Understanding Lean Principles that *Dramatically* Impact Process Performance

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Some Lean Principles

• Little’s Law – drives consistency in process’ cycle time and allows rapid re-prioritization
• Process Flow – balances the work load to increase throughput with same resources
• Set-up time reduction – provides greater productivity, revenue & profits from expensive assets and/or constrained resources
• Waste Identification & Elimination – reduces non-value added operations
Key Lean Concepts

**Process Cycle Time**

Goal: 
Reduce

**Cycle Time Interval**

Goal: 
Reduce cycle time, 
Increase no. of cycles, 
Decrease amount in each

**Throughput (Capacity)**

Goal: 
Increase

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Key Lean Definitions

• The following definitions are used in describing the velocity, efficiency, throughput, and capacity of a process:
  – **Process Cycle Time (PCT):** the time from when something or someone enters a process until that item is completed or that person is finished
  – **Work In Process (WIP):** items or persons that are within the boundaries of the process
  – **Exit Rate (Throughput):** the output of a process over a defined period of time
Key Lean Definitions (cont’d.)

• The following terms are used frequently to quantitatively describe the output of a process:
  – **Capacity**: the maximum amount of output a process can deliver over a continuous period of time
  – **Time Trap (Bottleneck)**: the operation or step that inserts the largest amount of time delay into a process. (There can only be one time trap at a time in a process and it controls the exit rate from the process)
  – **Constraint**: a time trap that is unable to produce at the exit rate required to meet customer demand
Traditional Processes:
Lots of Stuff in Process = Long Cycle Times
**Lean Processes:**

Time Trap Resolution Reduces WIP and PCT
Relationship Between WIP, PCT and Throughput

• Little’s Law* describes the relationship between WIP, PCT, and Throughput (also known as the Exit Rate):

  \[ \text{PCT} = \frac{\text{WIP}}{\text{Exit Rate}} \]

• This is the most fundamental relationship for any process (the “F = ma”, Force = Mass \times Acceleration – accepted law of physics)

• Used to size the inventory, people, paperwork, projects – in any process, no matter what it handles!

• Shorter Cycle Times = More “Learning Cycles” (Learning Cycles = no. of instances to learn about my process)

*John D. C. Little
Cycle Time = WIP / Exit Rate
“Your Amusement Park Experience”

- Think about the lines at Disney World in March...

\[ \text{Cycle Time} = \frac{\text{WIP}}{\text{Exit Rate}} = \frac{5}{1/\text{minute}} \]

\[ \text{Cycle Time} = 5 \text{ minutes} \]

- ...and then think about them in July...

\[ \text{Cycle Time} = \frac{\text{WIP}}{\text{Exit Rate}} = \frac{13}{1/\text{minute}} \]

\[ \text{Cycle Time} = 13 \text{ minutes} \]

- ...conclusion: Fixed Capacity (Exit Rate) + Increased People (WIP) = Slower Cycle Times (PCT)!
A Project Management Example

- **Traditional Approach:** Start all projects at once. Have each resource (4 in total) split their time evenly between 2 projects (each requiring 30 man-days of work).

- **Lean Approach:** Minimize the number of projects in process at any point in time. Team 2 people on a project.
Cycle Time ≠ Throughput (Capacity)

- Cycle Time = WIP / Exit Rate: A reduction in cycle time does not directly yield an increase in capacity
- An increase in capacity is obtained by decreasing the process time of the bottleneck operation/step

1. **Present State**
   - Assumes WIP Cap = 6 items
   - Bottleneck = 10 minutes
   - Capacity = 6 items/hour (1 item every 10 mins)
   - PCT = 6 items / 6 items per hour = 1 hour

2. **WIP Reduction**
   - Assumes WIP Cap = 3 items
   - Bottleneck = 10 minutes
   - Capacity = 6 items/hour (no improvement)
   - PCT = 3 items / 6 items per hour = 30 minutes

3. **Capacity Increase**
   - Assumes WIP Cap = 3 items
   - Bottleneck = 7 minutes
   - Capacity = 8.5 items/hour (1 item every 7 mins)
   - PCT = 3 items / 8.5 items per hour = 21 minutes
Cycle Time Effect on Capacity

• Cycle Time indirectly influences Throughput (and thus Capacity) by:
  – Increasing Labor and Constrained Resource Productivity:
    • Fewer items and/or persons being processed at one time by the process
  – Less Lost Paperwork, Information more easily traceable:
    • Fewer patients and patient information at any point in time, less confusion
    • Mistakes easier to catch, caught more quickly
  – Increase in Accuracy and Timeliness (decrease in mistakes; greater ability to recover quickly when they do occur):
Lean Supply Chain

- Faster feedback on process performance (increased learning cycles)
- Improved first pass yield (results in improved productivity)
- Improved process stability (results in improved throughput)
- Uncovers process deficiencies (forces problem resolution)
- Less in-process & buffer inventories (reduced risk of things being overlooked)
- Improved customer satisfaction (flexibility and responsiveness)
What is our Goal?

• The goal of Lean Six Sigma Improvement projects is to reduce variability in, and improve the speed of, a process.
  – Controlling and reducing Cycle Time, and cycle time variability, will generate faster feedback cycles on improvement projects (increase process velocity and, thus, more cycles of learning).
  – In addition, controlling and reducing cycle time (and cycle time variability) is a key driver for:
    • Increasing utilization of expensive capital resources
    • Facilitating productivity and capacity improvements
    • Remember: reducing cycle time shows us “where the rocks are!”
More Lean Definitions

• The following definitions are used in Lean Six Sigma to describe the relationship between the velocity and efficiency of a process:
  – **Process Cycle Efficiency (PCE):** the efficiency of a process is based upon the time in which value is added versus the total amount of time spent in the process
  – **Value-Add Time (VA Time):** the amount of time that value is actually applied to a product while it is “in process”
Why Cycle Efficiency Matters

“Any process with low cycle efficiency will have great opportunities for cost reduction (and increases in service level). Most processes whether in service, business, transactional, or product development run at cycle efficiencies of less than 10%. The result of this (are) hidden costs in overhead, rework, invested capital...and unhappy customers.”

Process Cycle Efficiency

Process Cycle Efficiency = \frac{"Customer Value Add" \, Time}{Process Cycle Time}

PCE = \frac{VA \, Time}{PCT}
Exercise:
Determine Process Cycle Efficiency

Process Cycle Efficiency = \frac{"Customer Valued" \ Process Time}{Total \ Observed \ Process Cycle \ Time}

• Transactional Example

In analyzing the billing operations of a hospital, it was noted that the bill goes through 9 steps, and the average “touch time” per bill was 19 minutes. Over a week’s time, 30 bills were time stamped going into the process and again as they left the process. The average time they were in the process was 3.75 days (7 working hrs. per day).

The PCE was \frac{.32}{3.75 \times 7} = \frac{.32}{26.25} = 1.22\%
Process Sizing

Variables:

• **WIP** – Patients, Receivables, Documents, Inventory
• **Exit Rate** – The customer required output, expressed in Items/Time (equal to the rate of the constraining operation)
• **Process Cycle Time** – Current cycle time, Requirement cycle time, Theoretical cycle time

\[
PCT = \frac{WIP}{\text{Exit Rate}}
\]
\[
\text{Exit Rate} = \frac{WIP}{PCT}
\]
**Example:**

- A regional medical system issues approximately 1500 PO’s per week to its suppliers. It has been determined the average value-add time for a PO is 30 minutes. Assuming a buyer is 75% efficient, how many buyers are required to issue PO’s?
Process Sizing Example

**Given:**
- Exit Rate = 1,500 / week
  - = 37.5 / hour (40 hr week)
  - = 0.625 / minute
- VA Time = 30 minutes/PO
- PCE = 75%

**Solution:**

PCE = “Customer Value Add” Time

\[ \frac{1}{\text{Process Cycle Time}} \]

\[ \text{PCT} = \frac{\text{“Customer Value Add” Time}}{\text{PCE}} = \frac{30 \text{ min.}}{0.75} = 40 \text{ minutes} \]

Buyers Required = (Exit Rate x PCT) / Working Hours per Buyer

\[
\begin{align*}
\text{Buyers Required} &= \frac{1,500 \text{ per wk} \times 40 \text{ min.}}{40 \text{ hours}} \\
&= \frac{60,000 \text{ min.s per week}}{2,400 \text{ min.s}} \\
&= 25 \text{ Buyers}
\end{align*}
\]
What About Variability?

“We have tended to use all our energy and Six Sigma science to move the mean [delivery time] to...12 days.

The problem is, as has been said, ‘the mean never happens,’ and the customer is still seeing variances in when the deliveries actually occur – a heroic 4-day delivery time on one order, with an awful 20-day delay on another, and no real consistency...

Variation is evil.” – Jack Welch, 1998
Can We Tolerate Variability?

- There will always be some variation present
- We can tolerate this variation if:
  - The process is on target, meeting performance specs.
  - The variation is small compared to the process specs.
  - The process is stable over time.
- However, as variability increases, cycle time increases.
- We need to recognize that variation should be minimized - the key is not just moving the mean, but reducing the span as well.
Reduction in Cycle Time Variation Gives Additional Utilization of Scare Resources

**Ratio of Wait Time to Actual (Value-Added) Time per Item or per Patient**

Results based on over 5000 simulation runs of an 11 station, single part workstation

R\(^2\) = 0.8723

R\(^2\) = 0.8908

R\(^2\) = 0.8162

Utilization Percent

Wait Time/Service Time

60% 70% 80% 90% 100%
Why Use Work Control Systems?

• Stabilize processes to make it easier to apply analysis and improvement tools (Six Sigma and Lean tools)

• Control and reduce the number of items in a process, allowing sharper focus on problem areas (less “stuff” to get in the way of analysis efforts)

• Control and reduce Cycle Time to generate faster feedback cycles on improvement projects (increase process speed and thus cycles of learning)

The primary goals of a work control system are to stabilize and then reduce process cycle time and cycle time variability

Work Control Systems limit the amount of “Stuff in Process” in order to control cycle time.

Governing Principle:

\[ \text{Start Rate} = \text{Exit Rate} \]
Work Control System Defined

Definition:

• A Work Control System establishes a **WIP Cap** on the amount of “stuff” within a predefined physical work area or process.

• To maintain the WIP Cap, the **Exits** from the process trigger **Starts** into the process.

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Establishing and maintaining the WIP Cap is the key to cycle time reduction!
The Power of a WIP Cap

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**Cycle Time**

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**No WIP Cap** - Cycle time fluctuates with the amount of WIP

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**Cycle Time**

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**With WIP Cap** - Cycle time is both: reduced & stable
Work Control System Benefits

• **Efficiency**: A pull system can attain the same throughput as a traditional push system, with less average WIP (and therefore, a shorter cycle time)

• **Productivity**: Less WIP means less “stuff” to get in the way, and thus more time spent adding value to the process

• **Ease of Control**: Pull systems rely on setting easily controllable WIP levels, creating a much more manageable process

• **Quality Improvement**: Low WIP (and associated cycle time) systems are more sensitive to quality (and therefore, force problem resolution) and facilitate it (by improving feedback and learning cycles)
Work Control Systems: Classic Example

- A classic example of a Work Control System is the admitting process at an Emergency Room:
  - Limited number of ER beds are available for patient use
  - As patients arrive, their status is assessed by ER doctors and each patient is assigned a priority
    - Critical patients are admitted into the process immediately – bed space and qualified resources may have to be “added” to accommodate surges in demand but will be removed as soon as possible
    - The “backlog” of patients is managed such that Marginal and Non-Critical patients are admitted as bed space is freed up
How to Size a Work Control System

1. Determine current Process Cycle Time (PCT)
2. Determine current Process Cycle Efficiency (PCE)
3. Identify appropriate target PCE
4. Calculate theoretical best PCT
5. Calculate WIP Cap
Step 1: Determine the Current Process Cycle Time (PCT)

- **PCT**: time from release of a product into a process until it’s completion, approximated by using Little’s Law

- **WIP**: “number of things in process” at any given time

- **EXIT RATE**: amount of work completed over a given period of time, which should also equal customer demand (“completions per hour”)

\[
PCT = \frac{\text{WIP}}{\text{EXIT RATE}}
\]
Example:

Step 1. Calculating Current PCT

WIP = Sum of all “things in process” = 100 orders

Our Example PCT is:

PCT = 100 orders / 20 orders per day
PCT = 5 days
Step 2. Determine the Current Process Cycle Efficiency (PCE)

**PCE**: measure of relative efficiency in a process - it represents the percentage of value-add time (changing form, fit, function) that a product experiences in its production.

$$PCE\% = \frac{\text{Value Add Time}}{\text{PCT}} \times 100$$

**PCE** is THE performance indicator for Work Control Systems.
Example:

Step 2. Calculating Current PCE

PCT = 5 days

Exit Rate = 20 units/day

WIP = Sum of all “things in process” = 100 units

Our Example PCE is:

PCE = 1.5 hrs / 5 days
PCE = 4.0%

Note: 7.5 hrs. per day
Step 3. Determine Target PCE

**Target PCE:** the Process Cycle Efficiency for a “world-class” environment by type of process (based on experience with over 100 companies).

<table>
<thead>
<tr>
<th>Application</th>
<th>Low End PCE (Typical PCE)</th>
<th>High End PCE (World-Class PCE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Processes (transactional)</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td>Business Processes (creative/cognitive)</td>
<td>5%</td>
<td>25%</td>
</tr>
<tr>
<td>Test/Continuous Process</td>
<td>30%</td>
<td>80%</td>
</tr>
</tbody>
</table>

**Rules of Thumb:**
- If current PCE << Low End Target, multiply current PCE by 10 for conservative Target
- If current PCE is < Low End Target, use Low End as Target PCE
- If current PCE ≥ or > Low End Target, use High End as Target PCE
Step 4. Calculate Theoretical Best PCT

Theoretical Best PCT is ...

…the “best” or lowest process cycle time achievable based on the process characteristics. It is measured as:

\[
PCT_{TB} = \frac{VA_{CP} \text{Time}}{\text{Target PCE}}
\]

VA\textsubscript{CP} is the value add time along the critical path. It does not include the value-add time of parallel process steps.

Our Example PCT\textsubscript{TB} is:

\[
PCT_{TB} = 1.5 \text{ hrs} / 0.1 = 15 \text{ hrs}
\]

\[
PCT_{TB} = 2.0 \text{ days}
\]
Step 5. Calculate the WIP Cap

The WIP Cap: determines the maximum WIP allowed within the process at any time. Measured as:

\[ \text{WIP Cap} = \text{PCT}_{TB} \times \text{Exit Rate} \]

Our Example WIP Cap is:

\[ \text{WIP Cap} = 2.0 \text{ days} \times 20 \text{ orders/day} \]
\[ \text{WIP Cap} = 40 \text{ orders} \]
Example:

Summary

Beginning State:

- PCT = 5 days
- Value Add time = 1.5 hrs
- PCE = 4.0%
- Exit Rate = 20 orders/day
- WIP Cap = 100 orders

Desired State:

- PCT = 2.0 days
- Value Add time = 1.5 hrs
- PCE = 10%
- Exit Rate = 20 orders/day
- WIP Cap = 40 orders

Remember that you can’t go from “Beginning” to “Desired” immediately – you have to transition to it at a reasonable pace!
How to Release WIP into a Work Control System

Release logic for Work Control Systems is all about discipline.

1. Count the WIP in your process
2. Determine if you can release work or not:
   – If the WIP $\geq$ WIP Cap, do not release any more work
   – If the WIP $<$ WIP Cap, release enough work to get to the WIP Cap or slightly above
Transitioning to WIP Cap

Typically the current WIP level will be significantly greater than the WIP Cap level. Therefore, a plan must be developed to reduce the WIP in steps.

<table>
<thead>
<tr>
<th>WIP Reduction Plan Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Current</td>
</tr>
<tr>
<td>Step 1</td>
</tr>
<tr>
<td>Step 2</td>
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<tr>
<td>Step 3</td>
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<tr>
<td>Step 4</td>
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</tbody>
</table>
Applying the Tools for Results

Lean Six Sigma Reduces Process Cycle Time and the Variation of Cycle Time for Overall Performance Improvement

Mean Delivery Time Reduced

Time Variation Reduced

Lead Time to Customer (days)
This is a Workshop

• That means we get to do some work and learn for ourselves about some of the Lean Principles

• Let’s get some experience with 2 Lean Principles
  – WIP Cap will stabilize our process’ cycle time
  – Balancing will allow us to accomplish more with the same resources
Alphabet Exercise Workshop

• Form teams of Five
• Explain Process
• Run Three Production Runs with and without WIP Cap
• Analyze Results
• Discuss Results
References

• Little, John D. C., “Tautologies, Models and Theories: Can We Find ‘Laws’ of Manufacturing?”, *IIE Transactions* 24:7 13

More about Prof. Little:
http://www.informs.org/Prizes/whoisLittle.html