TOC – a unifying theory?

Presented by: Dr Roy Stratton
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Structure

• Theory in Operations
  - Criteria for a good theory
  - Operations laws
  - Evaluation test (1 and 2)

• Theory Development
  - Cost sub-optimisation
  - Strategic choice (Skinner, Hayes, Wheelwright, Hill)
  - Continual improvement (Shewhart, Deming, Ohno)
  - Managing variation (Goldratt, TOC, Schmenner and Swink)

• Conclusion
  - TOC Evaluation
  - Application boundaries
  - So why is it not so widely embraced?
Theory in Operations
Knowledge is built on theory (Deming, 94)

- Rational prediction requires theory and builds knowledge through systematic revision and extension of theory based on comparison of prediction with observation.
  - ‘The barnyard rooster Chanticleer had a theory. He crowed every morning, putting forward all his energy and flapping his wings. The sun came up. The connection was clear: His crowing caused the sun to come up. There was no question about his importance.’

  ‘There came a snag. He forgot one morning to crow. The sun came up anyhow. Crestfallen, he saw his theory in need of revision.’

- Without his theory, he would have had nothing to revise, nothing to learn.
Criteria of a good theory

- **Explains** observed phenomena **simply**.
- **Predicts** cause and effect
- **Testable**
- **Useful** – “There is nothing so practical as a good theory” (Lewin, 1948)

- **Additionally**
- **Creative**, new insight (Lewis, 1998)
- Explains **the limitations of prior theory** (Schmenner and Swink, 1998)
- **Boundaries** of theory is defined (Whetten, 1989)
Theory Development  (Schmenner and Swink, 1998)

• 1  Identify and measure phenomena  
   (classification)
• 2  Observed regularities (logical or empirical)  
   (correlation)
• 3  Laws defining the regularity  
   (correlation)
• 4  Theory provides an explanation of the laws  
   (cause and effect)
   – Typically involving special terms or concepts
• 5  The more powerful the Theory  the better the unification of the laws and prediction that is testable.  
   (cause and effect)
Laws (empirical) of Ops Management

Law (trade-offs): A delivery system cannot simultaneously provide the highest levels of performance (quality, delivery lead time, delivery reliability, flexibility and cost) (Skinner, 1969 modified).

Law (focus): A delivery system that is aligned to a limited focus (e.g. order winning criteria or bottleneck) will be more productive than a similar delivery systems with a broader mission. (Skinner, 1974; Hill, 1985; Goldratt, 1984)

Law (cumulative capability): Improvement in delivery system performance is closely associated with developing capability cumulatively – first product quality, then process dependability, then speed, flexibility and finally cost. (Ferdows and De meyer, 1990)
Law (Variability): Increasing variability always degrades the performance of a delivery system. (Hopp and Spearman, 1995)

Law (Variability Buffering): Variability in a delivery system will be buffered by some combination of Inventory, Capacity and Time. (Hopp and Spearman, 1995)

Law (bottleneck): A resource with no buffer capacity dictates the delivery system throughput (and provides a focus for planning and control). (Goldratt, 1984 modified)

Law (variability pooling): Combining sources of variability so they can share a common buffer reduces the total amount of buffering required. (Hopp, 2008)
Evaluating TOC as a Theory

• **Test 1** *Explains the limitations of prior theory.*
  - Can the TOC 5 Focusing steps embrace wider systems theory / approaches?
    - Manufacturing Strategy; TQM; Lean

• **Test 2** *The more powerful the Theory the better the unification of the laws and prediction that is testable.*
  - Does TOC more fully explain the relationship between these laws?
Cost Based Operations Theory
Cost Optimisation: Quality

Cost

Failure costs

Total costs

Appraisal + prevention costs

0%

Acceptable Quality Level

100%

Quality
Cost Optimisation: Batch Size
(Harris 1915)

<table>
<thead>
<tr>
<th>Batch size</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Set-up cost</td>
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</table>

Economic Batch Quantity

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Manufacturing Strategy: Trade-off Driven Theory
Manufacturing Strategy: a systems view

Cost

Performance (quality, speed, etc)

Law of Trade-offs (1969)

Law of focus (1974)
The Cloud of Manufacturing Strategy

Acknowledging the strategic trade-offs

A Manage well

B Control cost

D Centralise the sub-functions

C Satisfy different market needs

D' Decentralise the sub-functions

Focused Factory (Skinner 1974)
Manufacturing Strategy: market demand is the limiting factor

1. **Identify** the system’s constraint(s)
   - *Order Winning Criteria (OWC)*
     - Law (focus) (Hill, 1985)

2. **Decide how to exploit** the system’s constraint(s)
   - *Focused factory concept*
     - Law (trade-offs) (Skinner, 1974)

3. **Subordinate** everything else to the above decision
   - *Align structural and infrastructural choices*
     - Law (trade-offs) (Skinner, 1969)
Infrastructural choice: reinterpreting the batching model (buffer choice)

- Law of focus (1974)
Continual Improvement: Quality Driven Theory
Cost Optimisation: Quality

Cost vs. Quality

- Failure costs
- Appraisal + prevention costs
- Total costs

0% - 100% Acceptable Quality Level
Revised model replace inspection with process improvement and control

Continual improvement

Cost

Total costs

Failure costs

Appraisal + Pretension cost

0%

100%

Law of variability

Law of cumulative capabilities (1990)
The cloud of operations (Quality)

Because...
Inspection is the only means of assuring quality

A Manage well
B Control cost
C Improve sales
D Optimise the level of defects
D' Continually reduce defects

A statistical process control.
Where quality (defects) are the limiting factor

1. Identify the system’s constraint(s)
   - OWC (product variation / defects)  
     - Law (focus)

2. Decide how to exploit the system’s constraint(s)
   - Process improvement (SS -DMAIC)  
     - Law (variability)

3. Subordinate everything else to the above decision
   - Statistical Process Control signalling  
     - Laws: (focus; variability)
   - Kaizen involvement of workforce  
     - Law (variability)
Continual Improvement: Lean Driven Theory
Just in Time (JIT)

Capacity Buffer required

Inventory Buffer resulting

Batch size

Law of variability buffering

Continual Improvement

Law of variability (process)

Law of variability buffering

Law of cumulative capabilities

Capacity Buffer required

Batch size

Inventory Buffer resulting

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Lean implementation steps at Toyota (Hopp, 2008: 91)

- ‘The machine-output ratio at Toyota Motors is two or three times that of similar companies. Indeed, for the same level of production, Toyota has far more equipment than other companies and this is one of its strengths.’ (Shingo, 1989: 72)

Eliminate direct waste

Substitute capacity for inventory buffer
Lean implementation steps at Toyota (Hopp, 2008: 91)

‘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.’ (Ohno, 1988: 36-37)
Theory of Swift and Even flow
(Schmenner and Swink, 1998)

- The more swift and even the flow of materials through a process, the more productive that process is.

  Thus productivity for any process rises with the speed by which materials flow through the process and it falls with increases in the variability associated with the flow, be that variability associated with demand on the process or the steps in the process itself.
The cloud of operations (lean flow)

Because...

Set-up time cannot be reduced
Inventory is an asset
Wasteful variation cannot be reduced
Buffering with capacity is a waste

A: Manage well
B: Control cost
C: Improved flow
D: Use inventory to optimise local performance (Push)
D': Minimise inventory (Pull)

Kanban control
Where (stable) flow is the limiting factor

• 1 Identify the system’s constraint(s)
  - (OWC) Manufacturing Lead time (JIT)  Law (focus)
• 2 Decide how to exploit the system’s constraint(s)
  - Reduce wasteful variation  Law (variability)
  - Utilise capacity buffer  Law (variability buffering)
• 3 Subordinate everything else to the above decision
  - Restructure around the value stream  Law (variability)
  - Pull (choke material release)  Law (variability buffering)
  - Kanban signalling  Laws (focus; variability & buffering)
  - Kaizen involvement of the workforce  Law (variability)
  - Cut batches (Reduce set-ups) (Shingo, 1989)  Law (variability)
Theory of Performance Frontiers: Integrated Theory
Theory of Performance Frontiers:
(Schmenner & Swink, 1998)

Law of trade-offs

Law of variability

Law of cumulative capabilities

Law of variability

Law of focus

Theory of swift and even flow

(Schmenner and Swink, 1998)
Managing Variability: TOC driven Theory
• Identify the system’s constraint(s)
  – *Time (CCR/Bottleneck)* Law (focus)

• Decide how to exploit the system’s constraint(s)
  – *Drum: close schedule CCR* Law (bottlenecks)
  – *Utilise buffer capacity* Law (variability buffering)

• Subordinate everything to the above decision.
  – *Choke material release* Law (variability buffering)
  – *Aggregate time buffer* Law (variability pooling)
  – *Buffer management* Laws (focus; variability; b’n’k; v. buffering)
  – *Cut batches* Law (variability)
Operations Management (MTO)
Simplified-Drum-Buffer-Rope (S-DBR)

• 1 Identify the system’s constraint(s)
  – (OWC) Time (operations lead time) Law (focus)

• 2 Decide how to exploit the systems constraint(s)
  – Drum: Market demand Law (focus)
  – Utilise available capacity buffer Law (variability buffering)

• 3 Subordinate everything to the above decision.
  – Choke material release Law (variability buffering)
  – Aggregate time buffer Law (variability pooling)
  – Buffer management Law (focus; variability; b’n’k; v. buffering)
  – Cut batches Law (variability)
  – Planned load Law (bottlenecks)
Project Management
Critical Chain Project Management (CCPM)

• 1 Identify the system’s constraint(s)
  – (OWC) Time (critical chain)  Law (focus)

• 2 Decide how to exploit the systems constraint(s)
  – Aggregate critical chain time buffers (project buffer)  Law (variability pooling)

• 3 Subordinate everything to the above decision.
  – Aggregate feeder buffers – protect non-critical tasks  Law (variability pooling)
  – Choke project release - reduce number of live projects  Law (variability buffering)
  – Update projected completions of live activities daily  Law (variability)
  – Buffer management  Law (focus; variability; var. buffering)
Conclusion
Theory of Performance Frontiers: integrating trade-off and continual improvement thinking

(Schmenner and Swink, 1998)
## Summary comparison using the TOC steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Man Stra</th>
<th>TQM/SS</th>
<th>TPS/Lean</th>
<th>DBR</th>
<th>SDBR</th>
<th>CCPM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> ID</td>
<td>-Order winning criteria</td>
<td>Variation (Defects)</td>
<td>-Time (ops lead time)</td>
<td>-Time (CCR / B’n’k)</td>
<td>-Time (ops lead time)</td>
<td>-Time (project)</td>
</tr>
<tr>
<td><strong>Step 2</strong> Exploit</td>
<td>-Focused factory</td>
<td>-Reduce process variation</td>
<td>-Reduce variation (waste) -utilise cap buffer</td>
<td>-Drum (CCR) -Utilise capacity buffer</td>
<td>-Drum (market) -Utilise capacity buffer</td>
<td>-Aggregate project buffer</td>
</tr>
<tr>
<td><strong>Step 3</strong> Subordinate</td>
<td>Restructure</td>
<td>Restructure -Pull(choke)</td>
<td>-Choke -Aggregate -BM</td>
<td>-Choke -Aggregate -BM</td>
<td>-Choke -Aggregate FB -BM</td>
<td></td>
</tr>
</tbody>
</table>

(Aggregate = Pooling)
Managing variation and uncertainty
(Hopp, 2008 modified)
Lean/SS vs TOC (Stratton 2012)

Because... buffer aggregation masks the source of the variation

A Manage well.

B Reduce wasteful variation

D Do not aggregate (pool) buffers

C Manage variation

D Aggregate (pool) buffers

Because... aggregation of variation reduces buffer requirements
Conclusions

• The TOC 5 steps have been shown to practically embrace the established systems theories and approaches (Test 1).

• The TOC 5 steps offer a theoretical explanation that encompasses all the cited laws (Test 2). This was not the case with the other approaches.

• The TOC applications notably extend the other theories/approaches by embracing the law of variability pooling through the use of buffer management.

• The management and reduction of different levels of variation and uncertainty helps define the boundaries associated with traditional TOC applications and the use of BM over other signalling systems.
Why is TOC not so widely embraced?

- TQM and Lean centre on local process improvement which is akin to the more familiar cost paradigm.
- Whereas BM is central to TOC, kanban is often treated as optional.
- Many applications of lean are based around a series of local improvement projects, such as Rapid Improvement Events (RIE) which are more readily adopted.
  - For example, Lean in healthcare is very dependent on RIE, however, due to no kanban equivalent the improvements are often not sustained. (Radnor et al., 2012)
- Lean is often cited but without a systems based signalling system in place is it really ‘lean’?
References

- Hopp W. (2008), *Supply Chain Science*
- Lewin, k. (1945), The research center for group dynamics at Massachusetts Institute of Technology. Sociometry 8, pp126-135.
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Roy is a Reader in Operations and Supply Chain Management and actively involved in TOC related teaching, research and consultancy. He is Director of the Centre for Performance Management and Lean Leadership and Director of studies of a number of TOC based doctoral students. His is also the Programme Manager of a portfolio of part time TOC based MSc courses delivered in collaboration with QFI Consulting. Previously, Roy worked for Rolls Royce Aero Engines in an internal consultancy role and has since been actively involved in a wide range of industry-based research projects. He has published widely in both professional and academic journals and has co-authored two educational books.

Roy is a chartered Engineer (F.I.Mech.E.) and has been awarded a BSc in Mechanical Engineering (Nottingham), an MSc in Manufacturing System Engineering (Warwick), and a PhD in Supply Chain Management (Nottingham Trent). He is certified in all TOC ICO fields.

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