Buffer Management in context

Presented By:  Dr Roy Stratton
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Key Supply Chain Elements (Goldratt, 2008)

1. Improving flow

2. Prevent overproduction
   - Ford used space; Ohno used inventory
   - Goldratt used aggregated buffers

3. Abolish local efficiencies

4. Focus activity to balance flow
   - Ford used direct observation.
   - Ohno used kanban removal
   - Goldratt used red zone signals.
Concept 2 (Goldratt, 2008; p19: modified)

- Insufficient Reaction time
- Management attention

Buffer (Work in progress)

Reduced variation – Ford and Ohno
Aggregate variation - Goldratt
Structure of presentation

• Buffer management
  – Aggregation of variation
  – Functions of BM

• Synergies with other approaches
  – The scientific method
  – Statistical Process Control
  – TPS (Kanban)

• Wider applications
  – Health

• Scientific Method
  – Synergies
  – Core conflict
Buffer Management
Aggregation of variability

- ‘The aggregated buffer is less than the sum of the parts’
- Buffer aggregation - key to the TOC applications
  - MTO - Drum Buffer Rope
    - Shipping buffer, Constraint buffer
  - ETO - Critical Chain Project Management
    - Project buffer, Feeder buffer
  - MTA - Distribution/replenishment solution
    - Plant warehouse
    - Network inventory buffers
Buffer Aggregation and DBR

Traditional Make To Order

Intermediate due dates protected by separate buffers

Due Date

Material Release

Manufacturing lead time (MLT)

time

Drum Buffer Rope

Buffer is aggregated: No intermediate due dates (Assumes touch time is not significant <10%)

Due Date

Material Release

Rope = MLT

time

Drum

Touch time:  Buffer:
Buffer Aggregation and Critical Chain

Critical Path Method

- 1(A)
- 2(B) → 4(C)
- 3(B) → 4(C)
- 5(D)

Critical path: 1(A) → 2(B) → 4(C) → 5(D)

Resources: A, B, C, D

Critical Chain

- 1(A) → 3(B) → 4(C) → 5(D)
- FB: Feeding Buffer
- PB: Project Buffer

Touch time: Buffer: Mixed:

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Buffer Aggregation and Distribution

The difference in variability of demand - supply point feeding 100 consumption points:

Notice the drop in variability with the number of consumption points:
Buffer Management

• TOC ICO 2007 Definition
  - Buffer management (BM) – A feedback mechanism used during the execution phase of operations, distribution, and project management that provides a means to prioritize work, to know when to expedite, to identify where protective capacity is insufficient, and to resize buffers when needed.

• TOCICO 2012 Definition
  - Buffer management (BM) - A control mechanism based on the amount of time (till the due date) or stock remaining used in the execution phase of TOC applications (operations, project and distribution). Buffer management consists of four main functions:
Buffer Management – 4 Functions

- **Prioritise** based on buffer penetration/consumption
- Signal when to **Expedite** individual tasks or orders
- Signal system instability and the need to **Escalate** urgent action or simply adjust system parameters.
- Identify prime causes of delay to **Target** continuous improvement.
Buffer Management – Function 1

Erlang Distribution

Buffer time (Rope)

Buffer origin (Drum)

Priority 1

Priority 2

Probability to finish

Time

Green

Yellow

Red
Buffer Management – Function 2

- **Green region**: 100%
- **Yellow region**: 5 - 10%
- **Red region**: Expediting
- **Rope/Buffer length**: Individual orders

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Buffer Management - Function 3

Growing red zone signals instability. **Escalate** immediate action.

- **Green region**: 100%
- **Yellow region**: 5 - 10%
- **Red region**: Growing red zone signals instability.
Buffer Management – Function 4

Target causes of red zone penetration

Cumulative Probability of completion

Green region

Yellow region

Red region

Rope/buffer length

100%

5 - 10%
Synergies with SPC
Synergies with SPC

‘The central problem of management in all its aspects, including planning procurement, manufacturing, research, sales, personnel, accounting and law, is to understand better the meaning of variation and to extract the information contained in variation.’

Deming, 1986, p20
Process control charting

Chances of a measurement point deviating from the average – assuming a normal distribution

- 68% of points
- 95.4% of points
- 99.7% of points

A standard deviation

\( \Sigma = \text{sigma} \)
SPC signalling system

Statistical Process Control Chart

Measure Of Quality

Outer tolerance value (specification limit)

3σ
Action limit

2σ
Warning limit

1σ

1σ

2σ
Warning limit

3σ
Action limit

Time
SPC and BM functions

- Gaining statistical control also applies to flow.
- In BM the level of stability is determined by the level of variation in combination with the level of buffering (inventory and capacity).
- Entry into the red zone is a warning signal - ensure there isn’t a ‘special cause’ and Expedite if necessary.
- Increasing red zone penetration (> 5-10%) signals system instability and the need to Escalate immediate action ‘special cause’.
- Causes of red zone penetration ‘common cause’ are analysed over time to Target improvement effort (e.g. set-up reduction, machine availability, process reliability, etc).
Synergies with TPS kanban
– In reality practicing these rules [the six rules of kanban] means nothing less than adopting the Toyota Production System as the management system of the whole company. (Ohno, 1988:41)
Ohno (1978) understood buffering

• ‘Just-in-time means that, in a flow process, the right parts needed in assembly, reaching the assembly line at the same time they are needed and only in the amount needed. A company establishing this approach throughout can approach zero inventories. From the standpoint of production management, this is an ideal state.’ (Ohno, 1988: 4)

• ‘The greater the fluctuations in quantity picked up, the more excess capacity is required by the earlier processes… Ideally, levelling should result in zero fluctuations in the final assembly line.’ (:36-37)
Shingo (1981) understood buffering

- ‘In a kanban system, semi-processed parts waiting between processes may take the place of minimum inventory in providing a cushioning effect. Fluctuation beyond a certain magnitude, however, cannot be absorbed in this fashion, and level production becomes necessary…Obviously, thorough consideration should be given to levelling production so that such fluctuations can be prevented.’ (Shingo, 1989: 187)
Kanban illustration

- One operation takes 3 minutes
- Inventory pile never goes above six
- One operation takes 3.1 minutes

- Operation 1
- Operation 2

- Give me six items
## Kanban functions/rules

<table>
<thead>
<tr>
<th>Functions of kanban</th>
<th>Kanban rules of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provides pick-up or transmission information.</td>
<td>1. Later process picks up the number of items indicated by the kanban at the earlier process.</td>
</tr>
<tr>
<td>2. Provides production information.</td>
<td>2. Earlier process produces items in the quantity and sequence indicated by the kanban.</td>
</tr>
<tr>
<td>3. Prevents over production and excessive transport.</td>
<td>3. No items are made or transported without a kanban.</td>
</tr>
<tr>
<td>4. Serves as a work order attached to goods.</td>
<td>4. Always attached a kanban to the goods.</td>
</tr>
<tr>
<td>5. Prevents defective products by identifying the process making the defectives.</td>
<td>5. Defective products are not sent on to the subsequent process. The result is 100% defect free goods.</td>
</tr>
<tr>
<td>6. Reveals existing problems and maintains inventory control.</td>
<td>6. Reducing the number of kanban increases their sensitivity.</td>
</tr>
</tbody>
</table>

The functions and rules of kanban (source: Ohno, 1988: 30)
Interpreting Ohno’s Functions

- Functions/rules 1, 2 and 4 are concerned with the transfer and production of information associated with standard predefined specifications, routings and transfer data.

- Function 3 is vital to the lean focus on Just-in-Time production and ensuring inventory between each work centre is kept to a predefined maximum level.

- Function 5 ensures the source of defects is made immediately visible, therefore ensuring rapid problem identification and resolution.

- Function 6 enforces continuous improvement. The number of kanbans in the replenishment cycle represents the inventory currently needed to ensure reliable supply. Reducing the number of kanbans reduces the buffer inventory and therefore time, so making the system more sensitive to problems in the drive towards perfection.
## Buffer Management (BM) and Kanban: Functional Comparison

<table>
<thead>
<tr>
<th>TBM Functions</th>
<th>Kanban Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prioritize</strong> - Provides relative priority based on planned completion time or availability rather than intermediate processing steps and inventory.</td>
<td>F1 – Pull intermediate inventory</td>
</tr>
<tr>
<td><strong>Choke material release (e.g. Rope)</strong></td>
<td>F2 – Pre-planned quantity and routing sequence</td>
</tr>
<tr>
<td><strong>Expedite</strong> - Proactive time based signalling of potentially late completion or shortages (red zone penetration).</td>
<td>F3 – Prevents over production at each stage</td>
</tr>
<tr>
<td><strong>Escalate</strong> - Proactive signalling of growing levels of expediting</td>
<td>F4 – Predefined works order data</td>
</tr>
<tr>
<td><strong>Target</strong>ing the repeated causes of expediting (red zone penetration) reduces the need for buffer (time or stock) and improves flow</td>
<td>F5 – Quality (variability in the process) signals immediate action.</td>
</tr>
<tr>
<td></td>
<td>F6 – Reducing the number of kanbans (inventory) is used to clearly expose causes of disruption to flow.</td>
</tr>
</tbody>
</table>
## Kanban and Buffer Management Assumptions

<table>
<thead>
<tr>
<th>TPS/Kanban assumes:</th>
<th>TBM assumes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predefined process steps</td>
<td>No predefined processing steps</td>
</tr>
<tr>
<td>Buffering is based on inventory and held at each</td>
<td>Buffering is based on time or stock and pooled</td>
</tr>
<tr>
<td>processing step</td>
<td></td>
</tr>
<tr>
<td>Process delays (quality problems) are not passed on to</td>
<td>‘Delays’ are only expedited when they threaten</td>
</tr>
<tr>
<td>the next process</td>
<td>delivery / availability</td>
</tr>
<tr>
<td>Level scheduling</td>
<td>Demand may vary, triggering (timely) escalation</td>
</tr>
<tr>
<td>Continual improvement is encouraged through reducing</td>
<td>Continual improvement is enabled by targeting</td>
</tr>
<tr>
<td>inventory to expose problems that are then targeted.</td>
<td>the causes of delay (e.g. red zone penetration)</td>
</tr>
<tr>
<td></td>
<td>then reducing the buffer.</td>
</tr>
</tbody>
</table>
Healthcare: Does it fit the assumptions?
Health and social care system - the chain of activities

- Emergency Room (ED)
- Medical Assessment Unit (MAU)
- Acute Care (Acute)
- Rehabilitation Hospital (Rehab)
- Social & Health Care
- Residential & Nursing Care (Residential & Nursing Care)

GP referrals → Ambulances → Outpatients → ED → MAU → Acute → Rehab → Home

Electives → Days

Minors
Buffer Management applications
(Stratton and Knight, 2010)

Buffer Management applications
(Stratton and Knight, 2010)
Buffer aggregation in healthcare

Emergency / Unplanned Care Pathway

Services e.g. diagnostics

Emergency Department

• Minors
• Majors
• Ambulance

Assessment Unit(s)

• In-Patient Wards
• In-Patient Wards
• In-Patient Wards

Discharge

• GP referrals
Scientific method: synergies and core conflict?
Scientific Method

Contribution

• **SS (Shewhart)**
  - Process control
  - PDSA Cycle

• **TPS (Ohno)**
  - Local causal predictions
  - Direct cause effect hypothesis test
  - Challenge local assumptions

• **TOC (Goldratt)**
  - System wide causal predictions
  - Core problem identification
  - Challenge global assumptions

Experiments to test prediction
Four rules of the TPS (Spear and Bowen, 1999)

• Rule 1  All work shall be highly specified as to content, sequence, timing, and outcome.

• Rule 2  Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses.

• Rule 3  The pathway for every product must be simple and direct.

• Rule 4  Any improvement must be in accordance with the scientific method, under the guidance of a teacher, the lowest possible level in the organisation.
Rule implications (Spears and Bowmen, 1999)

• Rule 3 – the pathway for every product and service must be simple and direct
  - ‘contrary to conventional wisdom about production lines and pooling resources’ (p7)
  - ‘By requiring that every pathway be specified, the rule ensures that an experiment will occur each time a path is used’ (p7).

• Rule 4 – any improvement must be made in accordance with the scientific method
  - Stresses the need to predict and then test hypotheses and with that challenge assumption (p8).
A Manage well.

B Reduce wasteful variation

C Manage variation

D Do not pool buffers

D Pool buffers

Because...

buffer aggregation masks the source of the variation

Because...

aggregation of variation reduces buffer requirements
Direction for improvement

• BM - function 4 has been largely ignored in the past
  – The emphasis was on the merits of buffer aggregation which was rapidly achieved.
  – More recently Eli emphasised the potential of targeting and incrementally reducing the variation.
  – To what extent does aggregation hide the source of the variation?

• Is more sophisticated data capture the answer?

• Can we stand on two shoulders to see further?
## Conclusion

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Six sigma</th>
<th>Lean</th>
<th>TOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Repeat process</td>
<td>Stable flow</td>
<td>Complex flow</td>
</tr>
<tr>
<td>Key word</td>
<td>Variation</td>
<td>Flow</td>
<td>Focus</td>
</tr>
<tr>
<td>Key assumption</td>
<td>Process variation drives both cost and quality.</td>
<td>Disruptions to flow drives buffering and waste</td>
<td>All systems exhibit inherent simplicity</td>
</tr>
<tr>
<td>Distinguishing Methodology</td>
<td>Plan, Do, Study, Act (Closely defined process flow supports hypothesis testing)</td>
<td>System level causal mapping of core conflict / challenge assumptions</td>
<td></td>
</tr>
<tr>
<td>Key change</td>
<td>Process variation</td>
<td>Disruption to flow</td>
<td>Management rules</td>
</tr>
<tr>
<td>Distinguishing improvement concept/tool</td>
<td>Statistical Process Control</td>
<td>Kanban control</td>
<td>Buffer management</td>
</tr>
<tr>
<td>Pre-requisite</td>
<td>Process data availability</td>
<td>Specify and simplify value streams</td>
<td>Aggregate buffers</td>
</tr>
</tbody>
</table>
Questions