The supply chain solutions of TOC:

Drum-Buffer Rope (DBR)
Simplified DBR (SDBR)
Distribution
Make to Availability (MTA)

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Presentation Structure

Systems thinking
- Understanding Dependent Flow
  - Lean (Kanban)
Buffer Rope (DBR)
- Simplified Drum Buffer Rope (S-DBR)
- Buffer Management
- Planned Load
- VATI

Distribution
- Make To Availability (MTA)
- Dynamic Buffer Management

Conclusion
From Cost to Systems Thinking

Analysis – Scientific reductionism
(Descartes, 1596-1650)
Take apart, understand, reassemble

Systems thinking (Von Bertalanffy, 1954)
- An approach to problem solving, by viewing "problems" as parts of an overall system
The Goal (Goldratt, 1984)

• This challenging of basic assumptions is essential to breakthroughs. Almost everyone who has worked in a plant is at least uneasy about the use of cost accounting efficiencies to control our actions. Yet few have challenged this sacred cow directly. Progress in understanding requires that we challenge basic assumptions about how the world is and why it is that way. If we can better understand our world and the principles that govern it, I suspect all our lives will be better.”

− Goldratt’s forward to The Goal (1984)
The Cloud of Operations
(Goldratt, 1999: Satellite Program viewer notes)

Because...
A resource standing idle is a major waste.

A  Be a good manager

B  Constantly fight to reduce waste

C  Constantly fight to increase flow

D  Use efficiencies as prime measurement

D’  Don’t use efficiencies as a measurement
TOC: The Five Steps of Focusing: the Value Focused (Throughput) Paradigm

1. Identify the system’s constraint(s)
   - (Improve Throughput (T))

2. Decide how to exploit the system’s constraint(s)
   - (Improve T)

3. Subordinate everything else to the above decision
   - Reducing variation reduces the levels of buffering (I) needed to protect T

4. Elevate the system’s constraint
   - (Improve T)

5. If in the previous steps a constraint has been broken, go back to step one.
   - Warning – don’t allow inertia to cause a system’s constraint.
     (Improve T)
UNDERSTANDING DEPENDENT FLOW
Operations Management Laws

Law (Little’s): \[ \text{Inventory} = \text{Throughput} \times \text{Flow Time} \] (Little, 1961)


Law (Variability Buffering): Variability in a delivery system will be buffered by some combination of Inventory, Capacity and Time (Hopp and Spearman, 1995, 2007).
Case 1  Should all resources work at 100%?

A dependent sequential process with no fluctuation

- Processing time per station is 10 min
- No buffers

What is the projected Throughput?
Case 2 Should all resources work at 100%?

A dependent sequential process with fluctuation

- Processing time per station averages 10 min
- No buffering

What is the effect on Throughput?
Case 3 Should all resources work at 100%?

A dependent sequential process with fluctuation

- Processing time per station averages 10 min
- With inventory buffers

What is the effect on Throughput? What has happened to the lead time?

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Case 4  Should all resources work at 100%?

A dependent sequential process with reduced fluctuation

- Processing time per station averages 10 min
- Reduced variation
- Reduced need for inventory

What is the effect on lead time?
Case 5  Should all resources work at 100%?

Lean thinking – reducing wasteful variation

- Processing time per station averages 10 min
- Reduced variation
- Reduced need for inventory
- Under capacity scheduling
Should all resources work at 100%?

TOC thinking – manage variation

- Processing time per station averages 10 min
- Acknowledge the role of buffer capacity
- Strategically manage buffers
- Target variation reduction

Distribution profile

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Marching soldiers analogy
(Goldratt and Fox, 1986)

Spreading troops means high inventory (long lead time)
Closely packed troops means lower inventory (short lead time)
Marching soldiers analogy (push)

- The traditional operations environment would have the separate soldiers (processes/ departments) work at their own rate (push).
- The first (gating) operation determines the level of WIP in the system.
Lean analogy of the KANBAN (pull)

- Rope tied between each pair of workstations
- All work at the same flow rate (takt time)
- Pace aligned with customer demand
• In DBR the rope simply controls the front row (raw material release) which in this case is tied directly to market demand (customer orders) leaving slack to protect overall pace.
Where there is a Capacity-Constrained Resource (CCR) this acts as the system Drum and has a detailed schedule (classic DBR). In this case the CCR Rope is tied to the front row.
A certain part of the shipping buffer is reserved for the last part leaving the CCR to be fully completed.

The CCR buffer is a certain fraction of the shipping buffer.

The order's due-date is protected by one shipping buffer, so all materials are released at the same time.

Capacity-constrained resource: CCR
Simplified Drum-Buffer-Rope (SDBR)

- With SDBR the market acts as the only drum with one rope and buffer (shipping).
- Promise dates to the customer may vary due to the overall load on the CCR (Planned Load).
Simplified Drum-Buffer-Rope (SDBR)

1 Rope and Buffer

In SDBR the CCR load needs to be carefully planned (Planned Load)
DBR/SDBR
BUFFER MANAGEMENT
The Functions of Buffer Management (DBR; SDBR)

1. Prioritise the flow of work
   - buffer penetration

2. Identify when to expedite potential delay.
   - Respond to individual red zone penetration

3. Signal when there is a need to escalate intervention.
   - Respond to significant and growing red zone penetration

4. Identify and target main sources of delay for improvement
   - Pareto analysis of causes of red zone penetration
Buffer Management (DBR; SDBR)

Skewed distribution

- Buffer time (Rope)
- Buffer origin (Drum)

- Green
- Yellow
- Red

Probability to finish

Time
Buffer Management – Function 1 (Prioritise)

- **Green**: Priority 1
- **Yellow**: Probability to finish
- **Red**: Priority 2

Buffer time (Rope)

Buffer origin (Drum)

Time

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Buffer Management – Function 2 (Expedite)

- **Green region**: 100%
- **Yellow region**: 5 - 10%
- **Red region**: Expedite individual orders

Cumulative Probability of completion vs. Rope/buffer length.
Buffer Management - Function 3 (Escalate)

Growing red zone signals instability
Escalate immediate action

- Green region: 5 - 10%
- Yellow region: 100%
- Red region: 100%

Cumulative Probability of completion
Rope/buffer length
Buffer Management – Function 4 (Target)

100%

Green region

Yellow region

Red region

Target causes of red zone penetration

Cumulative Probability of completion

Rope/buffer length

5 - 10%
SDBR
CCR PLANNED LOAD
In SDBR the CCR load needs to be carefully planned (Planned Load)
The planned load on the CCR is used to determine release and safe promise dates.

- Daily Load
- 50% of buffer
- 50% of buffer
- Full buffer
- Release point

We can safely deliver here.
Shipping buffer when the safe date is earlier than the standard lead time

- **release point**
- **full buffer**
- **Safe delivery**
- **Addition to the buffer**
- **We promise standard lead time**

**Time (days)**

**Daily Load**

**Standard lead time**
Committing to a Rapid Response Capability

- **Super fast**: Only this portion is free for allocation to normal orders.
- **Standard lead time**: Reserved for rapid response.
- **Fast**:
APPLYING THE 5 STEPS
Choking WIP release
(Goldratt, 2008; p19: modified)

Insufficient reaction time

Management attention

Jams, missed priorities

Buffer (Work in progress)

Reduced variation - Ford and Ohno
Aggregate variation - Goldratt
Buffer Aggregation & Buffer Management

Departmental performance protected by separate queues

Material Release

Buffer Aggregation & Buffer Management

Manufacturing lead time (MLT)

Drum-Buffer-Rope

Buffer is aggregated: No intermediate due dates (Assumes touch time is insignificant <10%)

Material Release

Buffer

Rope = MLT

Drum

Touch time:  
 Buffer:  

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Operations Management (DBR; SDBR)

– 1 IDENTIFY the system’s constraint(s)
   – Resource / Market demand
– 2 Decide how to EXPLOIT the system’s constraint(s)
   – Maximise CCR throughput / Delivery speed
– 3 SUBORDINATE everything else to the above decision.
   – Choke material release
   – Buffer aggregation
   – Buffer management
   – Cut batches where possible
   – Planned load
VATI ANALYSIS
The characteristics of structure ‘A’

- Description: Many raw materials are processed and assembled into relatively fewer end products
- Synchronization and availability of materials are the obvious problems
- This environment is where MRP was developed
- Typical industries: electronics, furniture
The characteristics of structure ‘V’
The characteristics of structure ‘T’
The characteristics of structure ‘I’

Product A
- M8
- M6
- M4
- M1
- RM2

Product B
- M8
- M6
- M4
- M1
- RM-3

Product C
- M8
- M6
- M1
- RM-4

Product D
- M8
- M6
- M1
- RM-4

Product E
- M8
- M6
- M4
- RM-2

Product F
- M8
- M6
- M4
- M1
- RM-5
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DISTRIBUTION
The Cloud of Distribution
(Goldratt, 1999: Satellite Program viewer notes)

A  Manage well.

B  Reduce costs.

C  Protect throughput

D  Hold less inventory

D’  Hold more inventory

Because…
Replenishment time is too long.

Vendors are unreliable.
Forecasts are inaccurate
Constraint – The factor that ultimately limits the performance of a system or organization. The factor that, if the organization were able to increase it, more fully exploit it, or more effectively subordinate to it, would result in achieving more of the goal. (TOCICO Dictionary, 2012).
1. IDENTIFY the system’s constraint(s)
   - Footfall (customer who come to buy)
   - The more customers the more Throughput

2. Decide how to EXPLOIT the system’s constraint(s)
   - Having the right inventory in the right place at the right time

3. SUBORDINATE everything else to the above decision.
   - This is where the challenge lies
The longer the replenishment time the slower the system reacts to actual demands.
It is possible to ‘film’ sections of the Insights using software like Screenium (Mac).

However, those slides with lots of words do not work in German!

Rudi Burkhard, 4/15/2013
Elements of Replenishment time

- Ordering lead time
- Supply time
- Production lead time
- Transport lead time
How can we operate according to a much more accurate forecast?

Is the relative accuracy of the forecast at the supply point the same as at a consumption point?
The difference in variability of demand - supply point feeding 100 consumption points:

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

Click on the buttons for more random distributions

Back

Next
Flow in the Supply Chain (Pull)

Production

Central Warehouse

Regional Warehouse

Client or Store

~2-4 weeks

~2-4 days

~1 day

NO Demand Surprises

~3-6 weeks inventory

~7 days inventory

3 days inventory

Lead Times

~3-6 weeks

~7 days

3 days
Each distribution point should order inventory to the following target:

**Average consumption within the average replenishment time, factored for uncertainty in demand and supply**

As a result the distribution system has inventory equal to this target minus ongoing consumption.
1. IDENTIFY the system’s constraint(s)
   - Footfall (customer who come to buy)
   - The more customers the more Throughput

2. Decide how to EXPLOIT the system’s constraint(s)
   - Having the right inventory in the right place at the right time

3. SUBORDINATE everything else to the above decision.
   - Aggregate stock buffer (plant warehouse)
   - Set stock target level based on replenishment time
   - Make to Availability
MAKE TO AVAILABILITY
Make To Availability (MTA)

1. For each item a stock target level is defined.
   - This concept actually fixes the stock in the system.

2. Replenish the stocks very fast.
   - The shorter the production time is the lower should be the inventories and safer is the availability.
   - Every day, decisions regarding release to the floor are taken based on the updated information regarding the stock levels.

3. Priorities are dictated by available stock relative to the target level at the node.
Buffer Status: Percentage of penetration into the buffer.

Or

\[(target - \text{on-hand}) \times 100\%

target\]
MTA - Prioritizing Orders on the Way

[Diagram showing stock levels and order priorities]

- Green Zone
- Yellow Zone
- Red Zone
- Stock On Hand

80 items taken from stock. Green order for 80 required.

Green order for 80 changes from green to yellow.

Another 70 items taken from stock. Green order raised for 70 items.
MTA – Prioritizing Orders on the Way

Three separate orders are in progress
The longer the replenishment time the slower the system reacts to actual demands.
Monitoring the target levels of inventory
WITHOUT FORECAST

Plot of inventory of a particular product in one warehouse:

The target inventory is divided into three zones:
Red - low inventory; Yellow - adequate inventory; Green - high inventory.
The size of the colored zones depends on the required service level.
Unless there are special circumstances the recommendation is to choose
each zone to be one third of the target inventory.

How do we use these zones to ensure
appropriate inventory level?
DYNAMIC BUFFER MANAGEMENT

The buffer status signals whether the target level is too large or too small and this can be used to signal automatic adjustments.
Example

- The consumption for a particular product DOUBLES within a period of ONE week.
- Replenishment time is 3 days.
- Frequency of delivery is 1 day.

Let's zoom on the period of change...
Notice:

Replenishment increases inventory according to the actual consumption when the order was placed - one replenishment time ago (in our case 3 days).
Notice:

After 1 replenishment time passes the inventory increases by the added target + actual consumption occurred 1 replenishment time ago.

Demand
After 1 replenishment time passes the inventory increases by the added target + actual consumption occurred 1 replenishment time ago.
Distribution (MTA)

1. IDENTIFY the system’s constraint(s)
   - Footfall (customer entering shop)

2. Decide how to EXPLOIT the system’s constraint(s)
   - Ensure products are available

3. SUBORDINATE everything to the above decision.
   - Aggregate stock buffer (plant warehouse)
   - Set stock target level based on replenishment time
   - MTA
     - Signal consumption daily and replenishment periodically
     - Adopt buffer management
1. **Prioritise the flow of work**
   - % Buffer penetration (consistent with DBR BM)

2. **Identify when to expedite potential delays.**
   - If the stock buffer availability shows red then chased next order in the system

3. **Signals when there is a need to escalate intervention**
   - If the on-hand is repeatedly in the red increase the target level
   - If the on-hand is repeatedly in the green reduce the target

4. **Identify and target main sources of delay for improvement**
   - Pareto analyse causes of red zone penetration due to supply
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- Consistent with systems thinking and operations laws
- Change of rules enables immediate improvement
  - Choke material release (pull)
  - Buffer aggregation
  - Buffer management
- Buffer management
  - Applicable to complex environments
  - Shop floor control consistent across MTO (DBR) and MTS (MTA)
  - Targeted reduction of wasteful variation
Roy Stratton

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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Rudolf brings more than 40 years of varied business experience to his work. He held positions in finance, technical service, sales, marketing, supply chain, project and business management and, most recently, management consulting at Du Pont’s European headquarters in Geneva. Except for a short period running a small company his experience comes from working in several of Du Pont’s business units within the Textile Fibres and Electronics Departments. In 2001 he left Du Pont to focus on Theory of Constraints consulting. He is the author of the article “You Can’t Spot Serious Shareholder Value? Check your Paradigms.” that won the 1999 PricewaterhouseCoopers prize for the best article on ‘Can you Spot Serious Shareholder Value?’

Rudolf has been consulting with TOC since 2001. In 2008 he and 4 partners started VISTEM GmbH und Co KG and the TOC Institute in Germany. He moderates the TOC4U discussion group on Linkedin and occasionally writes for his blog TOC4U-Focus.