Name _____

AQS110 – Introduction to Quality and Metrology – Fall 2016
LABORATORY EXERCISE #10

# MANUFACTURING- Lean Simulation

## Purpose

The purpose of this laboratory exercise is to demonstrate manufacturing variability and explore lean manufacturing principles.

The game(s) introduced in this exercise were taken directly and/or modified slightly from the following sources

The Dice Game(s), Washington State University, James R. Holt, PhD., PE
Variability Simulation, Lean Academy, MIT OCW (Massachusetts Institute of Technology Open Course Ware)

## Format:

~~Three~~ Two games will be played:

A) First, will be a traditional "push" operation.  This game will be played in three rounds.
   - There will be 1 team.  The team will contain 5 workers and  five observer/inspectors.
   - The team will be provided sufficient raw material to complete the exercise and a die for each worker.
   - The results of each day's production will be recorded on the data sheet by the observer/inspector.
   - Each operation will completed in sequence - #1 goes first, followed by #2, #3, #4, and #5.  Operation number #5 is the final step and the finished goods will be placed in the packaging (cup) provided.

B) Second, will be an assembly process
   - This will be performed as a class.
   - There will be 9 workers and 1 observer/inspectors.
   - This is a 3 step operation, with three potential products.

C) ~~Third will be a study in variation that will have a computer simulation for completion at home.~~

We will be using standard die and tokens.   The tokens represent raw materials, as it moves through the process to become a finished good.

## EXTRA CREDIT – 10 points

**Due Date:**    December 14, 2016

Perform Game #3 (pages 10-12).   Turn in table (page 12) and post lab questions (pages 10-11).

**Laboratory Exercise:**

**Game 1 (courtesy - Washington State University)**

There will be one team.  Each team will contain 5 workers and five observer/inspectors.

**Round #1**
1. Worker #1 will roll the die and remove the number of tokens from raw material inventory, placing these on the paper designated "Output #1"
2. Worker #2 will roll their die and remove that number of tokens from "Output #1" and place them on "Output #2".  If there are not enough, take as many as there are available.
3. Worker #3 will roll their die and remove that number of tokens from "Output #2" and place them on "Output #3".  If there are not enough, take as many as there are available.
4. Worker #4 will roll their die and remove that number of tokens from "Output #3" and place them on "Output #4".  If there are not enough, take as many as there are available.
5. Worker #5 will roll their die and remove that number of tokens from "Output #4" and place them in the Finished Goods cup.   If there are not enough, take as many as there are available.
6. Day One is now complete.
7. Repeat for 9 more rounds.

**Discussion Round #1:**
1. Record the following results on the board.  Do not count finished goods yet.
    Number of workers with less than 30 total
    Number of workers with  30 – 34
    Number of workers with 35 – 40
    Number of workers with greater than 40

2. How well did you do?
    a. Did each worker on the team achieve their potential (moved as many tokens as the number on the die)?
    b. Who performed to their potential and who did not?
    c. What should we do with the poor performers?

3. Now count number of finished goods in the cup and work-in-progress (WIP).  Record these also on the board.

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**Traditional Push System – Data collection (Round #1)**

STATION # _____            OPERATOR _____

| Day | Starting Inventory | Die Roll | Number Moved | Enough Available? |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Total | | | | |

**Round #2 - WIP will remain as it was when finished.**

1.  Worker #1 will roll the die and remove the number of tokens from raw material inventory, placing these on the paper designated "Output #1"
2.  Worker #2 will roll their die and remove that number of tokens from "Output #1" and place them on "Output #2".  If there are not enough, take as many as there are available.
3.  Worker #3 will roll their die and remove that number of tokens from "Output #2" and place them on "Output #3".  If there are not enough, take as many as there are available.
4.  Worker #4 will roll their die and remove that number of tokens from "Output #3" and place them on "Output #4".  If there are not enough, take as many as there are available.
5.  Worker #5 will roll their die and remove that number of tokens from "Output #4" and place them in the Finished Goods cup.   If there are not enough, take as many as there are available.
6.  Day One is now complete.
7.  Repeat for 9 more rounds.

**Discussion Round #2 (cont.):**

4.  Record the following results on the board.  Do not count finished goods yet.
    Number of workers with less than 30 totals
    Number of workers with 30 – 34
    Number of workers with 35 – 40
    Number of workers with greater than 40

5.  How well did you do?
    a.  Did each worker on the team achieve their potential (moved as many tokens as the number on the die)?
    b.  Who performed to their potential and who did not?
    c.  What should we do with the poor performers?

6.  Now count number of finished goods in the cup and work-in-progress (WIP).  Record these also on the board.

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Traditional Push System – Data collection (Round #2, with inventory from Round 1)

STATION #   _____          OPERATOR _____

| Day | Starting Inventory | Die Roll | Number Moved | Enough Available? |
|-----|-------------------|----------|--------------|-------------------|
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |
| Total | | | | |

**Round #3 - Everyone starts with same WIP**

1. Worker #1 will roll the die and remove the number of tokens from raw material inventory, placing these on the paper designated "Output #1"
2. Worker #2 will roll their die and remove that number of tokens from "Output #1" and place them on "Output #2".  If there are not enough, take as many as there are available.
3. Worker #3 will roll their die and remove that number of tokens from "Output #2" and place them on "Output #3".  If there are not enough, take as many as there are available.
4. Worker #4 will roll their die and remove that number of tokens from "Output #3" and place them on "Output #4".  If there are not enough, take as many as there are available.
5. Worker #5 will roll their die and remove that number of tokens from "Output #4" and place them in the Finished Goods cup.   If there are not enough, take as many as there are available.
6. Day One is now complete.
7. Repeat for 11 more rounds.

**Discussion (cont.):**

7. Record the following results on the board.  Do not count finished goods yet.
   Number of workers with less than 60 totals
   Number of workers with 60 - 68
   Number of workers with 70 - 80
   Number of workers with greater than 80

8. How well did you do?
   a. Did each worker on the team achieve their potential (moved as many tokens as the number on the die)?
   b. Who performed to their potential and who did not?
   c. What should we do with the poor performers?

9. Now count number of finished goods in the cup and work-in-progress (WIP).  Record these also on the board.

Traditional Push System – Data collection (Round #3, everyone starts with 6)

STATION #   _____          OPERATOR _____

| Day | Starting Inventory | Die Roll | Number Moved | Enough Available? |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |
| Total | | | | |

**Game 2 (courtesy - Washington State University)**

The set-up will be as follows:
  4 raw material stations
  2 intermediate (WIP) stations
  3 Finished good stations

Each worker will be provided one die.

The operation will be performed sequentially as described below:

1. Workers #1, #2, #3 and #4 will roll their die and place the results on the their respective "output " sheets.
2. Worker #5 will "assemble" the intermediate product.   The product contains one each of #1 and #2. The worker will roll the die and assemble the number of products required.  If there is an insufficient quantity of either #1 or #2, assemble as many as possible   The assemblies will be placed on the "output #5" sheet.
3. Worker #6 will "assemble" a second intermediate product.   The product contains one each of #3 and #4. The worker will roll the die and assemble the number of products required.  If there is an insufficient quantity of either #3 or #4, assemble as many as possible   The assemblies will be placed on the "output #6" sheet.
4. Worker #7 will assemble the first Finished Good.   This is simply the product manufactured by Worker #5. The worker will roll the die and move the quantity to "output #7".  If there are not enough assemblies, move as many as possible.
5. Worker #8 will assemble the third Finished Good.   This is simply the product manufactured by Worker #6. The worker will roll the die and move the quantity to "output #8".  If there are not enough assemblies, move as many as possible.
6. Worker #9 will assemble the second Finished Good.  This is a combination of both Output #5 & #6.  The worker will roll the die and move the quantity to "output #9".  If there are not enough assemblies, move as many as possible.

  This is the completion of Day #1.
  Repeat for 9 more days.

Discussion:

How well did the team do?
   a. Did each worker on the team achieve their potential (moved as many tokens as the number on the die)?
   b. Who performed to their potential and who did not?
   c. What should we do with the poor performers?
   d. Where are the bottlenecks?
   e. Would changing the sequence of Steps 4-6 make a difference?
   f. Would additional die at any of the steps be beneficial?  Why? and Where?

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**Assembly Process – Data collection**
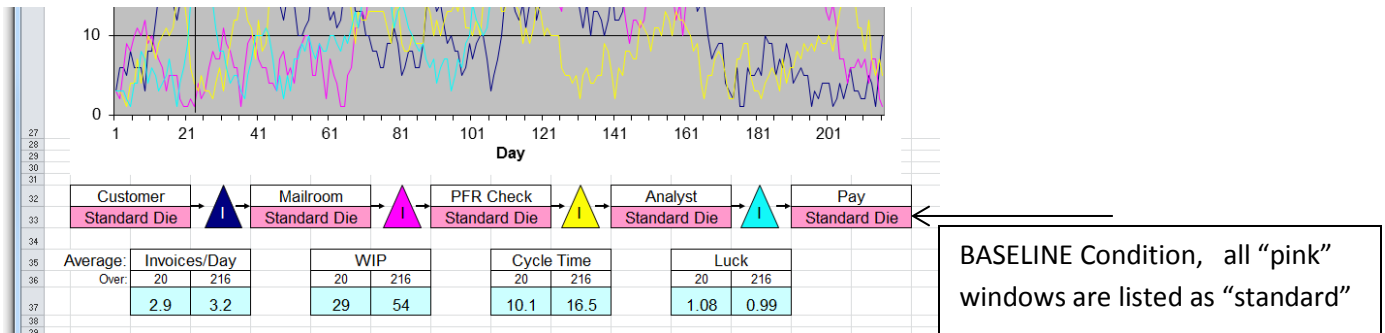
STATION #   _____                    OPERATOR _____

| Day | Starting Inventory | Die Roll | Number Moved | Enough Available? |
|-----|--------------------|----------|--------------|-------------------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Total | | | | |

**Game 3 (courtesy – MIT Open Course Work)**

**POST LAB**

The lean simulator – MIT, contained on blackboard will be used for the following question, comparing:
- Process output  (invoices/day)
- Inventory buildup (WIP)
- Turn-around-time (cycle time)

Baseline - "standard die" is visible in all the pink windows (see screenshot).



Use the attached data sheet for recording your results

What happens when:

    A)  A bottleneck is created by reducing the capacity at one of the stations?

        Select and change one (Mailroom, PFR check, Analyst, or Pay) to "Ave. reduced 30%"

        Record Invoices/day, WIP and Cycle time
        Was there significant change in the graph?

        Return sheet to baseline

    B)  Customer order variation is reduced?

        Select and change Customer to "var. reduced 70%"

        Record Invoices/day, WIP and Cycle time
        Was there significant change in the graph?

        Return sheet to baseline

    C)  Reduced customer demand?

        Select and change Customer to "Ave. reduced 20%"

        Record Invoices/day, WIP and Cycle time
        Was there significant change in the graph?

        Return sheet to baseline

D) Reduced total variation?

    Change all pink windows to "var. reduced 70%"

    Record Invoices/day, WIP and Cycle time
    Was there significant change in the graph?

    Return sheet to baseline

E) Constant demand, with no change in variation?

    Select and change Customer to "Constant (3)", all others remain "Standard die"

    Record Invoices/day, WIP and Cycle time
    Was there significant change in the graph?

    Return sheet to baseline

F) Constant demand, with low variation?

    Select and change Customer to "Constant (3)"and all others to "Var. reduced 70%"

    Record Invoices/day, WIP and Cycle time
    Was there significant change in the graph?

    Return sheet to baseline


**Is there a balance between Inventory and Cycle Time?    Which condition would be ideal and why?**

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_____

_____

_____

_____

_____

_____

**DATA COLLECTION -  MIT Process Simulation**

| Condition | Output (Invoices /day) | Inventory (WIP) | Turn-around-time (Cycle Time) | Comments – Variability viewed in the graph |
|---|---|---|---|---|
| Baseline | | | | |
| A)  Bottleneck | | | | |
| B)  Reduced Order  variation | | | | |
| C)  Reduced Customer Demand | | | | |
| D)  Reduced Total Variation | | | | |
| E)  Constant Customer demand (no process change) | | | | |
| F)  Constant Demand w/Low Variation | | | | |