



From flow line to project management: Does TOC offer a unifying theory?

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About Dr. Roy Stratton

- I have worked alongside the TOC community on numerous projects since my first encounter in 1986 when, as a new lecturer, I was looking for interesting teaching materials. The Race, The Goal and the OPT simulator provided my kick start and the rest is history.
- Over the years I have been part of Goldratt Schools, developed TOC based solutions for industry and for 8 years ran the MSc TOC (healthcare) with Alex knight and QFI Consulting. However, I have always been intrigued by the tentative acceptance of TOC by the academic community. **TOC is not bound by traditional functional boundaries, which is a particular challenge to the artificially insular world of the academic.** Therefore, my research has increasingly focused on looking to position TOC alongside established theory and practice in operations and supply chain management, the prime focus of this webinar.



From flow line to project management: Does TOC offer a unifying theory?

This webinar builds on Eli's 2009 paper '**Standing on the shoulders of giants**' broadening and deepening the links with operations best practice and theory. We will explore how established operations laws (principles) can be used to link the seminal developments, ranging from Ford's flow lines to Goldratt's project management. These developments are shown to use **management signalling tools** to resolve a common underlying conflict suited to different environments. TOC and buffer management is shown to be a natural extension of earlier systems approaches uniquely supported by the TOC thinking processes.



Common principles to overcome a common, if sacred, cow

“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.”

Dr. Eliyahu Goldratt 1984

Preface to The Goal



Redefining measures and priority of these principles (Goldratt and Fox, 1986)

Cost paradigm

OE↓

T↑

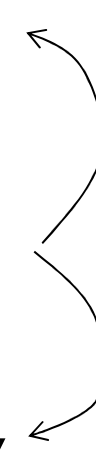
I↓

Throughput paradigm

T↑

I↓

OE↓





Principles: 10 Rules of OPT (Goldratt & Fox, 1986)

- Utilization and **activation of a resource** are not the same.
- The level of **utilization of a non-bottleneck** is determined not by its own potential but by some other constraint in the system.
- An **hour lost at a bottleneck** is an hour lost for the total system.
- An **hour saved at a non-bottleneck** is just a mirage.
- **Bottlenecks govern** both the throughput and inventory in the system.
- The transfer batch may not and often should not be equal to the process batch.
- The process batch should be variable, not fixed.
- Capacity and priority should be considered simultaneously, not sequentially.
- **Balance flow, not capacity.**
- The sum of **local optima** is not equal to the **global optimum**.

**Reflecting a paradigm shift from local to global thinking;
from efficiency to flow.**



Principles?

TOC vs Lean

The 5 Steps of Focusing (Goldratt, 1991)

1. **Identify** the systems constraint(s)
2. Decide how to **Exploit** the systems constraint(s)
3. **Subordinate** everything else to the above decision
4. **Elevate** the systems constraint(s)
5. If broken **Go back** to step 1

The 5 Lean Principles (Womack and Jones, 1996)

1. Specify what creates **value** from the customers perspective.
2. **Identify all steps** across the whole value stream.
3. Make those actions that create value **flow**
4. Only make what is **Pulled** by the customer just in time
5. Strive for **perfection** by continually removing waste

A Constraint [limiting factor]: 'A **factor** that ultimately **limits** the performance of a system or organisation. A factor that, if the organisation were able to increase it, more **fully exploit** it, or more **effectively subordinate** to it, would result in achieving more of the goal.' (TOC-ICO Dictionary, 2012)



Principles?

Fundamental concepts of Supply Chains

(Goldratt, 2008)

- 1. Improving **flow** (or equivalently lead time) is a primary objective of operations.
- 2. This primary objective should be translated into a **practical mechanism** that guides the operation when not to produce (**prevents overproduction**).
- 3. **Local efficiencies must be abolished.**
- 4. A **focusing process** to balance **flow** must be in place.



Common governing principles?

- TOC is not the only paradigm shifting systems approach
 - Manufacturing strategy (Skinner, 1969)
 - Quality management (Shewhart, 1931; Deming, 1986)
 - Flow lines (Ford, 1926)
 - TPS (Ohno, 1988)
 - TOC (Goldratt, 1990)
 - *SCM* (Forrester, 1958; Stevens, 1989)
- They similarly challenge the influence of ‘cost accounting efficiencies’ - But only indirectly!
- Is there opportunity to see these developments as part of a whole by identifying the underlying **‘principles that govern’**?



6 Wider Principles (laws) to be evaluated

- 1 Law of Trade-offs:** A delivery system cannot simultaneously provide the highest levels of performance (quality, delivery lead time, delivery reliability, flexibility and cost) (primary attribution: Skinner, 1969).
- 2 Law of Focus:** A delivery system that is aligned to make the most of a limiting factor (e.g. order winning criteria and bottleneck) will be more productive. (primary attribution: Skinner, 1974; Hill, 1985; Goldratt, 1984)
- 3 Law of Variability:** Increasing variability always degrades the performance of a delivery system. (Hopp and Spearman, 1996 modified)
- 4 Law of Variability Buffering:** Variability in a delivery system will be buffered by some combination of Inventory, Capacity and Time. (Hopp and Spearman, 1996 modified)
- 5 Law of Bottlenecks:** A resource with no buffer capacity dictates the delivery system throughput and provides a focus for planning and control. (Primary attribution: Goldratt, 1984)
- 6 Law of Variability Pooling:** Combining sources of variability so they can share a common buffer reduces the total amount of buffering required. (Hopp, 2008 modified)



Structure

- **Manufacturing Strategy**
 - *Law of trade-offs; law of focus*
- Quality and continual improvement
 - *Law of variability*
- Lean flow and reducing variability
 - Ford and flow lines
 - *Law of variability buffering*
- TOC Flow and managing variability
 - *law of bottlenecks; law of variability pooling; law of focus*
 - DBR; CCPM; MTA*
- Which signalling concept fits
 - Underlying assumptions
- Conclusions
 - Summary table



Manufacturing Strategy

- *'Its [manufacturing] management concepts are outdated, **focusing on cost and efficiency** instead of strategy, and on making piecemeal changes instead of changes that span and link the entire system.'*
 - (Skinner, 1971: 62)

- *'**A factory cannot perform well on every yardstick**'*
 - (Skinner, 1974)

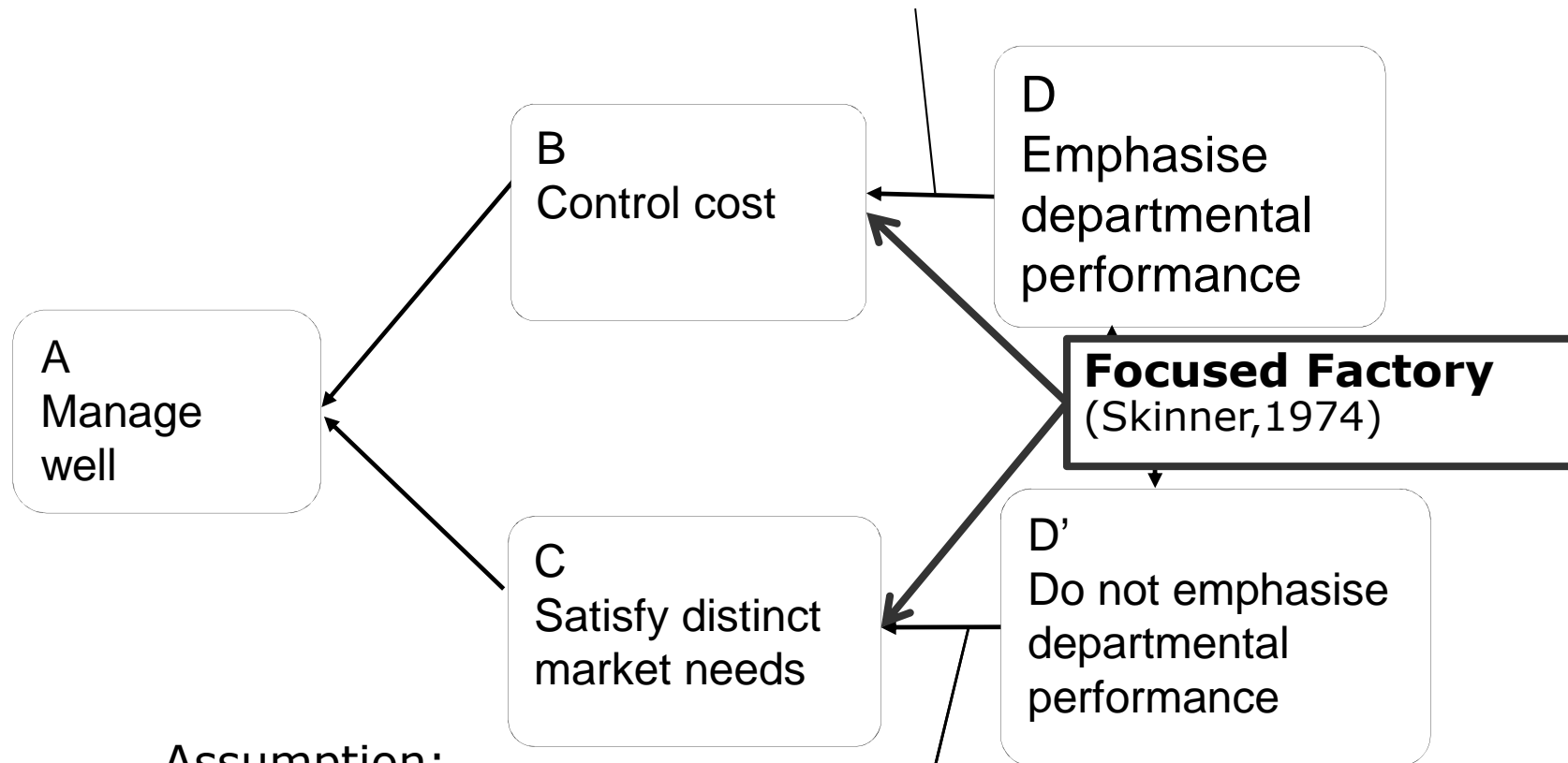
Law (trade-offs): A delivery system cannot simultaneously provide the highest levels of performance (quality, delivery lead time, delivery reliability, flexibility and cost)



The cloud of operations: strategy

Assumption:

Good departmental performance equates to global productivity



Assumption:

Price is not the only order winning criteria

Law focus): A delivery system that is aligned to make the most of a limiting factor (e.g. order winning criteria) will be more productive.



Where market focus is the limiting factor

- 1 **Identify** the system's constraint(s)
 - *Market demand*
- 2 **Decide how to exploit** the system's constraint(s)
 - *Focused factory concept*
- 3 **Subordinate** everything else to the above decision
 - *Align structural and infrastructural choices with specific order winning criteria*



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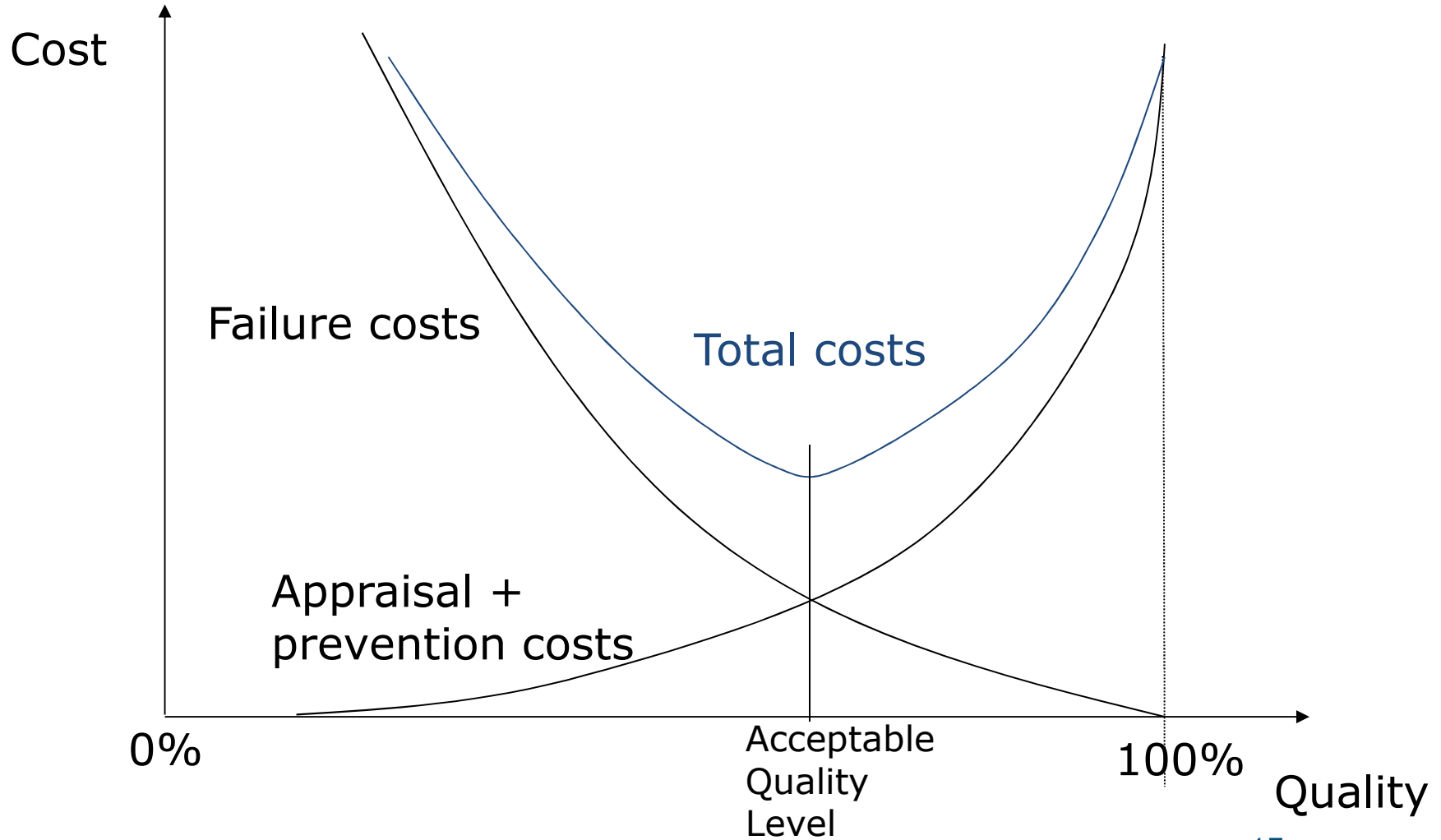
Quality: continual Improvement

‘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*

Law: (variability): Increasing variability always degrades the performance of a delivery system.



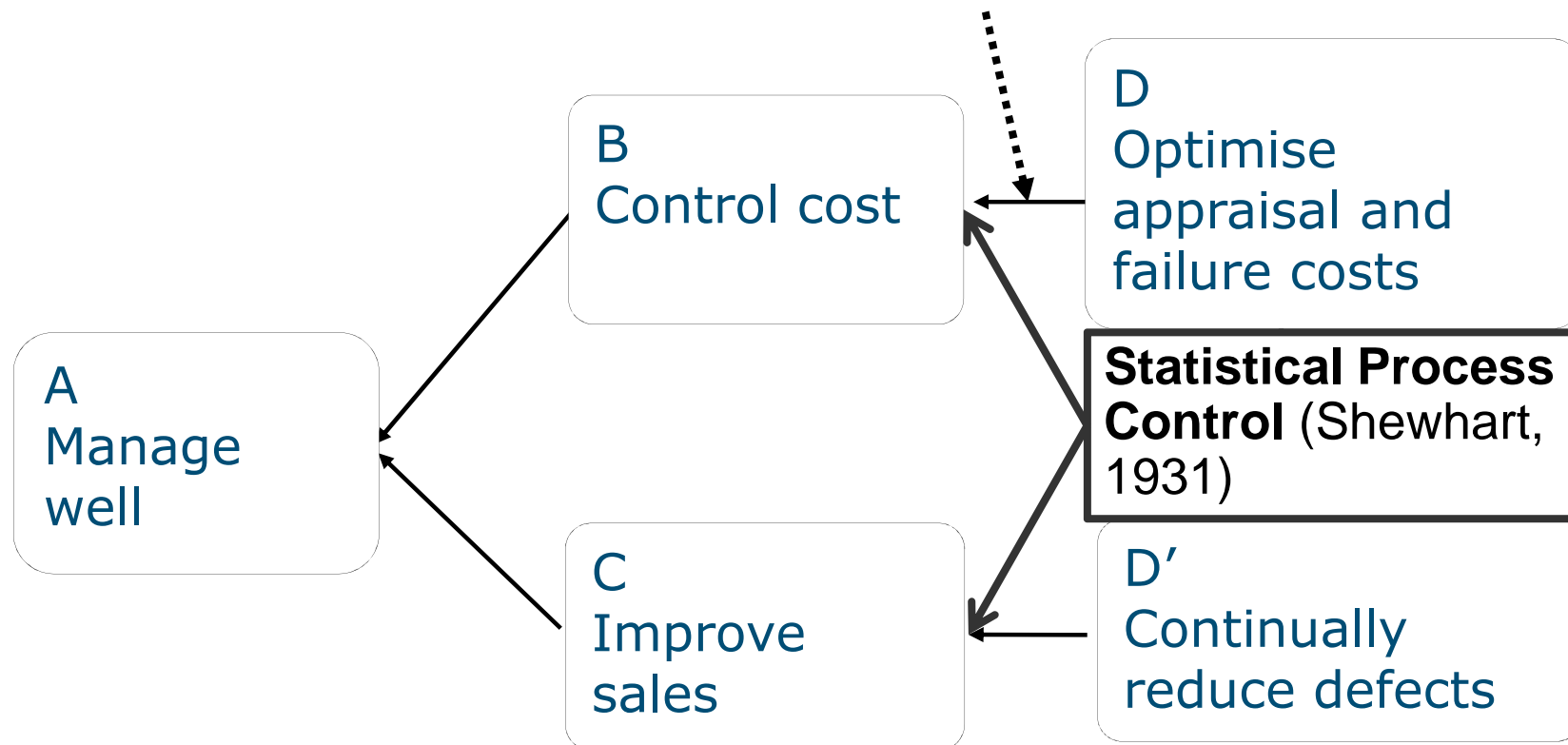
Quality: Cost Optimisation





The cloud of operations (Quality)

Because...
inspection (appraisal) is the only means of assuring quality



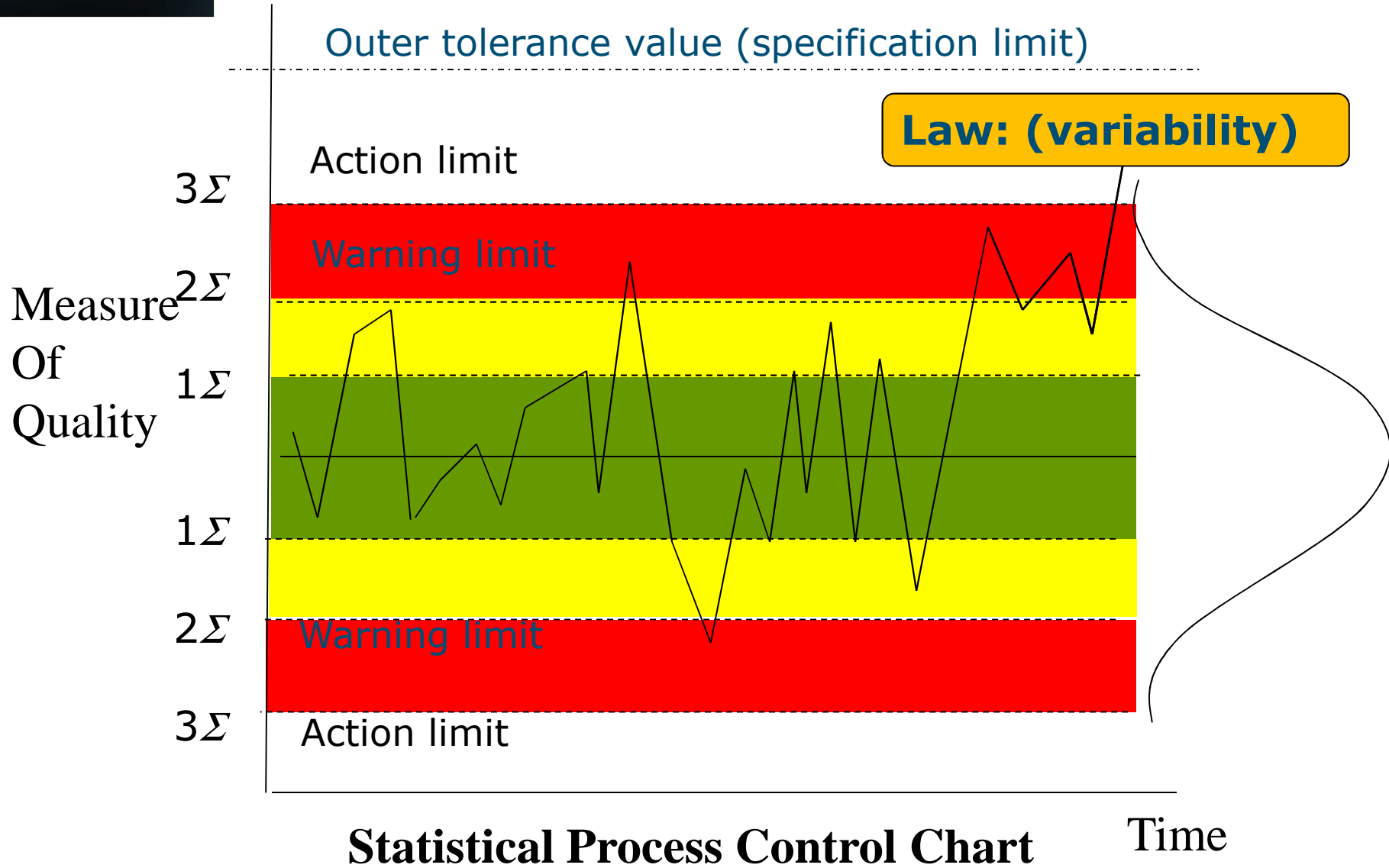


Where product quality (product variability) is the limiting factor

- 1 **Identify** the system's constraint(s)
 - *Product variation (quality)*
- 2 **Decide how to exploit** the system's constraint(s)
 - *Process improvement (e.g. PDSA; SS -DMAIC)*
- 3 **Subordinate** everything else to the above decision
 - *Statistical Process Control signalling*
 - *Kaizen involvement of workforce*



SPC management signalling tool (Shewhart, 1931;1939)





Structure

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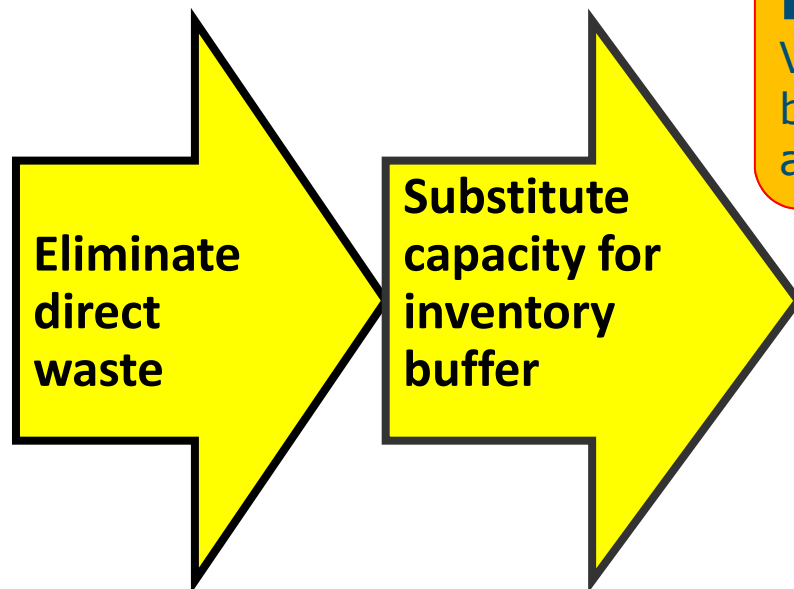
Ford's 'Model T': flow

- “The thing is to **keep everything in motion** and take the work to the man...”
- “If a machine breaks down, a repair squad will be on hand in a few minutes...the **machines do not often break down** because there is **continuous cleaning and repair work ...**”
 - (Ford, 1926; 103)
- “Our production cycle is about **eighty-one hours** from the mine to the finished machine in the freight car
 - (Ford, 1926; 118)



TPS (lean) flow

- *'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)



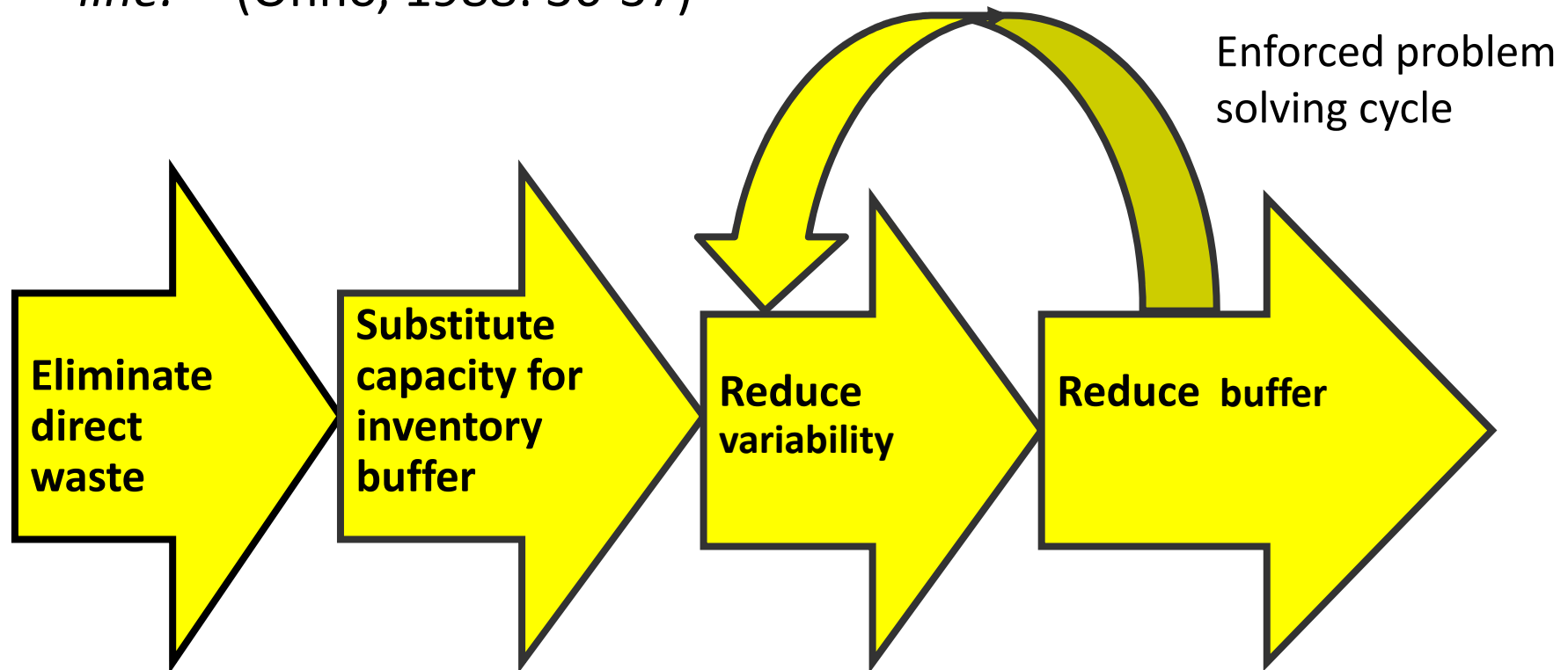
Law (Variability Buffering):

Variability in a delivery system will be buffered by some combination of Inventory, Capacity and Time.



TPS (lean) flow (Hopp, 2008: 91 modified)

'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)





Kanban : the TPS management signaling concept

- *‘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)



Kanban signalling concept

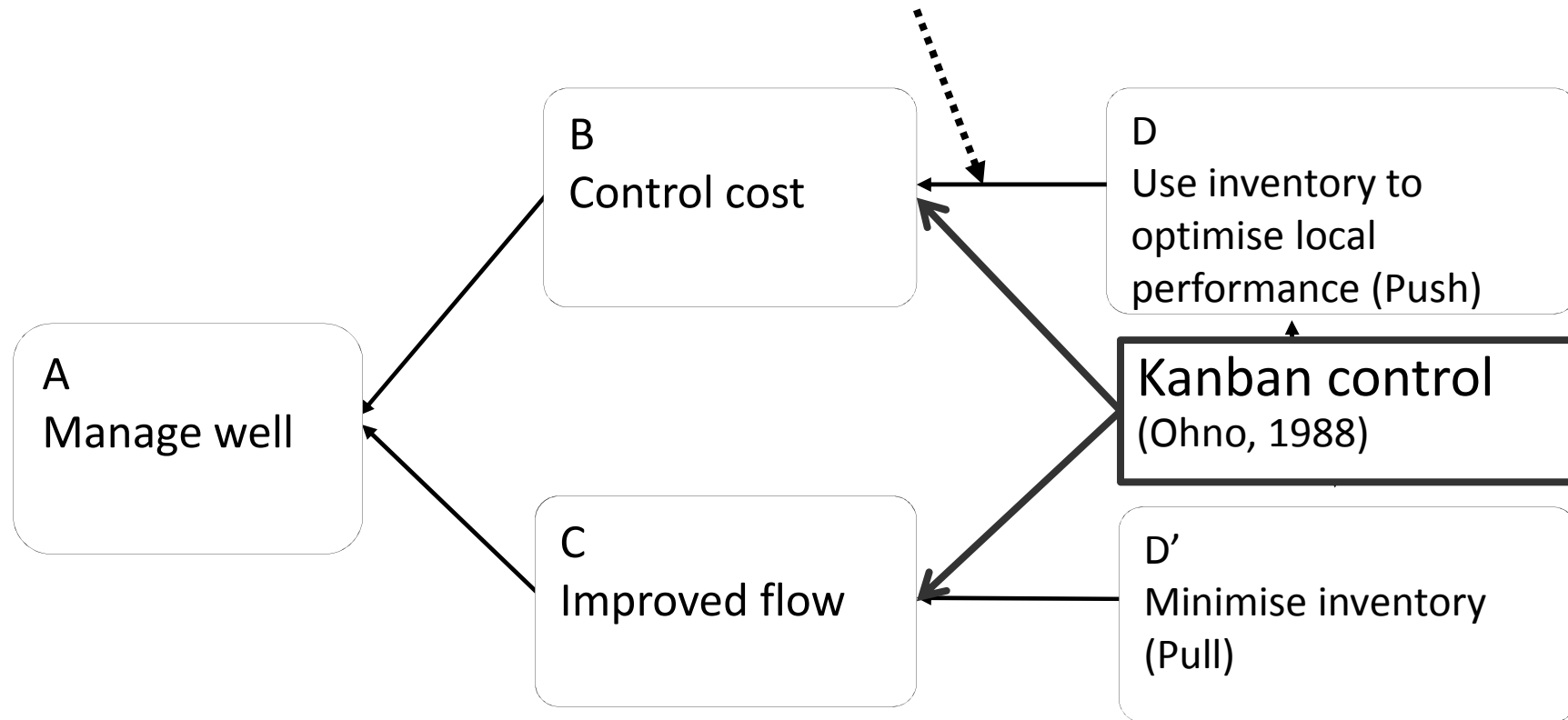
Functions of kanban	Kanban rules of use
1. Provides pick-up or transmission information.	1. Later process picks up the number of items indicated by the kanban at the earlier process.
2. Provides production information. [Priority order]	2. Earlier process produces items in the quantity and sequence indicated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

The functions and rules of kanban (source: Ohno, 1988: 30)



The cloud of operations (lean flow)

Because... Variability (e.g. set-up time)
cannot be systematically reduced



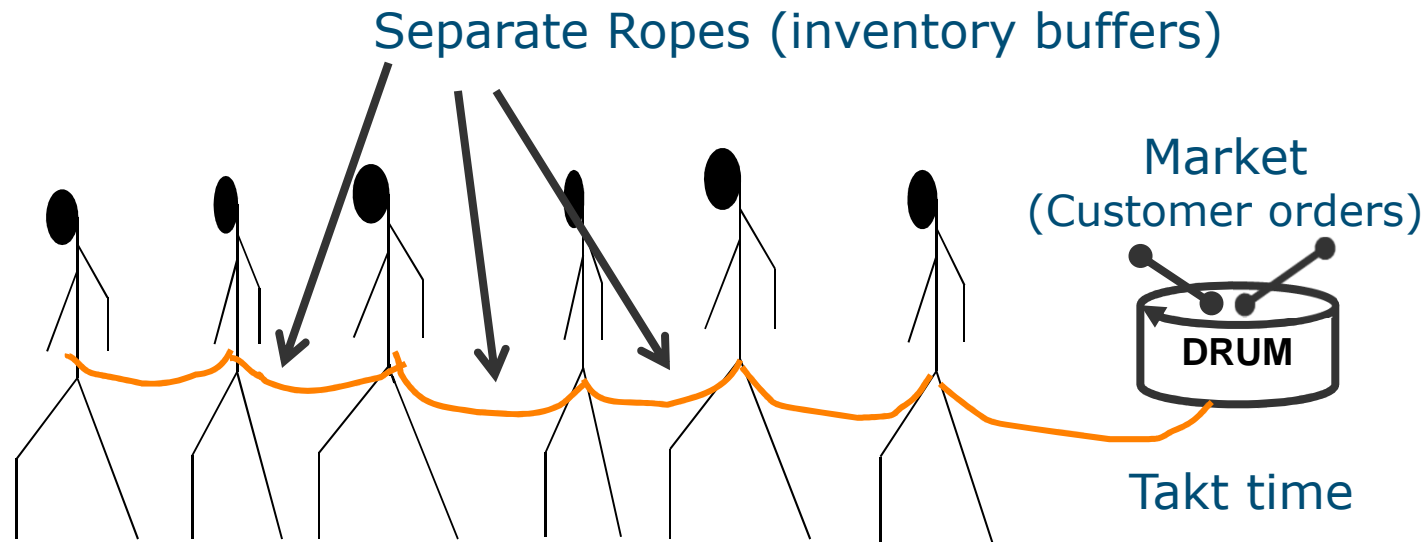


Where stable flow (Lean) is the limiting factor

- 1 **Identify** the system's constraint(s)
 - Manufacturing Lead time (JIT)
- 2 **Decide how to exploit** the system's constraint(s)
 - *Restructure around the value stream?*
 - *Substitute capacity for inventory buffering*
- 3 **Subordinate** everything else to the above decision
 - *Pull (choke material release)*
 - *Kanban signalling*
 - *Kaizen involvement of the workforce*
 - *Cut batches (Reduce set-ups) (Shingo, 1989)*

Analogy of **KANBAN** (pull signaling)

(source: Goldratt and Fox, 1986; modified)



Law (Variability Buffering)

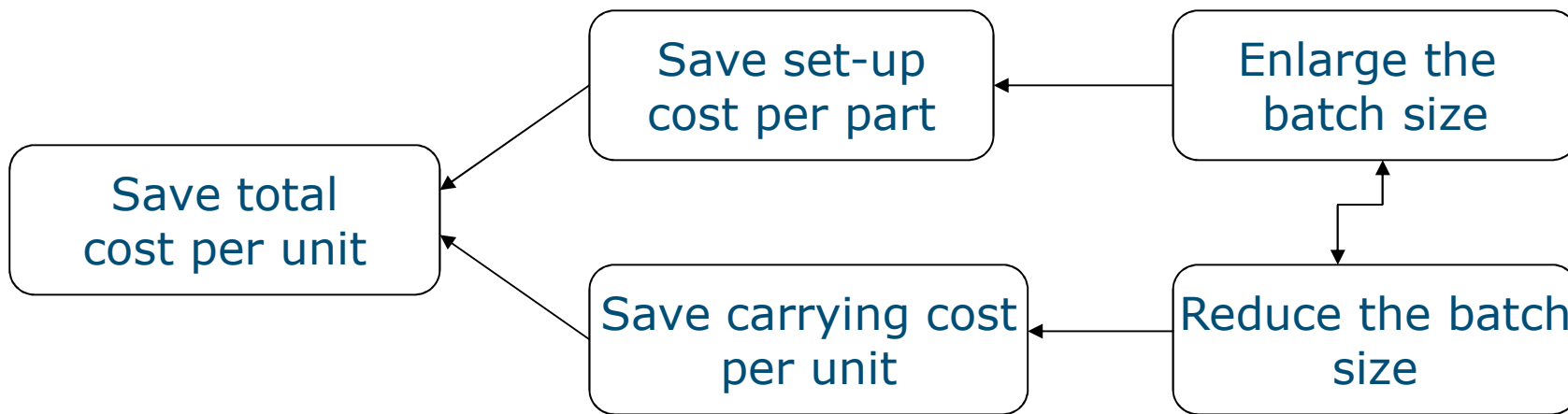
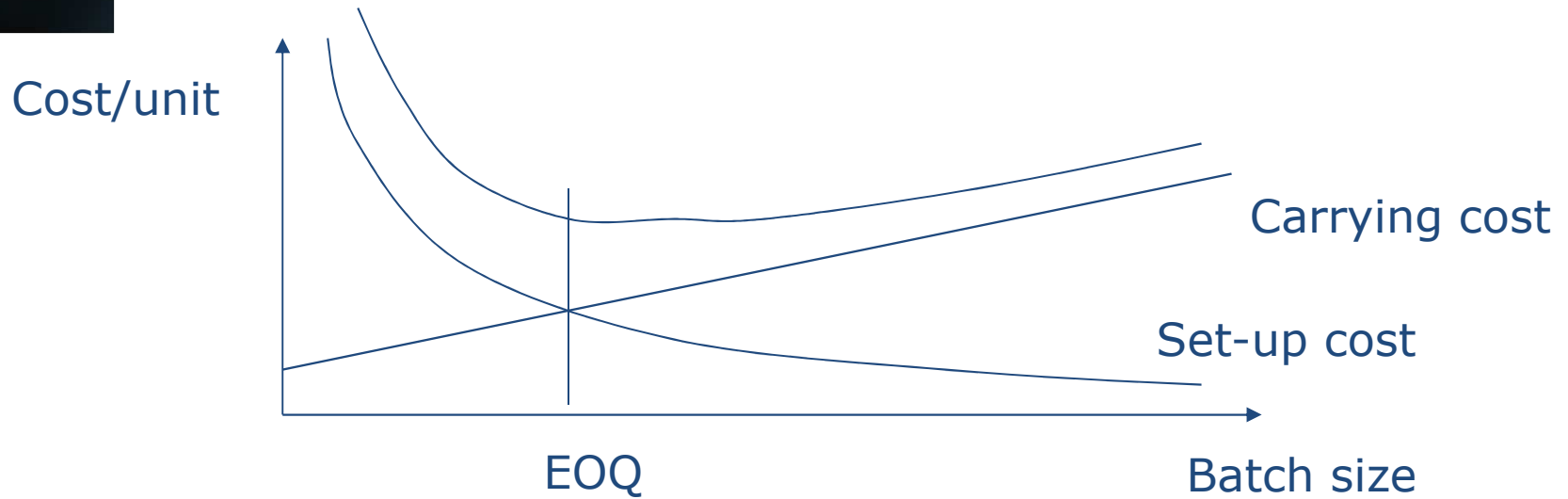


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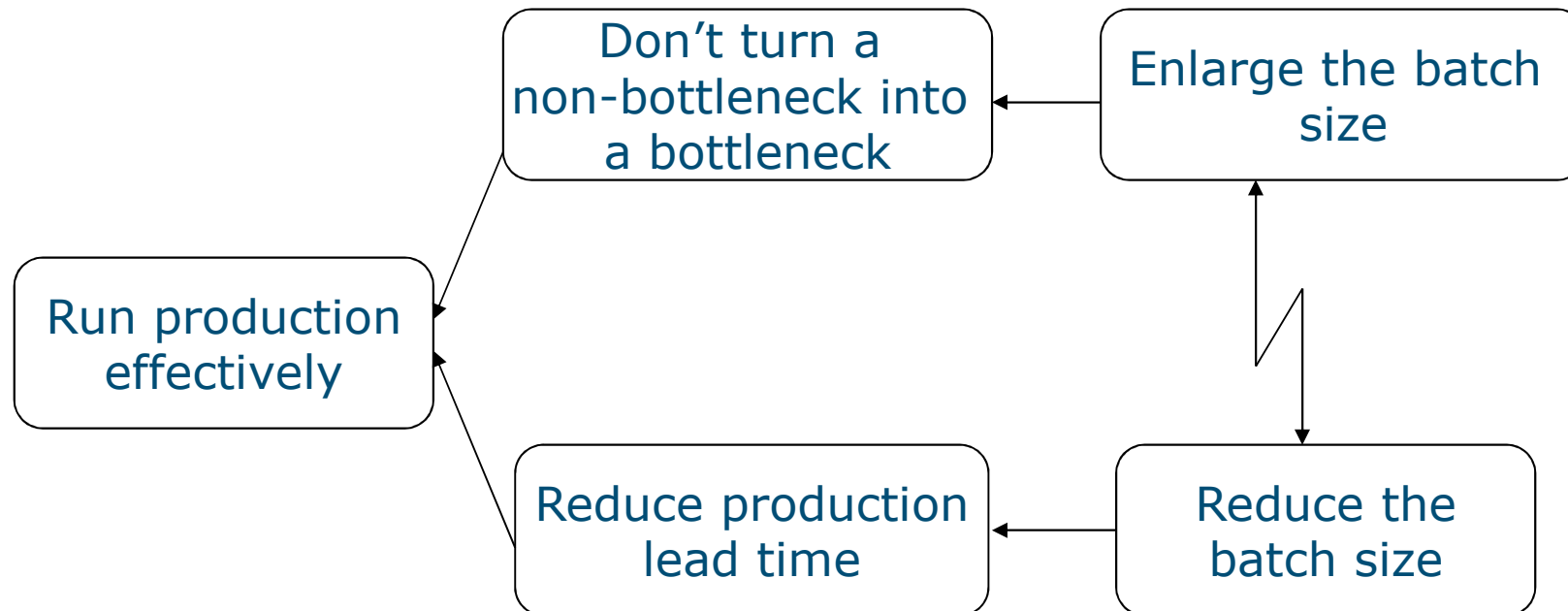
Goldratt: challenging the cost model more directly





The Reconstructed cloud based on Throughput (value) not Cost

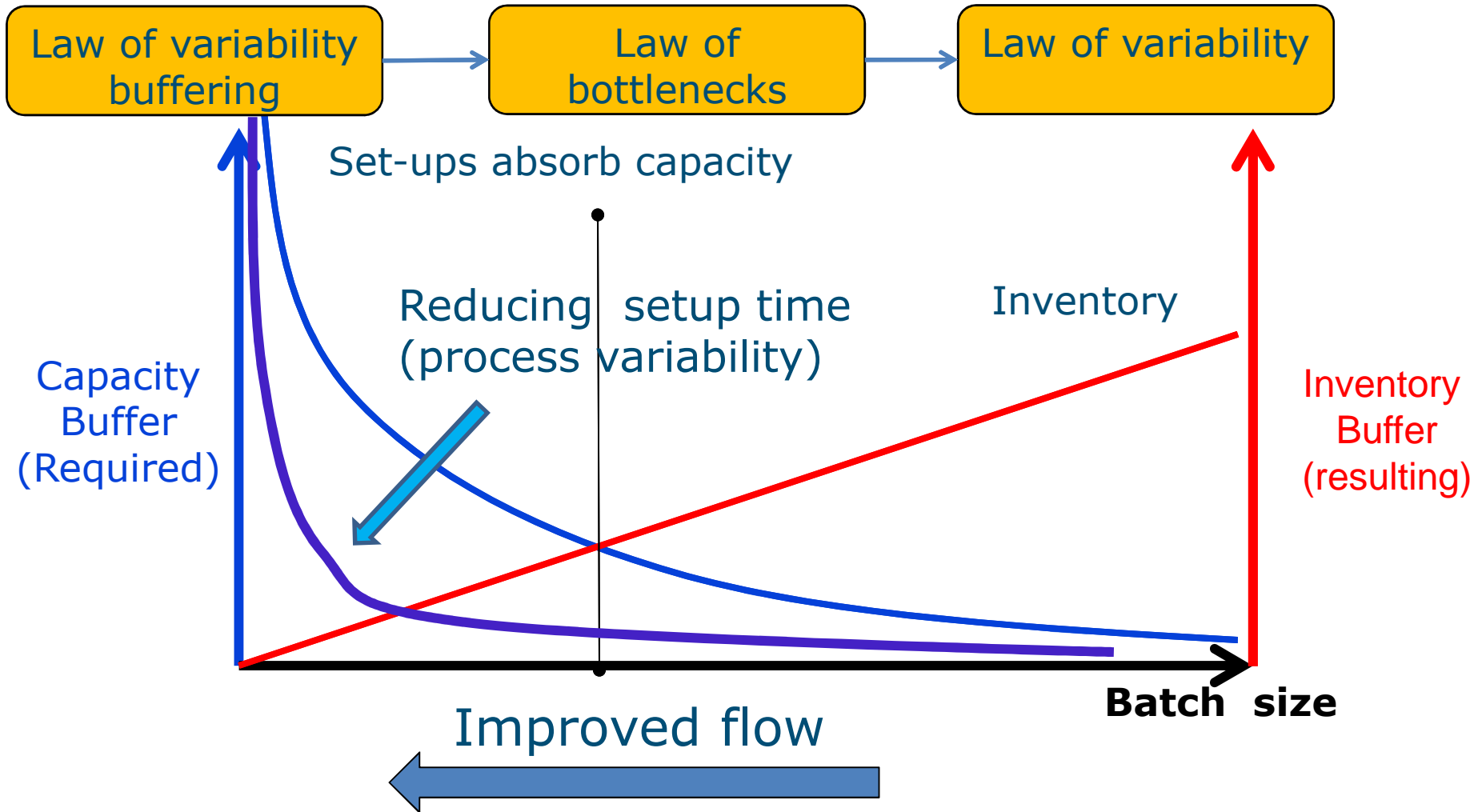
(Source: Goldratt, 2003)



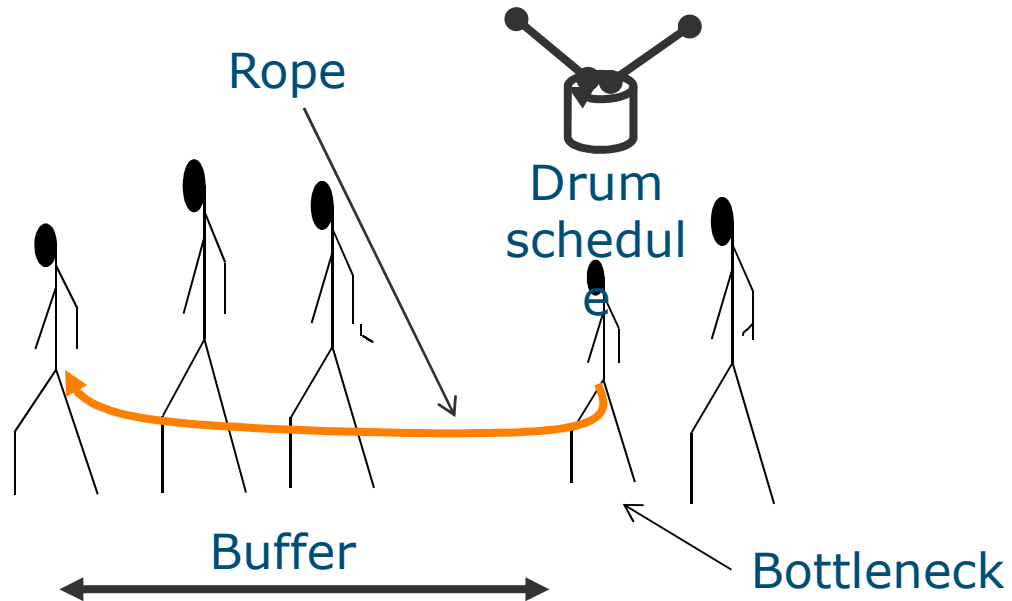
Law of Bottlenecks: A resource with no buffer capacity dictates the delivery system throughput and provides a focus for planning and control.



Reinterpreting the batch size cost model



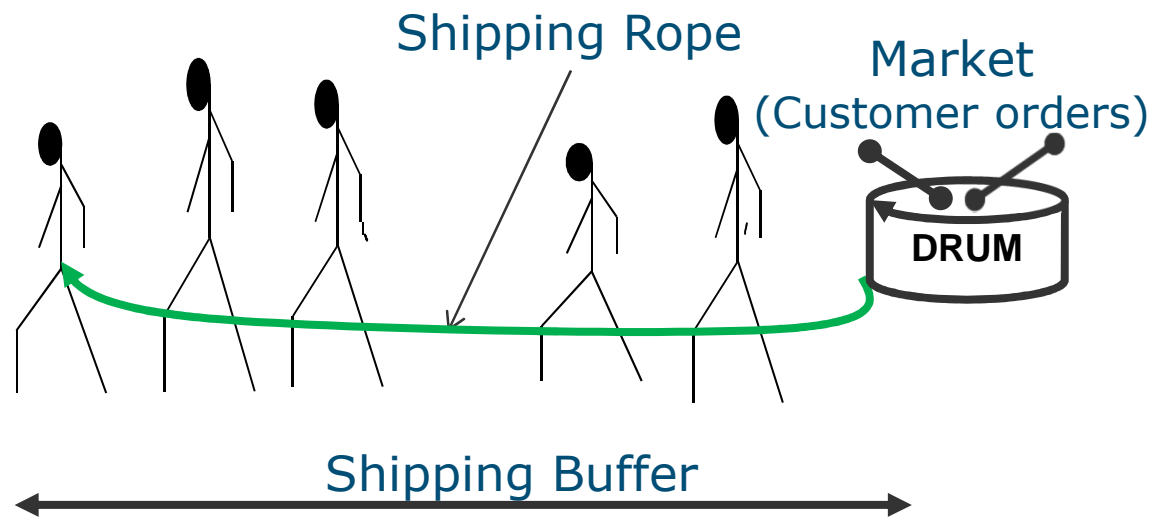
Drum Buffer Rope (Bottleneck)



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

Drum-Buffer-Rope (pull) (market drum)

(Source: Goldratt and Fox, 1986; modified)



Law (variability pooling): Combining sources of variability so they can share a common buffer reduces the total amount of buffering required.

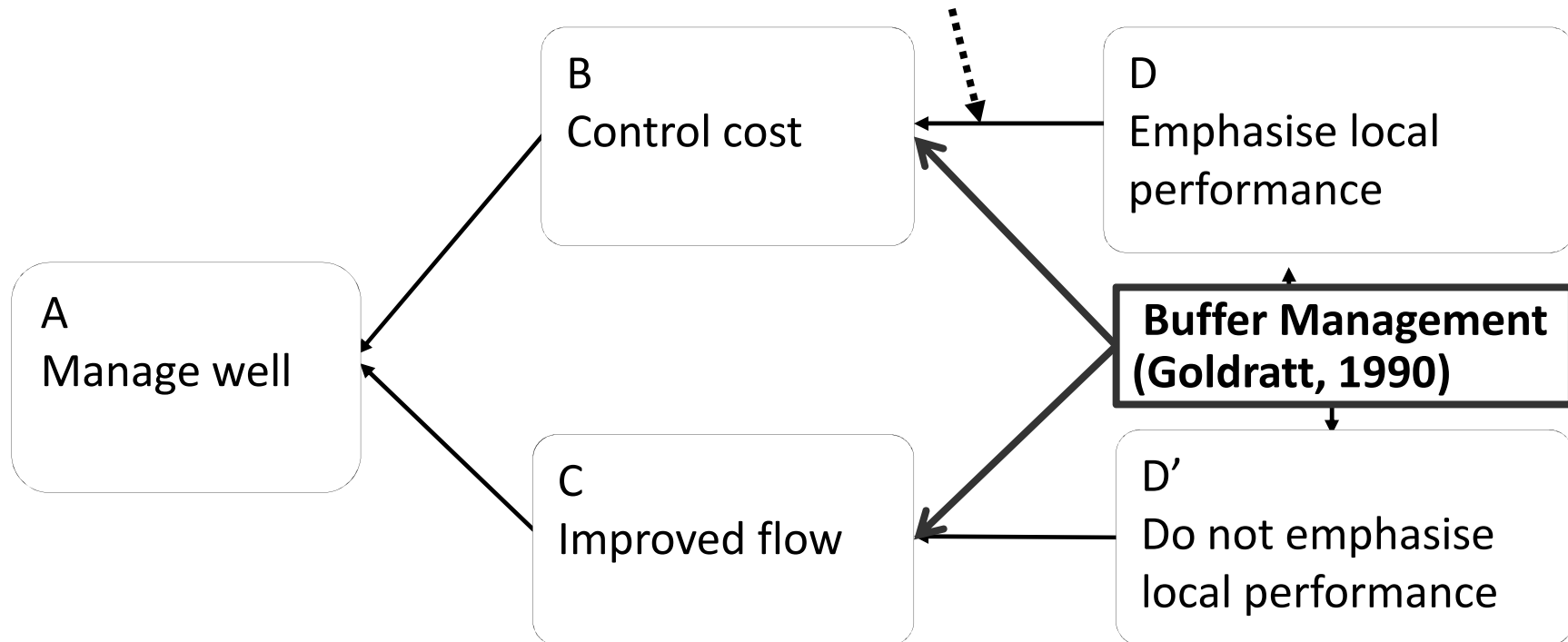
Law focus): A delivery system that is aligned to make the most of a limiting factor (e.g. **order winning criteria or bottleneck**) will be more productive.



The cloud of operations (TOC flow)

Because...

Excess capacity is a major waste



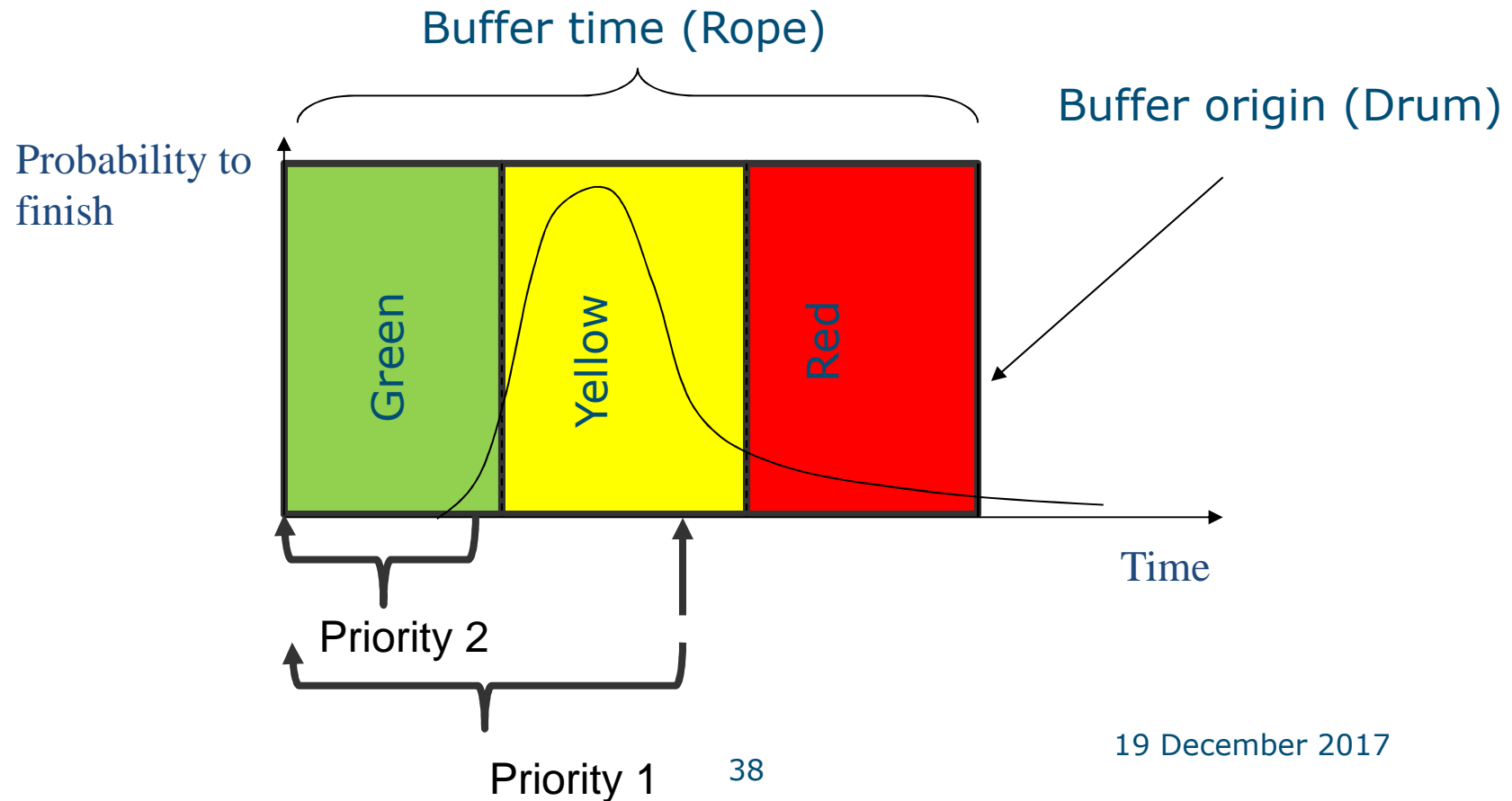


Where complex flow is the limiting factor (DBR; SDBR)

- 1 Identify the system's constraint(s)
 - *Time (Bottleneck/CCR)*
 - *Time (operations lead time)*
- 2 Decide how to exploit the systems constraint(s)
 - *Close schedule btlk. (special case)*
 - *Utilise available capacity across the delivery system to protect btlk. and reduce lead time.*
- 3 Subordinate everything to the above decision.
 - *Choke material release*
 - *Aggregate time buffer*
 - *Buffer management*
 - *Cut batches*

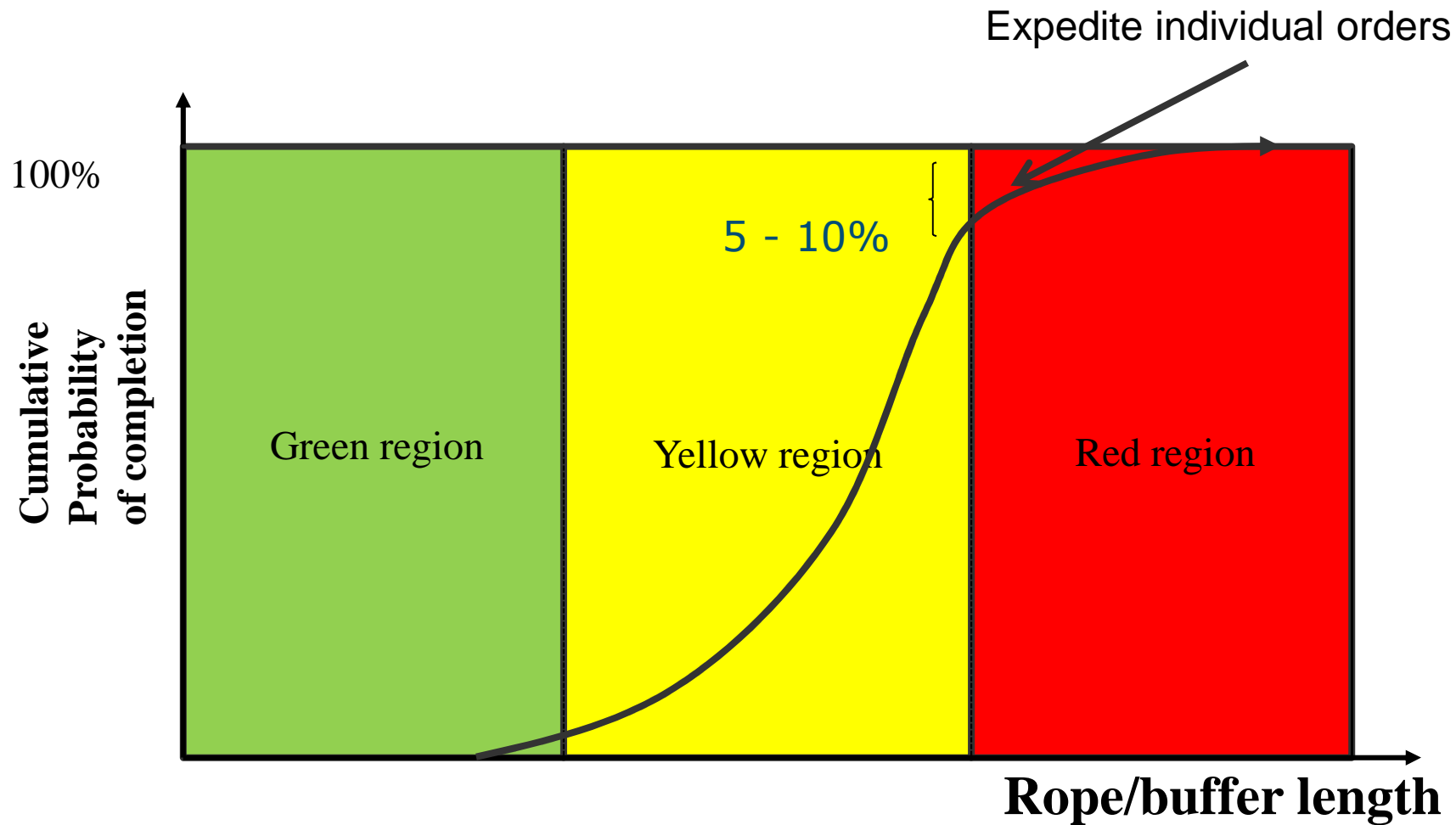


Buffer Management – Function 1 (Prioritise)





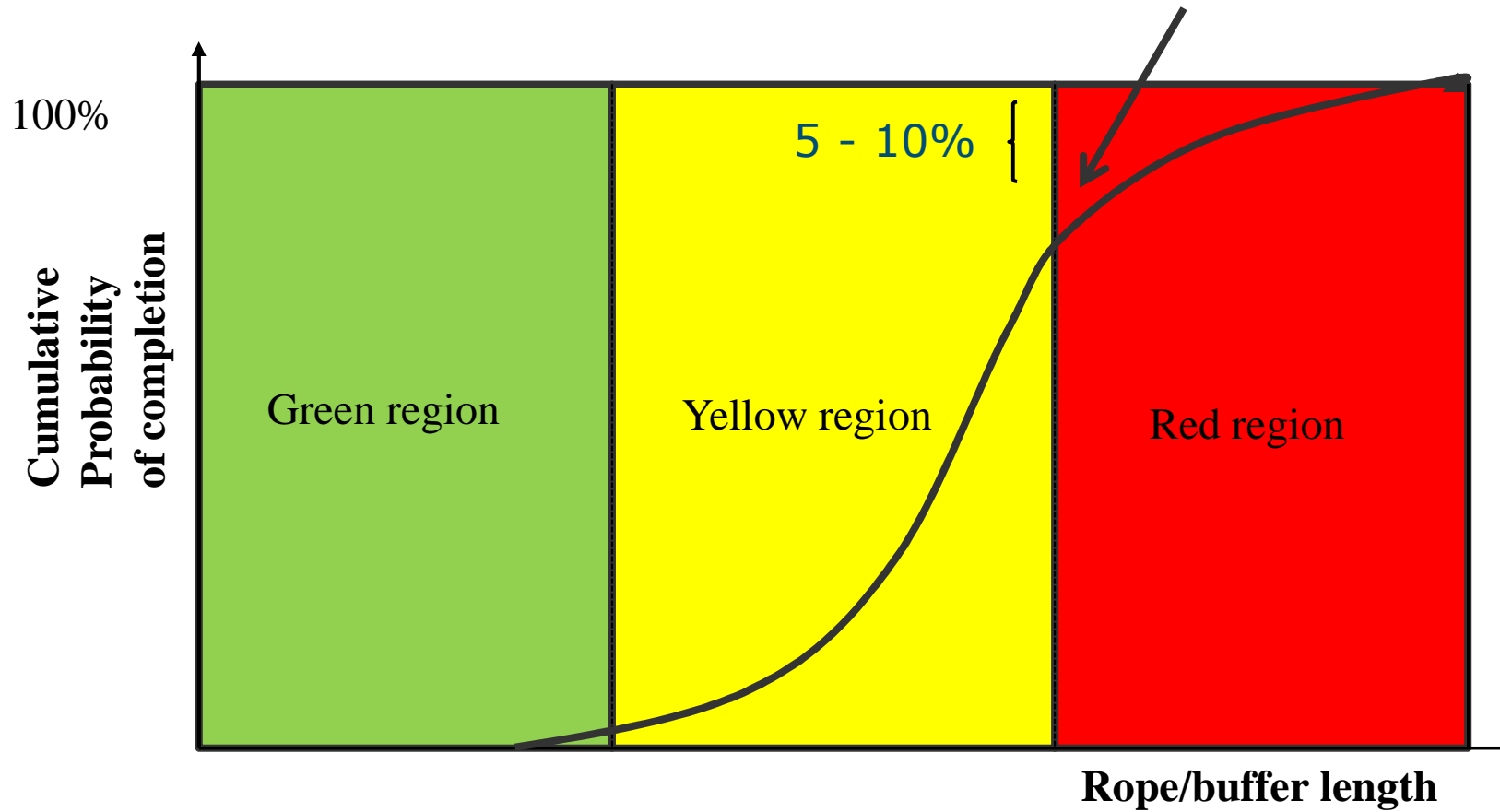
Buffer Management – Function 2 (Expedite)





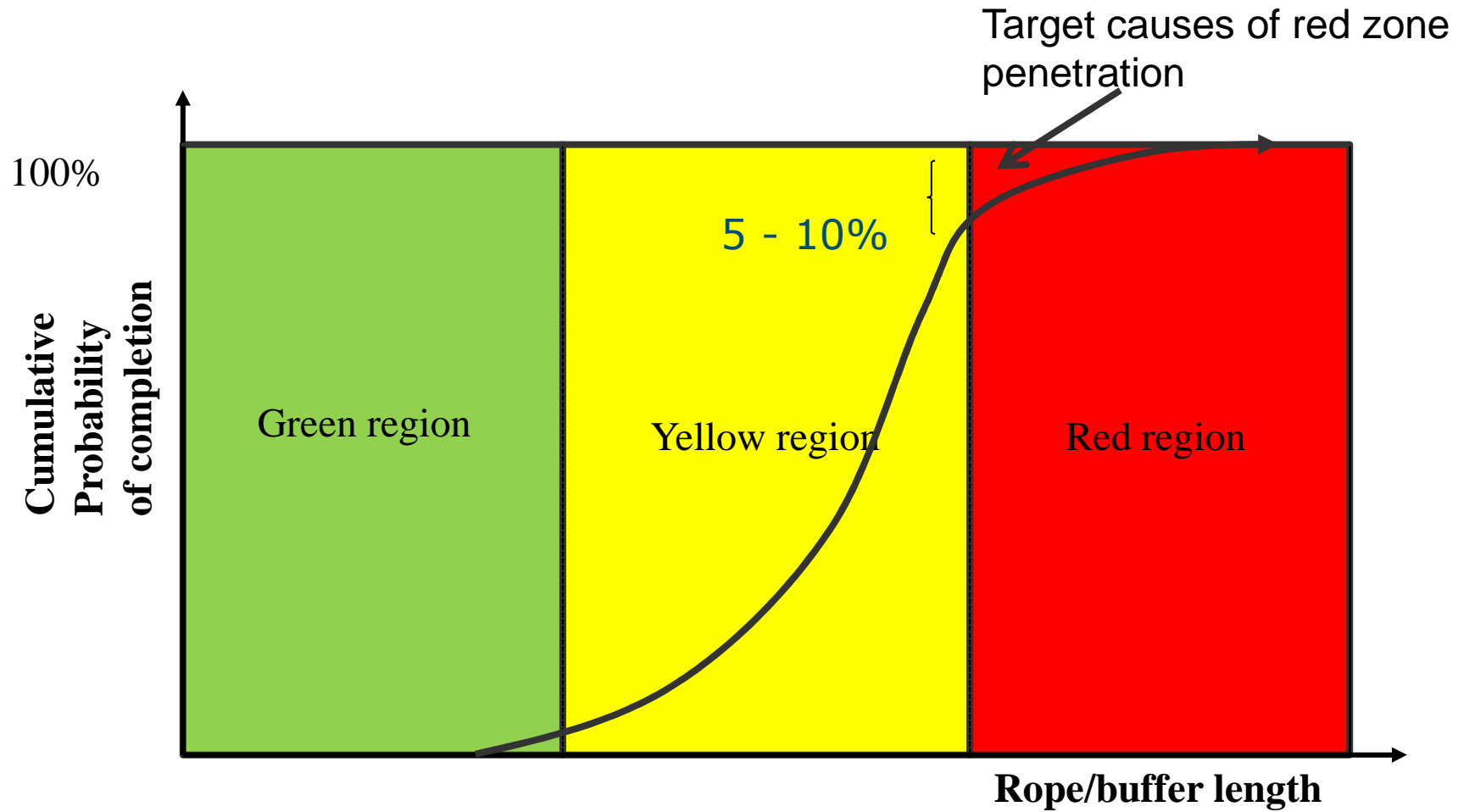
Buffer Management - Function 3 (Escalate)

Growing red zone signals instability
Escalate immediate action





Buffer Management – Function 4 (Target)





TBM and Kanban functions compared

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



Kanban and Buffer Management Assumptions

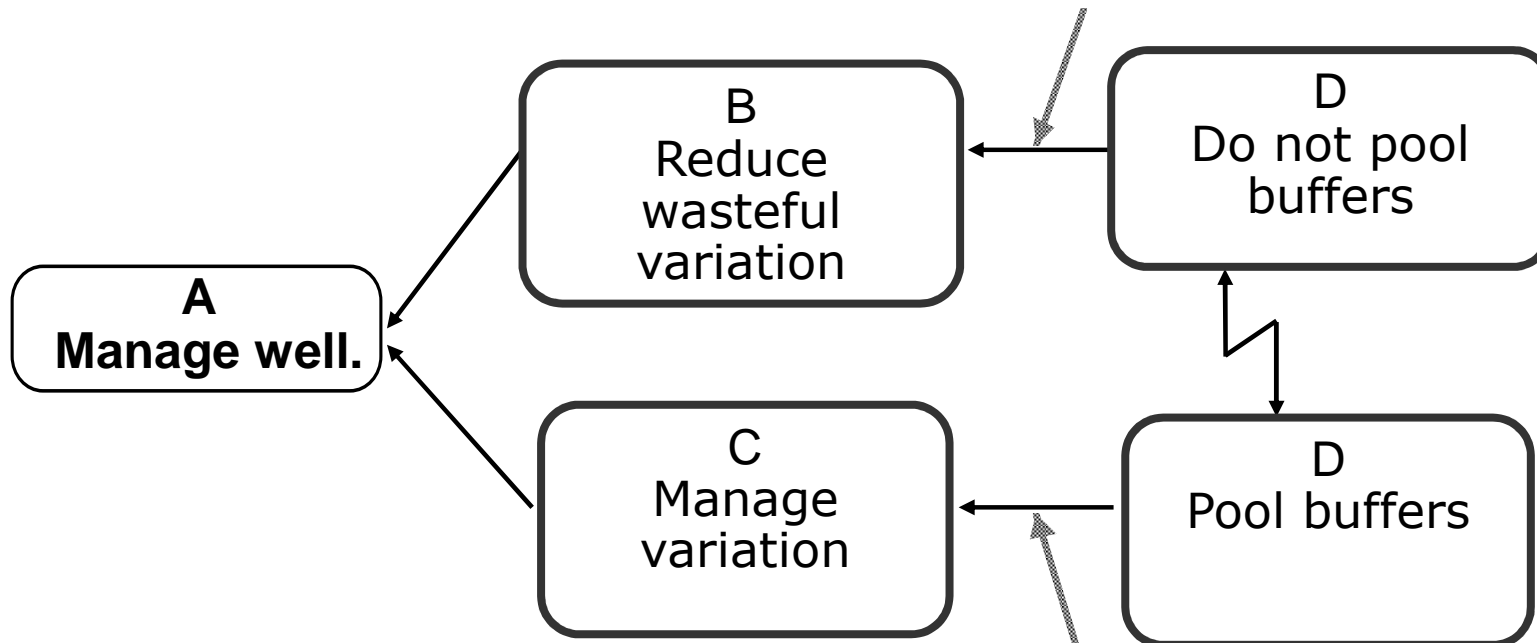
TPS/Kanban assumes:	TBM assumes:
Predefined process steps	No predefined processing steps
Buffering is based on inventory and held at each processing step	Buffering is based on time or stock and pooled
Process delays (quality problems) are not passed on to the next process	'Delays' are only expedited when they threaten delivery / availability
Level scheduling	Demand may vary, triggering (timely) escalation
Continual improvement is encouraged through reducing inventory to expose problems that are then targeted.	Continual improvement is enabled by targeting the causes of delay (e.g. red zone penetration) then reducing the buffer.



TPS / TOC Distinguishing Assumptions

Because...

buffer aggregation masks the source of the variation



Because...

aggregation of variation reduces buffer requirements



Project Management

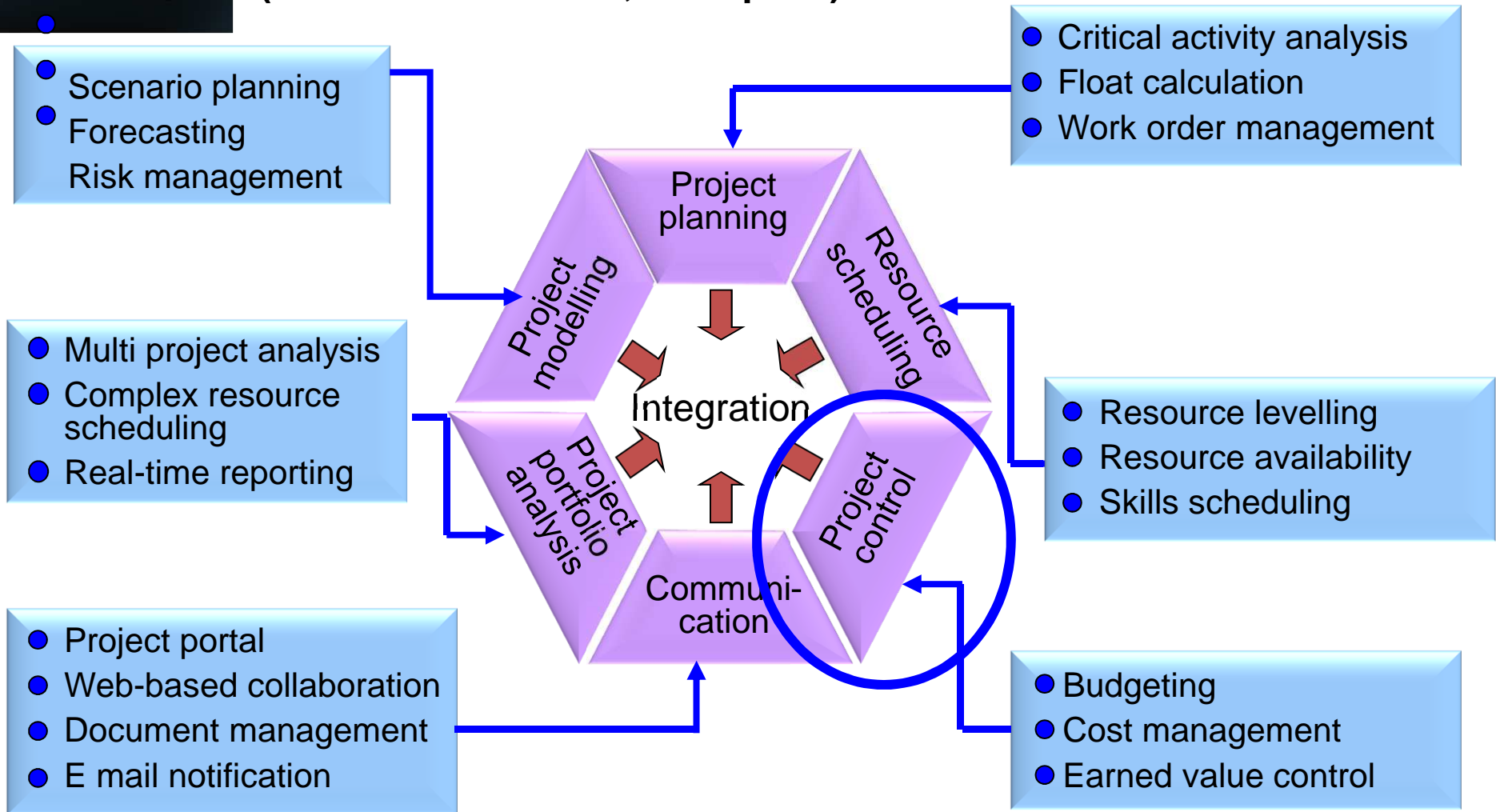
'All too often, however, only the original plan and scheduling data are ever produced. They continue to cover the office wall long after they are obsolete and bear little resemblance to the current progress of the job.'

(Handbook for construction management, Fondahl, 1980).



Some of the elements integrated in enterprise project management

(Source: Slack et al., 2012:p518)



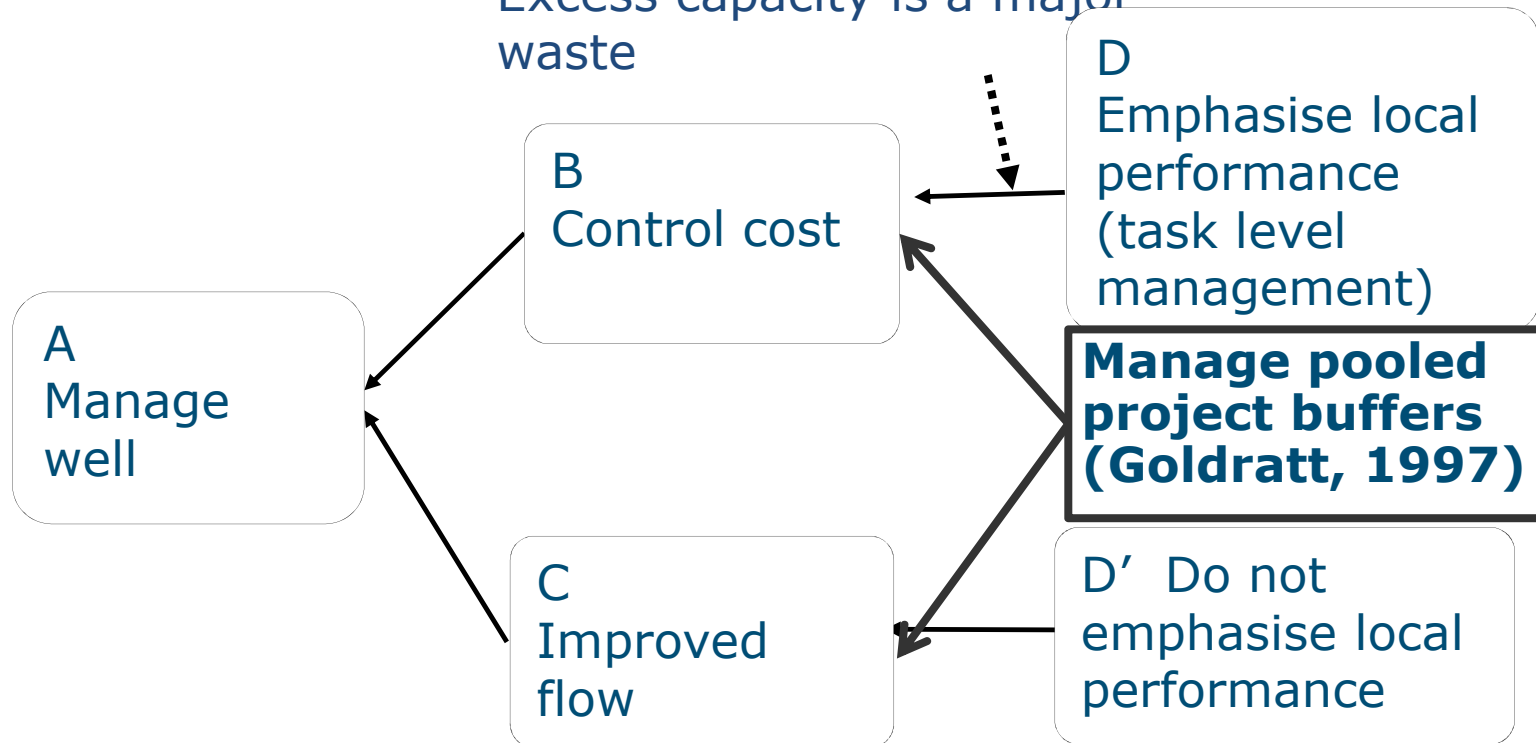


The cloud of operations (TOC project flow)

Because

...

Excess capacity is a major waste





Where Project flow is the limiting factor (CCPM)

- 1 Identify the system's constraint(s)
 - *Time*
- 2 Decide how to exploit the systems constraint(s)
 - *Aggregate critical chain time buffers (project buffer)*
- 3 Subordinate everything to the above decision.
 - *Aggregate feeder buffers – protect non-critical tasks*
 - *Choke project release - reduce number of live projects*
 - *Update projected completions of live activities daily*
 - *Buffer management*

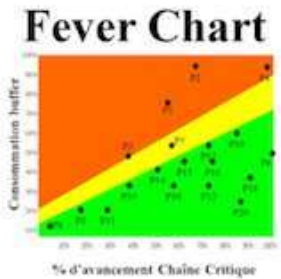
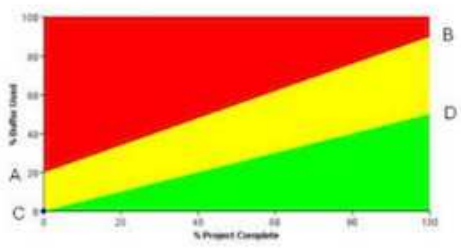
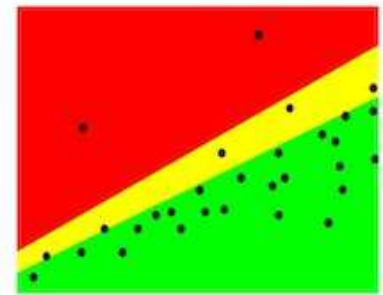
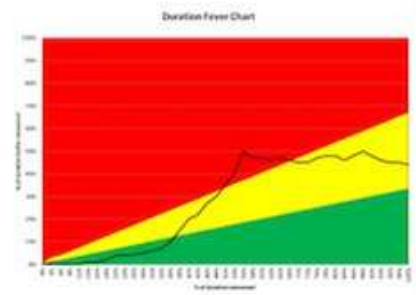
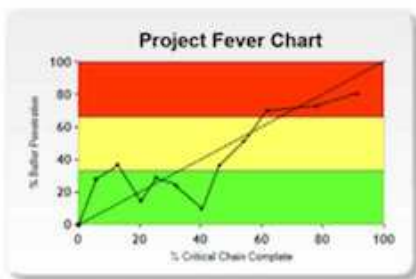
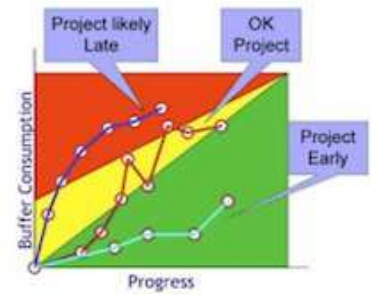
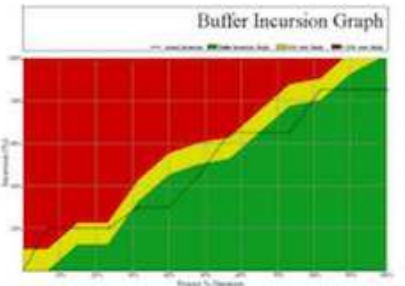
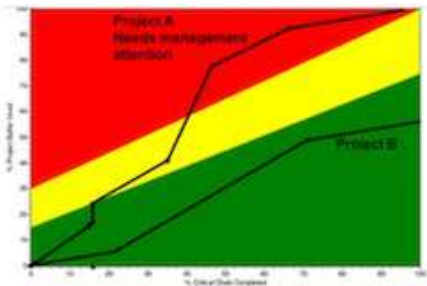
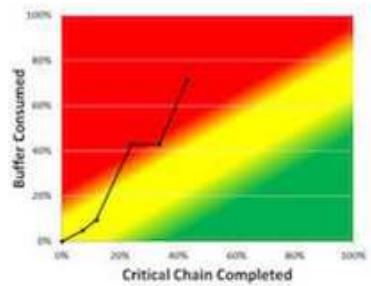
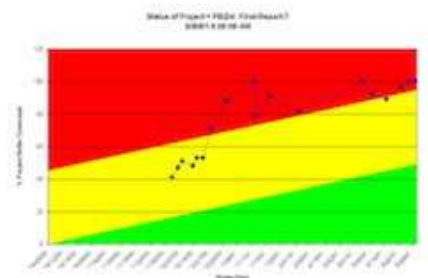


Functions of Buffer Management: applied to Project Management

- ***Prioritise the flow of work***
*Based on a ratio of buffer penetration to project CC completions
(green / yellow / red)*
- ***Identify when to expedite potential delays.***
Respond locally at the task level to minimise consumption of the buffers
- ***Signals when there is a need to escalate intervention***
Red zone signals when project and programme level action is required.
- ***Identify and target main sources of delay for improvement***
Pareto analyse causes of red zone penetration.



CCPM Buffers?





Does TOC offer a unifying theory?

- TOC is one of several innovative operations developments centred on variability and time as opposed to cost and efficiency.
- These seminal developments are centred on management signalling tools (SPC, Kanban, buffer management) to suit different limitations.
- The first 3 steps of TOC can be used to embrace all these developments.
- The six laws (principles) provide a means of clarifying the distinguishing assumptions.



Summary Table

Attribute	Mfg. Strategy	QM /Six Sigma	TPS /Lean	TOC DBR	TOC CCPM
Environment	Mfg. plants	All processes	Inherently stable flow	Complex MTO flow	Complex ETO flow
Key word	Trade-off	Variability	Flow	Focused flow	Focused flow
Key assumption	Variability drives strategic trade-offs	Process variability drives quality cost trade-off	Wasteful variation needs to be exposed and reduced	Buffer capacity needs to be holistically managed to enable flow	Project duration not task time needs to be managed
Distinguishing Method	Product Profiling	Plan, Do, Study, Act/ Scientific process	Value Stream Mapping	Abductive reasoning/ conflict resolution	
What to change	Separate out delivery systems by order winning criteria	Manage and systematically reduce process variability	Redesign process flow/choke RM release/manage discrete inventory buffers	Choke RM release / managed pooled time buffer	Limit multi-tasking / expose and manage pooled time buffer
Distinguishing systems concepts/ signalling tools	Focused factory	Statistical Process Control	Kanban control	TBM – touch time insignificant	TBM – touch time significant
Distinguishing Law(s) (Principles)	Law of trade-offs Law of focus	Law or variability	Law of variability buffering	Law of b't'ks Law of variability pooling Law of focus	Law of variability pooling

Questions





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