈ 26.20 bills**. While in the *np* chart they are located at $\overline{np} \pm 3\sqrt{\overline{np} \cdot (1 - \bar{p})} = 14.7 \pm 3\sqrt{14.7 \cdot 0.9706}$, which is **LCL ≈ 3.37 bills** and **UCL ≈ 26.03 bills**. The *np* chart will always have tighter bounds than the *c* chart. Since we'd like smaller Type II error when we talk about quality (smaller chance of customer getting a defective product), then we should choose an *np* chart over a *c* chart.





Problem 3. Vinyl Defects: You are manufacturing sheet vinyl that will be used for automobile upholstery. You plan to chart defects per 100 ft. of sheet vinyl. Which chart would you use to track the number of defects per 100 ft.?

Circle the correct chart to use:

Xbar-R I-MR *p* *np* ***c*** ***u***

Solution: Data is "count" or attribute data, and we are counting the number of defects per constant unit (100 ft. of sheet vinyl). Here the unit is an OBJECT (100 ft. of sheet vinyl), not a finite sample, and so a Poisson is appropriate. Since the unit size is constant (100 ft.), then we would track with a c chart. A u chart is technically correct as well, since a c chart is the same as a u chart with a constant sampling unit.

Problem 4. Furniture Blemishes: A furniture manufacturer is concerned about customer complaints related to surface blemishes, including color, scratches, dents, grain, and finish, on wooden end tables.

Data Collection: A quality team inspects each table for the nonconformities indicated above. For about 3 weeks, the team records the number of surface blemishes (and the number of pieces inspected).

Data Set: Description of variables and data contained in the Minitab worksheet for Homework 8.

Variable	Description
C7: Date_1	Date tables were manufactured
C8: Blemishes	Number of blemishes on each table

Circle the correct chart to use if just plotting nonconformities in column C8.

Xbar-R I-MR *p* *np* ***c*** *u*

Bonus: Column C9 has the number of tables inspected each day. If we use this additional information in constructing the control chart for the defect data in column C8, what type of control chart is appropriate?

Xbar-R I-MR *p* *np* *c* ***u***

Solution: Data is "count" or attribute data, and we are counting ***the number of defects per unit (table)***, where the ***unit size is changing*** (not same number of tables each day). Here the unit is an OBJECT, not a finite sample, and so a Poisson is appropriate. Since ***the unit size changes with the date***, we must track with a u chart (not a *c* chart).

Date	Blemishes	Pieces Inspected	
7/14	5	200 (tables inspected)	-> 5 blemishes per 200 tables inspected; all of the blemishes
7/15	8	250	could come from the same table; also, there could be
7/16	8	150 …	infinitely many blemishes (in theory)

Problem 5. Inspecting Gear Assemblies: Each morning, the production supervisor of a gear assembly line reviews the production numbers from the previous day. If the percentage of defective assemblies is greater than the goal of 14%, the department goes on "red alert" status. An engineer, who is newly trained in Statistical Process Control (SPC), convinces the supervisor to collect the data over a trial period without acting on it, so that they can observe random variation.

Data Collection: Inspectors record the number of assemblies that are inspected and rejected each day over a two-month period. If the percentage is too high, the department will go on red alert.

Data Set: Description of variables and data contained in the Minitab worksheet for Homework 8.

Variable	Description
C11: Date/Time	Date the gears were manufactured
C12: Assemblies Inspected	The number of gear assemblies inspected each day
C13: Rejects	Number of rejects in each subgroup of assemblies

Circle the correct chart to use:

Xbar-R I-MR **p** *np* *c* *u*

Solution: Data is "count" or attribute data, and we are counting number of rejected assemblies per total number of gear assemblies inspected each day -> Binomial and track with a p chart since sample size n is changing with each day (see Minitab worksheet).

Date	Assemblies Inspected	Rejects
2/1	1150	156
2/2	1212	164
2/3	1285	189
2/4	1202	171
2/5	1152	184
2/6	1204	157 …

Problem 6. Inspecting Gear Assemblies: Each morning, the production supervisor of a gear assembly line reviews the time it takes to assemble an engine. He tracks the individual assembly times & plots them.

Circle the correct chart to use:

Xbar-R **I-MR** *p* *np* *c* *u*

Solution: The data, time to assemble an engine, is continuous or measurement data -> variable chart. Since the subgroup size is 1, then we use I-MR charts.

Problem 7. Greeting Card Quality: A greeting card printer implements a quality initiative to decrease the number of defects in its oversized cards. Before the initiative, the process was in statistical control. The printer compares pre- and post-initiative process performance and inspects the cards for smudges, orientation, color, and wrinkles.

Data Collection: Each day inspectors randomly sample 250 cards as a subgroup. They check each card and record the sample date, as well as the total number of nonconformities that are in each subgroup.

Data Set: Description of variables and data contained in the Minitab worksheet for Homework 8.

Variable	Description
C15: Dates	Date greeting cards were printed
C16: Flaws	Number of flaws observed in a sample of 250 greeting cards

Circle the correct chart to use:

Xbar-R I-MR *p* *np* ***c*** ***u***

Solution: Data is “count” or attribute data, and we are counting the number of flaws per unit (greeting card), where the unit size is staying the same (250 cards). Here the unit is an OBJECT, not a finite sample, and so a Poisson is appropriate. There can be more than one flaw per card, and the number of flaws per 250 greeting cards could go beyond 250 if each card has more than 1 flaw. Since the unit size does not change with each sample, we would track with a c chart. +1 also for saying u chart – u is ok if you choose sample size to be 1. The u chart is appropriate if the sampled number of greetings cards fluctuate, such as 250, 254, 251, 240, etc.

Problem 8. Suppose every morning (around 11 a.m.) that Square Donuts personnel sample 100 of it’s “square” donuts to make sure that they are indeed square. They record the number out of 100 that are not actually square. That is, they “fail” the square test. They do this same test in the afternoon (around 4 p.m.). The data for the number of donuts that are defective (i.e., not square) out of 100 is stored in Column C19. The constant sample size is recorded in Column C20.

Circle the correct chart to use:

Xbar-R I-MR ***p*** ***np*** *c* *u*

Solution: We have a sample size of n = 100, and we are counting defects out of this constant sample size. Either a p or np chart is appropriate.