Fall 1999

Introduction to Industrial Engineering: Manufacturing Variability

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IE 150 Fall 1999	**Class Exercise 12: Manufacturing Variability**

Introduction

Suppose that as a group we were to take a 10 mile hike. If I could force all of you to walk *exactly* at 2 miles per hour (by yelling, money, threats, etc.), all of us would complete the hike in 5 hours. Unfortunately, this is unrealistic, and we can expect that several of you would finish before 5 hours (since you would walk faster than an average of 2 miles per hour) and others would finish after 5 hours (since you would walk slower than an average of 2 miles per hour).

Consider a manufacturing line in which one station feeds into another:

In planning the production of this type of system, one would want movement of parts to be constant. For example, all stations take the same amount of time and parts move from station to station.

Such an approach would have capability exactly matched to demand and as a result there would be minimal work-in-process (WIP).

Unfortunately, most production systems are impacted by *variation* in processing times and operations (*e.g.*, not all of you walk 2 miles per hour). As a result, developing a balanced production line is not as easy as it appears.

The Game

The production system we will consider is intended to process pennies. It does this by processing (moving) a quantity of pennies thought production stations (plates) in succession. A roll of a dice determines how many pennies can be moved from one plate to the next. The dice represents the capacity of each plate (*i.e.*, the capacity of each processing station), where each plate is a stage in the penny processing. Each has exactly the same capacity as the others, but its actual yield will fluctuate somewhat.

Throughput in this system is the speed at which pennies come out of the last plate. *Inventory* consists of the total number of pennies in all the plates at any time. We will assume that market demand is exactly equal to the average number of pennies that the system can produce.

The idea is to move as many pennies as you can from the plate to your left to the your plate. When it's you turn, you roll the die and the number that comes up is the number of pennies you can move. But, you can only move as many pennies as you have on you plate. So if you roll a 5 and you only have 2 pennies on your plate, then you can only move 2 pennies. And if it comes to your turn and you don't have any pennies, then naturally you cannot move any.

How many pennies do you think move through the line each day (i.e., all production stations)? That is, if you are able to process a maximum of 6 and a minimum of 1 during your daily production, what's the average number that you ought to be able to process/move?

So, how many pennies do you think you should have moves after 10 days? After 20 days?

Recording Information

Operation Performance for Work Station # ______

Roll Number (Day number)	**Actual Roll**	**Pennies Moved**	**Station WIP** (end of day)	**System WIP** (end of day)	**System Output** (end of day)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Results

If things worked out like I expected, you will find that throughput is down, inventory went up, and operating expenses increase (suppose we had a carrying cost on pennies).

How many pennies did the plant manage to ship (we expected 35)?

Note that this is nowhere near the maximum potential of each station. If this has been a real manufacturing system, many of out orders would have been late. We'd never be able to promise specific delivery dates. And if we did that, out credibility with customers would drop through the floor.

Why Did It Happen?

Why didn't the balanced production system work?

As a result, a key area of industrial engineering – manufacturing systems – is concerned with determining the production capability of production lines and controlling the variation of the process.

What solution would you propose?

IE 150 Fall 1999	Class Exercise 14: Manufacturing Variability – Part 2

Introduction

As we saw last class, whenever the output of our plant is less than the expected or required amount, we often result to the use of overtime. However, this is done in a reactionary fashion and does not increase shipments to the degree expect – though it does help. *What it does not consider is how overtime impacts worker moral and safety.*

Let's play the game again, and change the results of a roll of the die. If the die roll returns at 1, 2, or 3, then you attempt to move 2 pennies. If the die roll return a 4, 5, or 6, then you attempt to move 4 pennies. For a given roll, you will again expect to move an average of 3.5 pennies.

Note: average = (3+3+3+4+4+4)/6 = 3.5.

Over ten rolls, one would expect to still move and process 35 pennies. Let's see what happens to our game…

Recording Information

Operation Performance for Work Station # ______

Roll Number (Day number)	**Actual Roll**	**Pennies Moved**	**Station WIP** (end of day)	**System WIP** (end of day)	**System Output** (end of day)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Results

If thing work out like I expected, your production output was probably pretty close to the 10 day quota of 35 pennies. Why?

A New Game

Given the last example, it would seem reasonable that one should be concerned about reducing the processing variability of a station. Unfortunately, this is only partly true. Let's examine the roll of a bottlenecks in a manufacturing system. For this game, if **station 2** in the line rolls a 1, 2, or 3, then this person attempts to move **2** pennies. If **station 2** rolls a 4, 5, or 6, then this person attempts to move **3** pennies. **All other stations** attempt to move whatever they roll. Note that we are in essence giving station 2 less processing capacity than all the other stations. At best, station 2 can produce 3 pennies per day, whereas the other stations can produce 6 pennies per day. Let's see how this impacts the results:

Recording Information

Operation Performance for Work Station # ______

Roll Number (Day number)	**Actual Roll**	**Pennies Moved**	**Station WIP** (end of day)	**System WIP** (end of day)	**System Output** (end of day)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Results

In general, what did you observe?

General Conclusions

Here are some general observations you can make about manufacturing systems:

- even in a balanced system, bottlenecks can occur (game 1)
- To help the bottleneck, extra capacity is needed to make-up for the lost production
- Overtime is reactionary and depending upon where it falls in the system, does not necessarily help
  - Early station in line – little help – just shifts the problem
  - Towards end of line – gets product out the door
- A bottleneck at the beginning of the process starved the rest of the line. Not bad, just do not plan for 100% utilization of upstream stations
- A bottleneck at the end of the process causes WIP to build up in front of it (great way of identifying the bottleneck)