Travis Smith, Dominic Hoff, Jack Goldrick
Manufacturing
Homework #4
3/15/24

Q1)

Part 1: Read the article “The Missing Ingredient?” by Richard Schonberger, Industrial Engineering, June 2011.

a) Briefly describe the assembly lines Boeing uses in its Renton manufacturing plant

> Boeing has 3 lines in its Renton factory. The first is a moving assembly line that handles most of their orders. The second is a stationary line that handles the extra orders, and the third is a stationary line that handles custom orders.

b) What is the main objective in adopting a LEAN manufacturing strategy in this plant?

> The main objective of their LEAN strategies is to reduce onsite storage of parts so that they can reduce the size of their plant, which reduces the time it takes to move parts to the assembly line.

c) Name five LEAN manufacturing actions taken by Boeing. For each, state what kind of “waste” is being eliminated or reduced.

   i) Boeing altered the movement and use of the large overhead cranes which significantly reduced waited/waiting time
   ii) The about 55/60% cut to in-process aircraft reduces the waste generated by overproduction.
   iii) The Switch to JIT for subassemblies helped reduce waiting and transportation waste
   iv) The switch to plug and play assembly reduced the waste generated from over-processing
   v) The color coding helps reduce waste generated from non-optimized motion.

d) Under current operations, what is the main problem in the assembly line observed by the author that prevents Boeing from observing further benefits of LEAN manufacturing? What further changes are proposed?

The author says that Boeing’s biggest problem is how their lines are designated. They propose that line 1 is dedicated to the “default” plane design and that line 2 is dedicated to more custom designs.

e) Name three advantages of the advanced LEAN system proposed by the author.
    i) Total production costs are lowered
    ii) Lower supplier and customer service costs
    iii) Higher reliability will gradually lower the overall production time
f) What is the consolidation move that is being planned? Why does the author claim that this is not a good idea?
    i) They want to take their 4 main production lines and consolidate them into one massive super assembly line. The author believes that the consolidation will result in longer average lead times with delays that will compile at a much larger rate. The author is also concerned about Boeing's ability to scale certain technology departments with the assembly line while making the line less resistant to single catastrophic disruptions.
g) Compare the issues raised in your chosen article/video with what you know already about Lean Manufacturing and Just-In-Time systems. Does the pandemic reveal any issues with our global supply chains? Do you think there are any specific products (e.g. toilet paper) or industries (e.g. healthcare, automotive) that should stockpile inventory rather than operating under a just-in-time model? Why or why not?
    i) The focus of much of lean manufacturing, specifically in Boeing’s case, is cutting down costs by streamlining the manufacturing process and reducing waste, time, and support requirements. This and just-in-time models both share the risk of becoming more susceptible to complications, such as messing up parts or supplies showing up late. Nowhere is a more unprecedented situation than the impacts of COVID-19. The surge of demand for everyday products such as toilet paper, tissues, basic medical supplies, and more brought scarsities of these products. While cheaper to maintain just-in-time systems (less warehouse costs), it is also more dangerous for necessary products that customers may require. This does not pertain to every industry. For example, customers will never be in dire need of porch grills if they go out of stock for prolonged periods of time, so just-in-time systems can be cheaper and more viable. Many electronics industries should operate under a stockpile industry model to avoid shortages of key electronic materials in building computers, hardware, measurement devices, and coolant systems. As an ex-Digicom warehouse employee myself, many products stored there have been on the shelves since 2001. Even though electronics technology moves quickly, many components are designed to be modular and can have parts easily updated later, which just so happens to have been one of my main duties. Therefore, electronic technologies should not operate under just-in-time models.

Q2)

Problem 2 (20 pts total): A secret facility under Denver International Airport is made up of many identical stations like the one shown in Figure 1. At each one, a single operator follows the following procedure to produce batches of chemtrail canisters optimized for specific missions.

a) Analyze the procedure and spaghetti diagram and suggest a new station layout to reduce wasted motion. (Drawing by hand is fine. 10 pts.)

Procedure:

- Load empty **canister** into machine **output**.
- Get additional ingredients from **supply closet**.
- Load and program **mixer**.
- Get full canister from **output**.
- Transfer to **lab bench** for diagnostics.
- Get test supplies from **supply closet** as needed.

- If bad batch, scrap in **waste barrel**, restart from 1.
- If good, give to **test subject**, run tests.
- Read and interpret test **readout**.
- If test fails, scrap in **waste barrel**, restart from 1.
- If test passes, make several batches (1 – 4).
- Move canisters to **finished product** shelf.

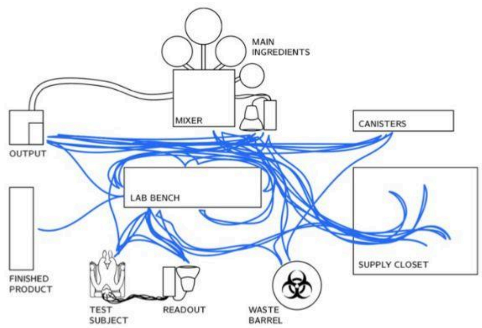
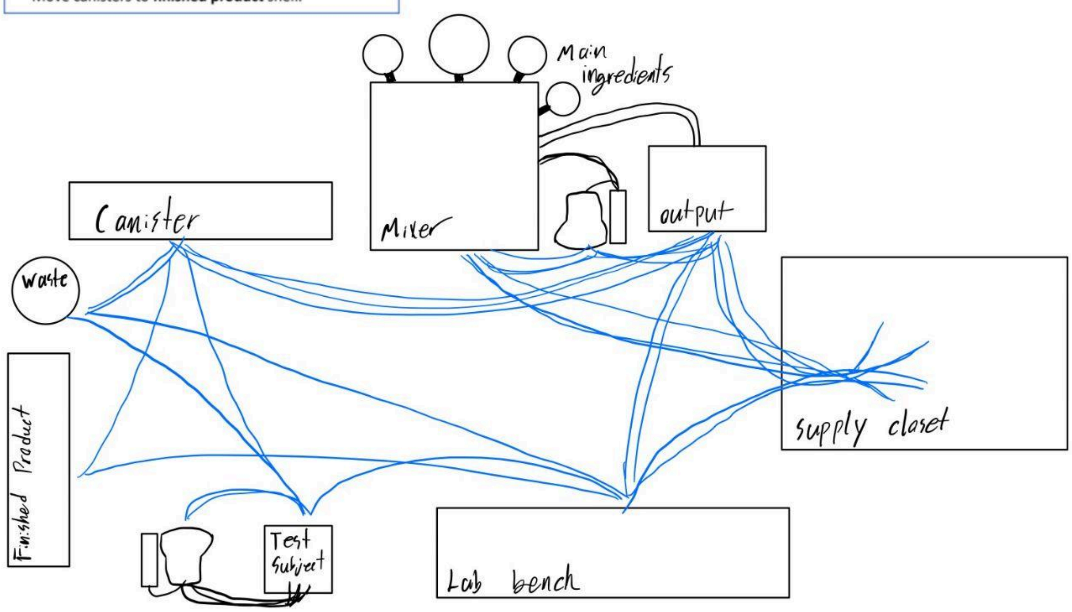


Figure 1: A spaghetti diagram of a typical chemtrail production station.



b) Briefly discuss **at least 2 strategies** that could be implemented to better keep each station stocked and producing chemtrail canisters. (10 pts)

The task of keeping each station stocked with supplies is left to several interns who wander around the facility and periodically check random stations. At a station, the interns first check the fluid level in the storage tanks containing the main ingredients. They do this by opening each tank, sticking their heads inside, and deciding whether or not the tank needs to be refilled. Next, the same intern also checks the shelf of empty canisters, as well as the supply closet, and restocks them as needed.

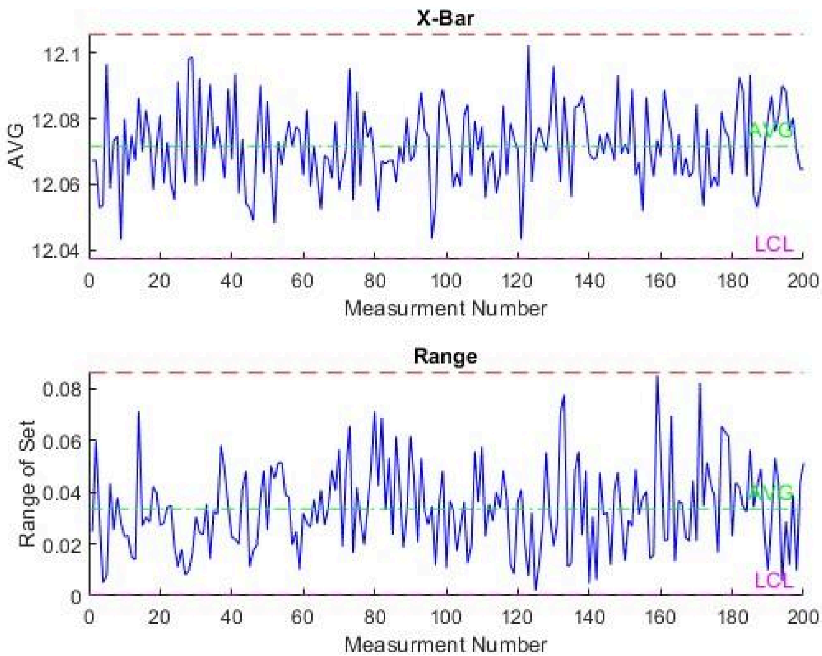
- They could attach fluid level indicators to the outside of the tanks so you can tell their fluid level at a glance.

- 2 color coated buckets could be used for each item in the supply closet and when the second bucket is being used, order more supplies.

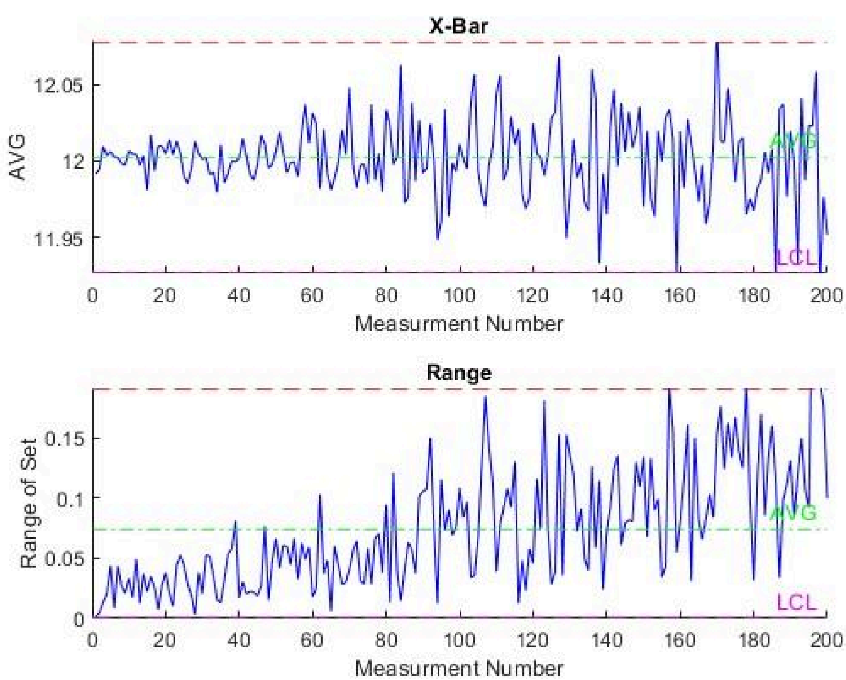
Q3)

a. Plots

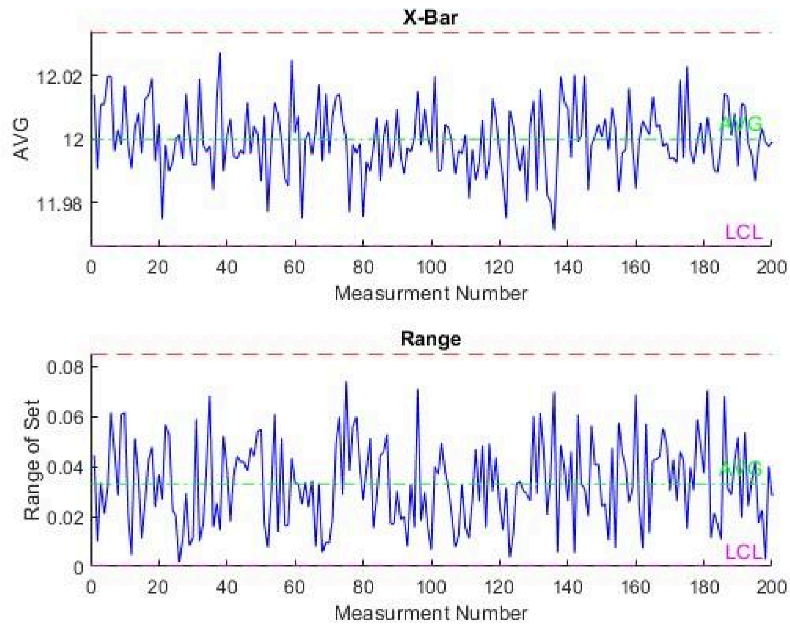
i.



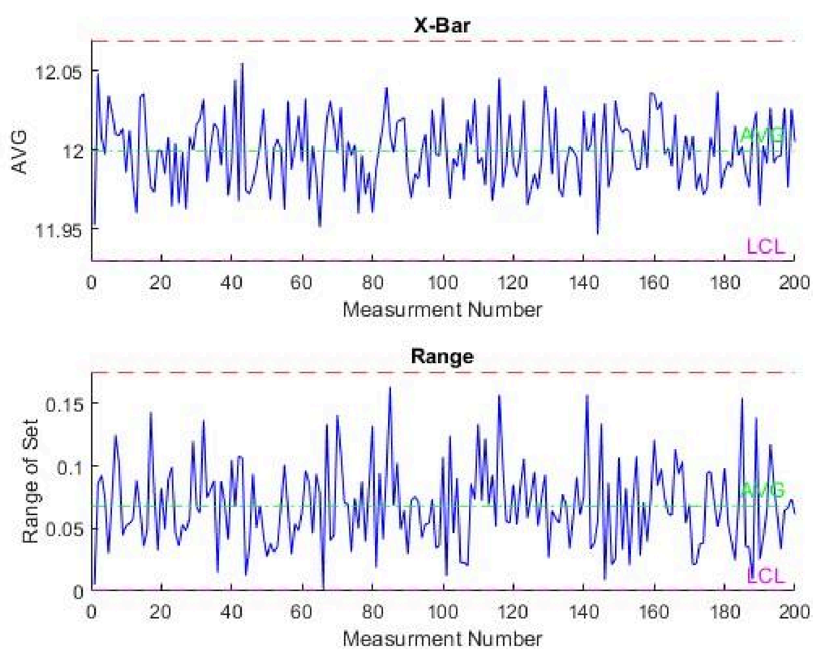
ii.



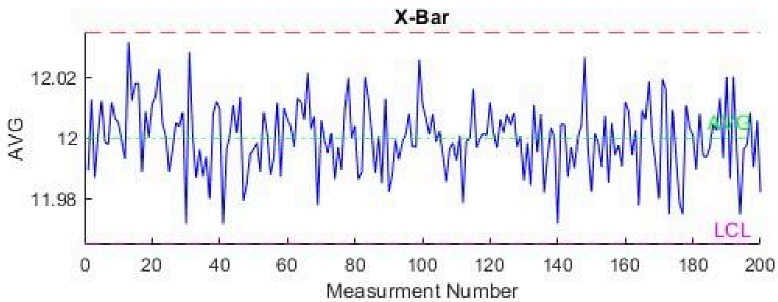
iii.

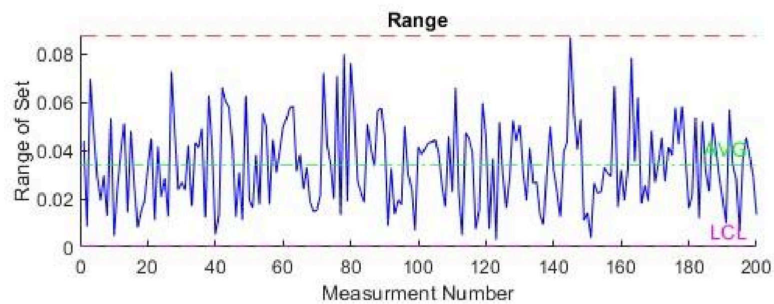

X-Bar
AVG
12.02
12
11.98
AVG
LCL
0
20
40
60
80
100
120
140
160
180
200
Measurment Number
Range
Range of Set
0.08
0.06
0.04
0.02
0
AVG
LCL
Measurment Number

iv.

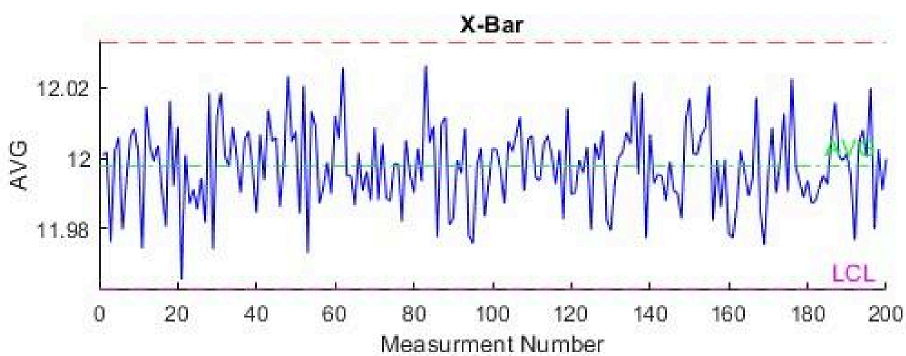

X-Bar
AVG
12.05
12
11.95
AVG
LCL
0
20
40
60
80
100
120
140
160
180
200
Measurment Number
Range
Range of Set
0.15
0.1
0.05
0
AVG
LCL
Measurment Number

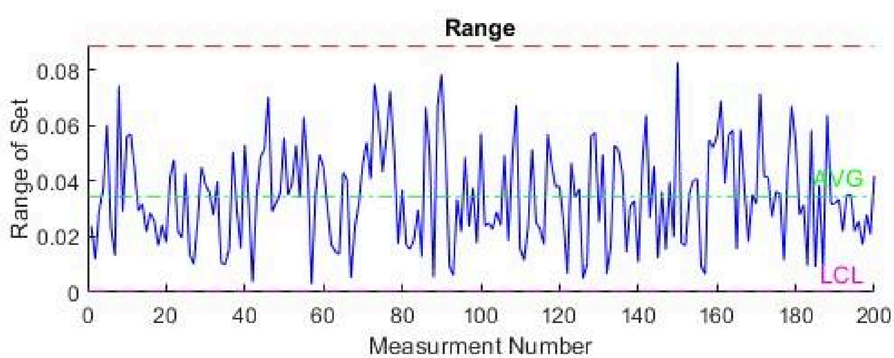
v.


X-Bar
AVG
12.02
12
11.98
AVG
LCL
0
20
40
60
80
100
120
140
160
180
200
Measurment Number

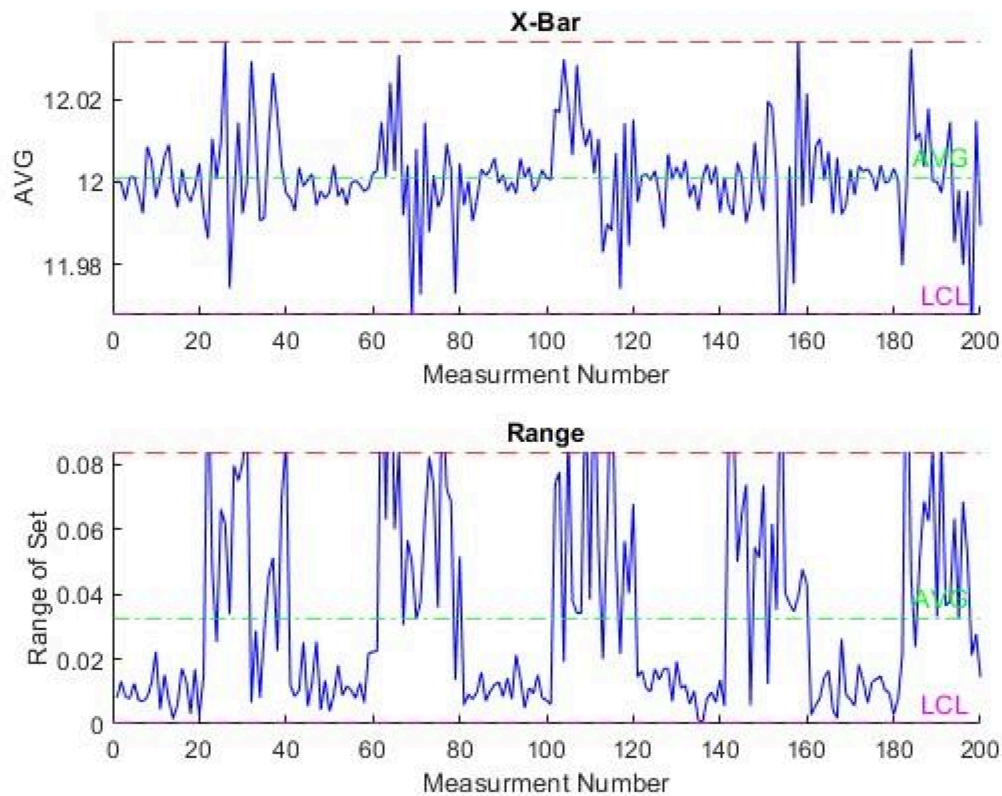

Range
Range of Set
0.08
0.06
0.04
0.02
0
AVG
LCL
0
20
40
60
80
100
120
140
160
180
200
Measurment Number

vi.


X-Bar
AVG
12.02
12
11.98
AVG
LCL
0
20
40
60
80
100
120
140
160
180
200
Measurment Number


Range
Range of Set
0.08
0.06
0.04
0.02
0
AVG
LCL
0
20
40
60
80
100
120
140
160
180
200
Measurment Number

vii.



b. C values
   i. Machine 1
      1. Cp = 2.8128
      2. Cpk = .8013

   ii. Machine 2
      1. Cp = 1.260426830572124
      2. Cpk = 1.232615873508036

   iii. Machine 3
      1. Cp = 3.133774704907336
      2. Cpk = 3.131136927324882

   iv. Machine 4
      1. Cp = 1.522072564516653
      2. Cpk = 1.509168222619085

   v. Machine 5

1. Cp = 2.898503367427535
2. Cpk = 2.893781193359284

vi. Machine 6
   1. Cp = 2.835701342803148
   2. Cpk = 2.772689821115705

vii. Machine 7
   1. Cp = 2.826639450560743
   2. Cpk = 2.799792682087314

c. Looking at the charts and the Cp and Cpk values, you notice that 4 of the 7 machines are not functioning as they should. (8 pts)
   - Which machine likely has a worn bearing, causing the spindle to shake and vibrate more than it should? Hint: this is analogous to the machine becoming less precise.
     - Machine 4
   - Which machine likely has a tool that's wearing out very quickly? Hint: remember, tools are prone to chatter and become less precise as they dull.
     - Machine 2
   - Which machine is likely operated by an inexperienced machinist? Hint: the workers switch every shift, and 20 samples are collected each shift.
     - Machine 7
   - Which machine likely has a misaligned fixture? Hint: otherwise, this machine works just fine.
     - Machine 1

Code:

- Six Sigma:

```
classdef SixSigma
  properties(Access = public)
    x_barbar;
    r_bar;
    xbar_line;
    r_line;
    data;
    sizes;
```

```
        Cp;
        Cpk;
        x_sigma;
        r_sigma;
        x_UCL;
        x_LCL;
        r_UCL;
        r_LCL;
    end
    methods
        function obj = SixSigma(input)
            obj.data = input;
            obj.sizes = length(input(1,:));
            obj.r_line = zeros(obj.sizes, 1);
            obj.xbar_line = zeros(obj.sizes, 1);
            obj = obj.bar_chart(obj);
            obj = obj.set_avgs(obj);
            obj = obj.set_sigma(obj);
            obj = obj.set_limits(obj);
            obj = obj.set_Cp(obj);
            obj = obj.set_Cpk(obj);
        end
    end
    methods(Static, Access = public)
        function [out] = get_Xbarbar(obj)

            out = obj.x_barbar;

        end
        function [out] = get_xbarLine(obj)

            out = obj.xbar_line;

        end
        function [out] = get_size(obj)

            out = obj.sizes;

        end
        function [out] = get_rLine(obj)
```

```
        out = obj.r_line;

    end
    function [out] = get_rBar(obj)

        out = obj.r_bar;

    end
    function [out] = get_Cp(obj)

        out = obj.Cp;

    end
    function [out] = get_Cpk(obj)

        out = obj.Cpk;

    end
  end
  methods(Static, Access = private)
    function obj = set_Cp(obj)
        obj.Cp = (2 * .1) / (6 * obj.x_sigma);
    end
    function obj = set_Cpk(obj)
        obj.Cpk = min((obj.x_barbar - 11.9) / (3 * obj.x_sigma), (12.1 - obj.x_barbar) / (3
* obj.x_sigma));

    end
    function obj = set_limits(obj)
        % obj.x_UCL = obj.x_barbar + 3 *obj.x_sigma;
        % obj.x_LCL = obj.x_barbar - 3 *obj.x_sigma;
        obj.x_UCL = obj.x_barbar + 1.023 *obj.r_bar;
        obj.x_LCL = obj.x_barbar - 1.023 *obj.r_bar;
        obj.r_UCL = obj.r_bar * 2.575;
        obj.r_LCL = 0;

    end
    function obj = set_sigma(obj)

        obj.x_sigma = sqrt( (1 / (obj.sizes - 1)) * (transpose(obj.xbar_line - obj.x_barbar)
* (obj.xbar_line - obj.x_barbar)) );
```

```
        obj.r_sigma = obj.r_bar / 1.693;

    end
    function obj = set_avgs(obj)

        V_one = ones(1,obj.sizes);
        obj.x_barbar = ((V_one) * obj.xbar_line) / obj.sizes;
        obj.r_bar = ((V_one) * obj.r_line) / obj.sizes;
    end
    function obj = bar_chart(obj)
        for i=1:obj.get_size(obj)
            for j=1:3
                obj.xbar_line(i) = obj.xbar_line(i) + obj.data(j, i);
            end

            obj.xbar_line(i) = obj.xbar_line(i) / 3;
            obj.r_line(i) = abs(max(obj.data(:, i)) - min(obj.data(:, i)));
        end
    end
  end
end
```

- Plotter:

```
import SixSigma.*
load('HW4_machine_data.mat');
m = [SixSigma(machine_1);
    SixSigma(machine_2);
    SixSigma(machine_3);
    SixSigma(machine_4);
    SixSigma(machine_5);
    SixSigma(machine_6);
    SixSigma(machine_7);];
for i=1:7
  figure(i)
  hold on
  tiledlayout(2,1)

  % Top plot
  ax1 = nexttile;
```

```
  hold on
  title(ax1,'X-Bar')
  ylabel(ax1,'AVG')
  xlabel(ax1, "Measurment Number")
  ylim (ax1, [m(i).x_LCL - .000005, m(i).x_UCL + .000005]);
  plot(ax1, m(i).xbar_line,'-b');
  plot(ax1, yline(m(i).x_barbar,'-.g', "AVG"));
  plot(ax1, yline(m(i).x_UCL, '--r', "UCL"));
  plot(ax1, yline(m(i).x_LCL, '--m', "LCL"));
  hold off
  % Bottom plot
  ax2 = nexttile;
  hold on
  title('Range')
  ylabel('Range of Set')
  xlabel("Measurment Number")
  ylim (ax2,[m(i).r_LCL - .000005, m(i).r_UCL + .000005]);
  plot(ax2, m(i).r_line,'-b');
  plot(ax2, yline(m(i).r_bar,'-.g', "AVG"));
  plot(ax2, yline(m(i).r_UCL, '--r', "UCL"));
  plot(ax2, yline(m(i).r_LCL, '--m', "LCL"));
  hold off
  hold off

end
```

- **Q4)**

4) a. $PC_A = \mu \pm 3(1.50 \text{ thou}) = \mu \pm 4.50 \text{ thou} > 1.00 \text{ thou}$

$PC_B = \mu \pm 3(0.15 \text{ thou}) = \mu \pm 0.45 \text{ thou} < 1.00 \text{ thou}$

$PC_C = \mu \pm 3(3.00 \text{ thou}) = \mu \pm 9.00 \text{ thou} > 1.00 \text{ thou}$

So only process B is capable.

b. For process B: $C_B = \$2.00 \cdot x + \$5000 + \$1.00x + \$0.75x + \$1.00x$

$C_B = \$4.75x + \$5000$

For buying: $C_{buy} = \$5.00x + \$10 + \$1.00x$

$C_{buy} = \$6.00x + \$10$

$C_B = C_{buy} \rightarrow \$4990 = \$1.25x \rightarrow x = 3{,}992$

Company would have to produce 3,992 Q01s in order for process B to become cheaper.

c. $C_{B1} = \dfrac{\$4.75x + \$5000}{x}$ $C_{B1}(10{,}000) = \dfrac{\$4.75(10000) + \$5000}{10000}$

$C_{B1} = \$5.25$ per part

\

4) d. $CP_A = \mu \pm 4.50$ thou $<$ 10 thou

$CP_C = \mu \pm 9.00$ thou $<$ 10 thou

So processes A, B, and C are capable.

Process A: $C_A = \$1.50x + \$1.00x + \$\frac{0.75}{8}x + \$1.00x + \$1000$
$C_A = \$3.59375x + \$1000$

Process B: $C_{Bnew} = \$2.00x + \$1.00x + \$\frac{0.75}{8}x + \$1.00x + \$5{,}000$
$C_{Bnew} = \$4.09375x + \$5000$

Process C: $C_C = \$0.50x + \$1.00x + \$\frac{0.75}{8}x + \$1.00x + \$7{,}000$
$C_C = \$2.59375x + \$7000$

At 10,000 parts: $C_A = \$36{,}937.50$ $\quad C_{Bnew} = \$45937.50$

$C_C = \$32{,}942.50$ $\quad C_{Bold} = \$52{,}500$

new lowest cost: $\min(C_A, C_{Bnew}, C_C) = C_C$

Money saved $= C_{Bold} - C_C = \$19{,}557.50$

e. The savings come from eliminating waste and eliminating non-value adding processes (too much inspection) as part of lean manufacturing.

f. AHG is not performing as desired ($C_{pk} = 0.92 < 1$) not capable.

g. To correct this either redefine LSL/USL or minimize the variance in the process such as using a different process.