RECOGNIZING AND MANAGING BOTTLENECKS IN PROCESS PLANTS

Peter L. King
Lean Dynamics, LLC
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Definition of a bottleneck
Bottlenecks in process plants
Capacity Constraint Resources (CCRs)
Finding the bottleneck ~ Value Stream Mapping
Root causes of bottlenecks
Bottleneck management ~ Theory of Constraints
Bottlenecks can move!
Successive bottlenecks
Additional examples
BOTTLENECK DEFINITION

- Any resource where capacity is less than or equal to Takt (rate)
- Any resource whose capacity is less than or equal to the demand place upon it
- Any process step with a utilization of 100% or greater

- The process step with the lowest capacity
WHY BOTTLENECKS REQUIRE ATTENTION

- A primary objective of Lean is to achieve smooth continuous flow
  - Bottlenecks restrict flow
- Bottlenecks cause inventory
  - Bottleneck management requires more inventory
- A bottleneck may prevent you from making Takt

Thus bottlenecks must be identified and opened up as much as practical
  - And bottlenecks must be very well managed
BOTTLENECKS IN PROCESS PLANTS
BOTTLENECKS IN PROCESS PLANTS

- In parts manufacture and assembly processes – people are often the limiting factor
- So managing bottlenecks focuses on people
  - Appropriate staffing
  - Task leveling
  - Judicious use of overtime, extra shifts
- In most process plants, throughput is limited by equipment - not by people
- So managing bottlenecks becomes optimization of the performance of the bottleneck step
Examples of process bottlenecks

- Paper making – lineal speed of the web processing equipment
- Paint manufacture – resin production batch time
- Synthetic fiber manufacturing – threadline windup speed or meter pump capacity
- Batch chemicals – reaction time
- Synthetic rubber – chemical reaction time, extrusion rates

Additional labor or overtime won’t help

Most plants are run 24 x 7, so running additional shifts is not an option
CAPACITY CONSTRAINTS

- Throughput can be limited by equipment design, by the inherent capacity or a piece of process equipment
- Throughput can be limited by a piece of equipment ‘s performance
  - Reliability issues
  - Yield losses
  - Changeover time
- Throughput can also be limited by equipment scheduling, and by how well flow is synchronized with other process steps
- A Capacity Constraint Resource (CCR) is defined as:

  Any resource which, if not properly scheduled and managed, is likely to cause the actual flow of product through the plant to deviate from the planned flow.

  *Synchronous Manufacturing*, Umble and Srikanth, 1990
CAPACITY CONSTRAINT IN CEREAL PLANT

SHAPE MANUFACTURING

FLAKE MANUFACTURING

STORAGE SILOS

PACKAGING

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Any resource that has enough effective capacity to meet customer demand — but can’t because of poor scheduling — is called a Capacity Constraint Resource.

- The VSM shows the packaging area at 75% Utilization
- Silos often fill up, so flake or shape production goes down
- The culprit is poor scheduling, no synchronization
One of the best tools for finding the bottlenecks in your process is a

VALUE STREAM MAP
**Example**

- A salad dressing line has weekly demand of 45,000 cases for the flavors made on that line
- Three eight-hour shifts per day, 5 days per week
- Production continues through lunch, breaks, shift changes
- Available time = $3 \times 8 \times 5 = 120$ hours/week
- Takt = 45,000 cases /120 hours = 375 cases/hour
- So the plant must produce 375 cases per hour to satisfy customer demand
The concept of Takt is that you want to synchronize your throughput to Takt

- You are meeting customer demand
  - With no overproduction
  - With minimal inventories

\[ Takt \text{ Rate} = \frac{\text{Customer demand}}{\text{Available time}} \]
Effective Capacity

- It represents realistic expectations, not perfection
- It should represent what we can realistically do today

Effective Capacity = \( \text{Max Demonstrated Rate (MDR)} \times \text{OEE} \)

- If the salad dressing line could pack 500 cases/hour on a perfect day
- And OEE (or UPtime) is 85%
- Then Effective Capacity is 425 cases/hour
Utilization

- A measure of how fully occupied a process step is, how busy it is

\[ \text{Utilization} = \frac{Takt \text{ rate}}{\text{Effective capacity}} \]

- If our salad dressing line has an effective capacity of 425 cases/hour
- Utilization = 375 cases per hour / 425 cases per hour
- Utilization = 88%

Utilization is a good indication of how close to a bottleneck any process step is
Root causes of bottlenecks can be diagnosed from the data boxes:

- This is a B/N!
- Machine failures are the primary culprit
- Changeover times also contribute to the constraint (11% of capacity)
- Both must be improved to resolve the B/N
This is also a B/N!

Yield and reliability are not the problem

Changeover times are the issue here – 22% of the available capacity is consumed in C/Os
Once a bottleneck has been identified, it is important to understand why it is a bottleneck.

The most common causes in process plants:

- Inherent equipment capacity limitations
- Mechanical or electrical reliability problems
- Yield losses
- Long changeovers
- Inappropriate scheduling or lack of synchronization (CCRs)
TYPICAL BOTTLENECK ROOT CAUSES

Based on a small sampling of VSMs from process plants
- Data boxes of bottleneck or near-bottleneck resources were studied for most significant root cause
- When more than one reason contributed, partial weight was given to each

Disclaimer: this is not based on any scientific, statistically valid study!
MANAGING
THE
BOTTLENECK
MANAGING THE BOTTLENECK

Once the bottleneck has been identified and its root cause(s) determined, it’s time to open it up, to increase flow.

If that can’t be done, at least make sure the bottleneck is not further constrained by limitations elsewhere in the process

*Theory of Constraints* is the best way to do this
CONSTRAINT MANAGEMENT PROCESS

IDENTIFY THE BOTTLENECK

EXPLOIT THE BOTTLENECK

SUBORDINATE EVERYTHING TO THE BOTTLENECK

ELEVATE THE BOTTLENECK CAPACITY

FIND THE NEXT BOTTLENECK AND REPEAT

Theory of Constraints
Eliyahu M. Goldratt, 1990
IDENTIFY THE BOTTLENECK

- Look for inventory
- Study the VSM
- Mathematical analysis (Excel, FlexSim)

EXPLOIT THE BOTTLENECK

- Make sure the B/N is running at max rates
- Reduce changeover times - SMED
- If CCR, improve flow synchronization

SUBORDINATE EVERYTHING TO THE BOTTLENECK

- Don’t let the B/N be constrained by upstream or downstream limitations

*Theory of Constraints* Eliyahu M. Goldratt, 1990
Where is the bottleneck?

What is the flow through the bottleneck?

48 GPM?

Wrong! The average flow is 39 GPM. \((48 \text{ GPM} \times 90\% \times 90\%)\)

The bottleneck resource suffers whenever there is an upstream or downstream interruption.
- Buffer inventories can alleviate the interaction
  - They can de-couple the various interruptions
- They won’t eliminate the bottleneck
  - But they will prevent the bottleneck flow from being further constrained
This should be kept full to feed Step B when Step A is down.

If max downtime duration on Step A is 2 hours….

Buffer should be ~ 5800 gallons

(2 hr x 60 min x 48 GPM)

This should be kept empty so that there is a place to put material from Step B while Step C is down.

How large should this buffer be?
CONSTRAINT MANAGEMENT PROCESS

- Increase the effective B/N capacity
  - Reduce Yield losses
  - Improve reliability – implement TPM
- Increase ideal capacity – modify the equipment

Once this B/N is no longer the B/N
- Find the new B/N
- There is usually a B/N!

Theory of Constraints Eliyahu M. Goldratt, 1990
MOVING BOTTLENECKS
The bottleneck may move as the process cycles through the various products being made.

- In his case, both forming and bonding have enough capacity to meet customer demand.
PRODUCT 432A

When forming products with very high basis weight, forming must run at slower lineal speeds - mass flow is the limiting factor

- Thus forming becomes the bottleneck when making these products
PRODUCT-SPECIFIC BOTTLENECK

### PRODUCT 4516F

For products that must be bonded at higher temperature, the bonder must run slower to allow more time in contact with the heated roll:

- So for these products, bonding becomes the bottleneck
PRODUCT-SPECIFIC BOTTLENECK

Other examples:

- Synthetic fiber production
  - Fiber winding is the B/N for very fine fibers
  - The metering pump is the B/N for thicker fibers

- Salad dressing and ketchup bottling lines
  - For larger bottles, the bottle filler will be the B/N
  - For smaller bottles, the label applicator may be the B/N
  - For very small cartons for convenience stores, the carton erector/filler may become the B/N
WHY DOES THIS MATTER?

PRODUCT 432A

PRODUCT 4516F

Doesn’t it all average out over time?

- Yes, but so does commuter traffic
  and you see what can happen during rush hour!
WHY DOES THIS MATTER?

The process runs at the rate of the slowest asset

- So you can’t catch up – things don’t average out!
- Buffering ala Theory of Constraints will minimize the consequences of moving bottlenecks
- **You must understand all of the steps that can be B/Ns – to make sure all buffers are in place**
Once the bottleneck has been opened, and is no longer a bottleneck, don’t assume that the process can now make Takt.

- There may be other steps which are bottlenecks – this may have been masked by the most obvious bottleneck
- An accurate VSM would have brought this to light
- However….. The primary bottleneck can restrict flow in a way that masks restrictions at other steps
- Or…… managers may be making assumptions about bottleneck locations without benefit of a VSM
The plant manager of a salad dressing production and bottling facility wanted to increase throughput on a sold-out line from 300 BPM to 400 BPM.

He and the plant engineer believed (correctly) that the bottleneck was in the bottle filling step – based on experience and intuition.

The technical staff developed a new filling nozzle, which could fill at the higher flow rate with no increase in pressure.

However, before fabricating a complete set of new nozzles, they developed a VSM.
EXAMPLE – SALAD DRESSING

BN #2

HOMOGENIZER

EFF CAPACITY 60 GPM
TAKT 75 GPM
UTILIZATION 125%
OEE 90%

SURGE TANK

BN #1

BOTTLE FILLING MACHINE

EFF CAPACITY 300 Bot/Min
TAKT 400 BPM
UTILIZATION 133%
OEE 85%

BN #3

BOTTLE CAPPER

EFF CAPACITY 500 BPM
TAKT 400 BPM
UTILIZATION 80%
OEE 94%

BN #4

BOTTLE LABELER

EFF CAPACITY 360 BPM
TAKT 400 BPM
UTILIZATION 111%
OEE 82%

CASE PACKER

EFF CAPACITY 33 cases/min
TAKT 34 cases/min

NOTE: All capacities and Takt are relative to 24 oz bottles, which is the primary size run on his line

Salad Dressing Bottle Filling Line

Current State VSM, with the higher Takt requirement
The plant manager of a salad dressing production and bottling facility wanted to increase throughput on a sold-out line from 300 BPM to 400 BPM.

He and the plant engineer believed (correctly) that the bottleneck was in the bottle filling step – based on experience and intuition.

The technical staff developed a new filling nozzle, which could fill at the higher flow rate with no increase in pressure.

However, before fabricating a complete set of new nozzles, they developed a VSM.

This revealed three other steps which would become bottlenecks as throughput approached 400 BPM.

The new nozzles would increase the bottle filler to 400 BPM, but line speed would only increase to 320BPM!
The cost of fitting the bottle filler with new nozzles was easily justifiable.

However, the cost of eliminating all 4 potential bottlenecks was not.

The decision was made to build a new line to handle the increased demand.

- This also provided additional capacity for future demand growth.

They ultimately would have gone that way.

- The VSM and bottleneck analysis got them to the right decision much sooner.
- And avoided the cost of a set of stainless steel nozzles.
Do you have any bottlenecks in your plant?

Is it clearly understood where they are?

How do you manage them?
MORE EXAMPLES OF BOTTLENECKS IN PROCESS PLANTS

1) Film slitters in a plastic film plant
2) Curing ovens in a electronics circuit board factory
X-RAY FILM MANUFACTURING EQUIPMENT CONFIGURATION

X-ray Casting Machine 1

X-ray Casting Machine 2

X-ray Casting Machine 3

Coater 1

Coater 2

Coater 3

Coater 4

Roll Slitting Machine 1

Roll Slitting Machine 2

Roll Slitting Machine 3

Chopper 1

Chopper 2

Chopper 3

Chopper 4

Chopper 5

Pouching, Boxing, Palletizing
Is there a bottleneck?

- Theoretically each step should have more than enough capacity to handle the throughput

- Especially the slitters - Utilization is ~ 70%

- But flow can’t match demand

- The Value Stream Map showed the Slitter OEE to be 60%

- Root causes
  - Slitters had low maintenance priority
  - TPM wasn’t being practiced
  - PMs weren’t being done
Solution

- Give slitters an equal priority for maintenance
- Implement TPM

Result

- Slitter Utilization > 85%
- Slitters no longer a bottleneck
- Flow matches demand
2 – CURING OVENS – ELECTRONIC SUBSTRATES

- Ovens (2) have a 12 hour curing cycle
- Ovens are very much the bottleneck
- Oven utilization ~ 100%
- Next is the Laminator, at 75%

- OEE on the Laminator and Edge Trimmer is good, = 90%
- But that means they are down 10% of the time each
Solution – put buffers in front of and after the Bottleneck

- That won’t relieve the bottleneck
  – it’s still the bottleneck
- But at least it won’t suffer from Laminator or Trimmer downtime
Bottlenecks matter!
- They constrain material flow
- They prevent you from meeting customer demand
- They require inventory

Bottlenecks in process plants are usually the equipment, not staffing
- Adding people won’t help, nor will overtime, extra shifts
- So you must confront the root causes

Opening the bottleneck requires performance improvement
- Yield improvement
- Reliability improvement (TPM)
- Changeover reduction (SMED)

Whenever there are bottlenecks, Theory of Constraints should be applied
The material in this presentation is featured in

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Questions?

peterking@LeanDynamics.us

(302) 239-1667
(302) 528-2700
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