NOTTINGHAM TRENT UNIVERSITY

TOC PA
Moscow
May 2012

TOC, Lean and Six Sigma

Dr Roy Stratton, CBP&LL, Nottingham Business School, NTU, UK

(roy.stratton@ntu.ac.uk)

Roy Stratton

Roy Stratton is based in the UK and is Principal Lecturer in Operations and Supply Chain Management at Nottingham Business School, Nottingham Trent University where he is actively involved teaching, research and consultancy. He is Director of the Centre for Performance Management and Lean Leadership and Programme Manager of the MSc Theory of Constraints (Health Care Management). 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 and government funded knowledge transfer research projects. He has published widely in both professional and academic journals and has co-authored two educational books.

Roy is a chartered Engineeer (MIMech 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).

Philosophy… Theory… Approach?

- **Philosophy** is the study of general and fundamental problems, distinguished from other ways of addressing such problems by its critical, generally systematic approach and its reliance on rational argument.
- **Theories** are analytical tools for understanding , explaining and making predictions about a given subject matter.
- An **Approach** is a way of dealing with something

Approach… Theory…Philosophy?

Attribute	Approach / Theory / Philosophy		
	Six Sigma	**Lean**	**TOC**
Process steps	Define Measure Analyse Improve Control	Identify value Map value stream Flow Pull Perfection	Identify constraint Exploit Subordinate Elevate Go back
Origins	Shewhart Western Electric 1920s	Ohno Toyota 1950s	Goldratt Creative Output 1980s
Emphasis	Reduce Defects	Reduce Waste	Manage Constraints
Perspective	Processes	Supply Chain	Wider system

Approach… Theory… Philosophy?

Attribute	Approach / Theory / Philosophy		
	Six sigma	**Lean**	**TOC**
Environment	All processes	Inherently stable flow	Complex flow
Key word	Variation	Flow	Focus
Key assumption	Process variation drives the cost vs. quality trade-off	Batching drives buffering and waste	Buffers need to be strategically managed
Distinguishing Methodology	Plan, Do, Study, Act	Value stream mapping	Cause & Effect mapping / Conflict resolution
What to change	Specific Processes	Process flow	Management Rules
Distinguishing improvement concept/tool	Statistical Process Control	Kanban control	Buffer management
Application sequence?	2	2	1

TOC, Lean, Six Sigma: some perspectives

- The Scientific Method
- Goldratt, Ohno and Ford in context
  - Standing on the shoulders of giants
- TOC - changing the rules
  - Buffer aggregation and buffer management
- Interpreting Lean using TOC thinking
- Statistical Process Control and Buffer Management
- Kanban and Buffer Management
- Conclusion

Adaptation of the Scientific Method

From the introduction to “The Goal”

“Finally, and most importantly, I wanted to show that we can all be outstanding scientists. The secret of being a good scientist, I believe, lies not in our brain power. We have enough. We simply need to look at reality and think logically and precisely about what we see. The key ingredient is to have the courage to face inconsistencies between what we see and deduce and the way things are done. 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.”

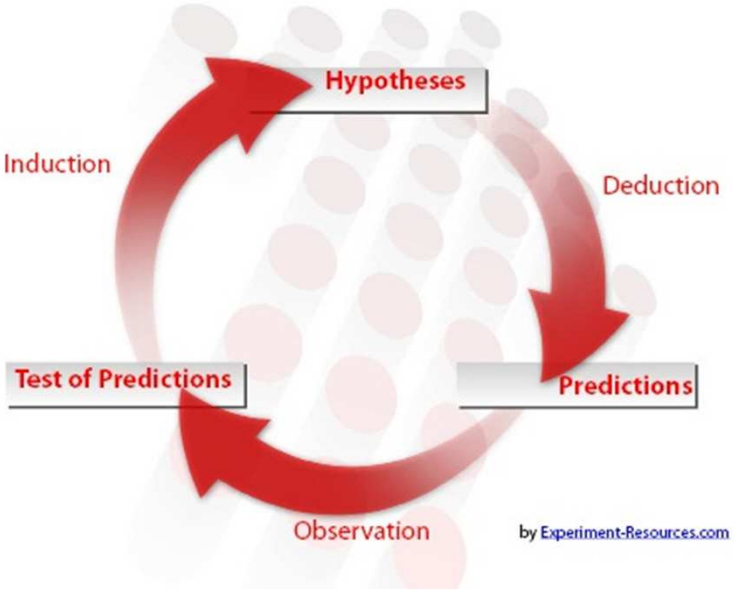
Dr. Eliyahu Goldratt 1984

Scientific Method

Contribution

- Shewhart
  - Process control
  - PDSA Cycle
- Ohno
  - Process mapping
  - Broad incremental improvement
- Goldratt
  - Focused causal mapping
  - Core problem identification
  - Challenging assumptions (clouds)

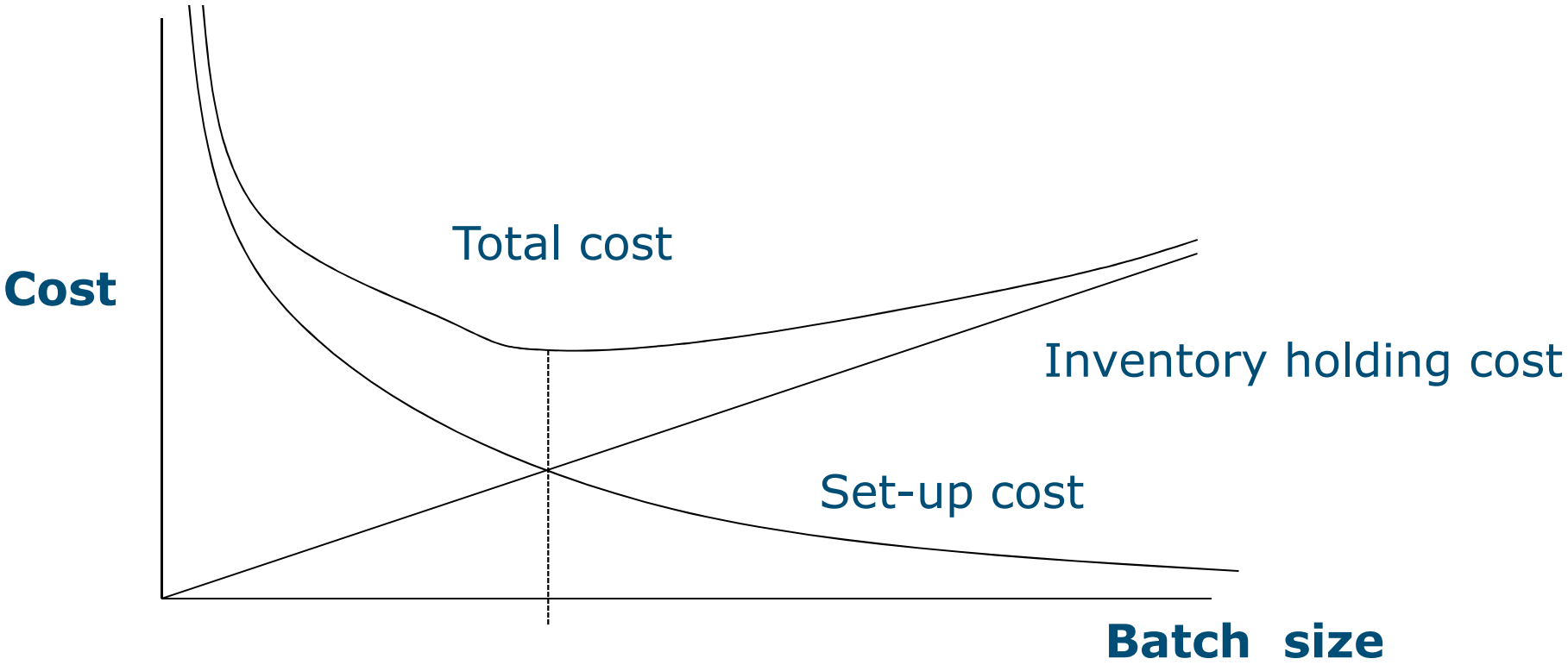
Experiments to test prediction



Interpreting Lean (JIT) using TOC Thinking

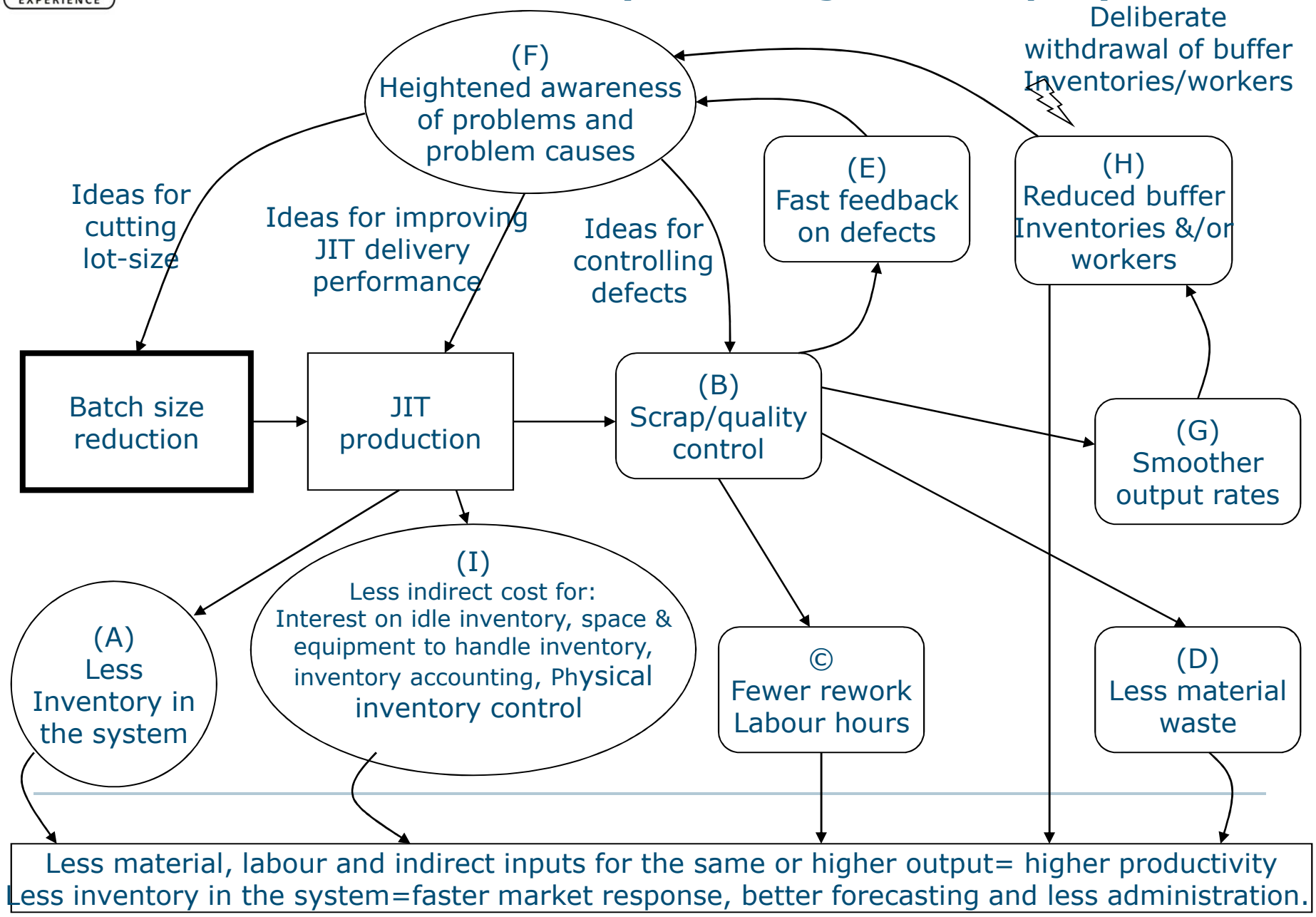
Systematically challenging assumptions

The Traditional Batching Cost Model

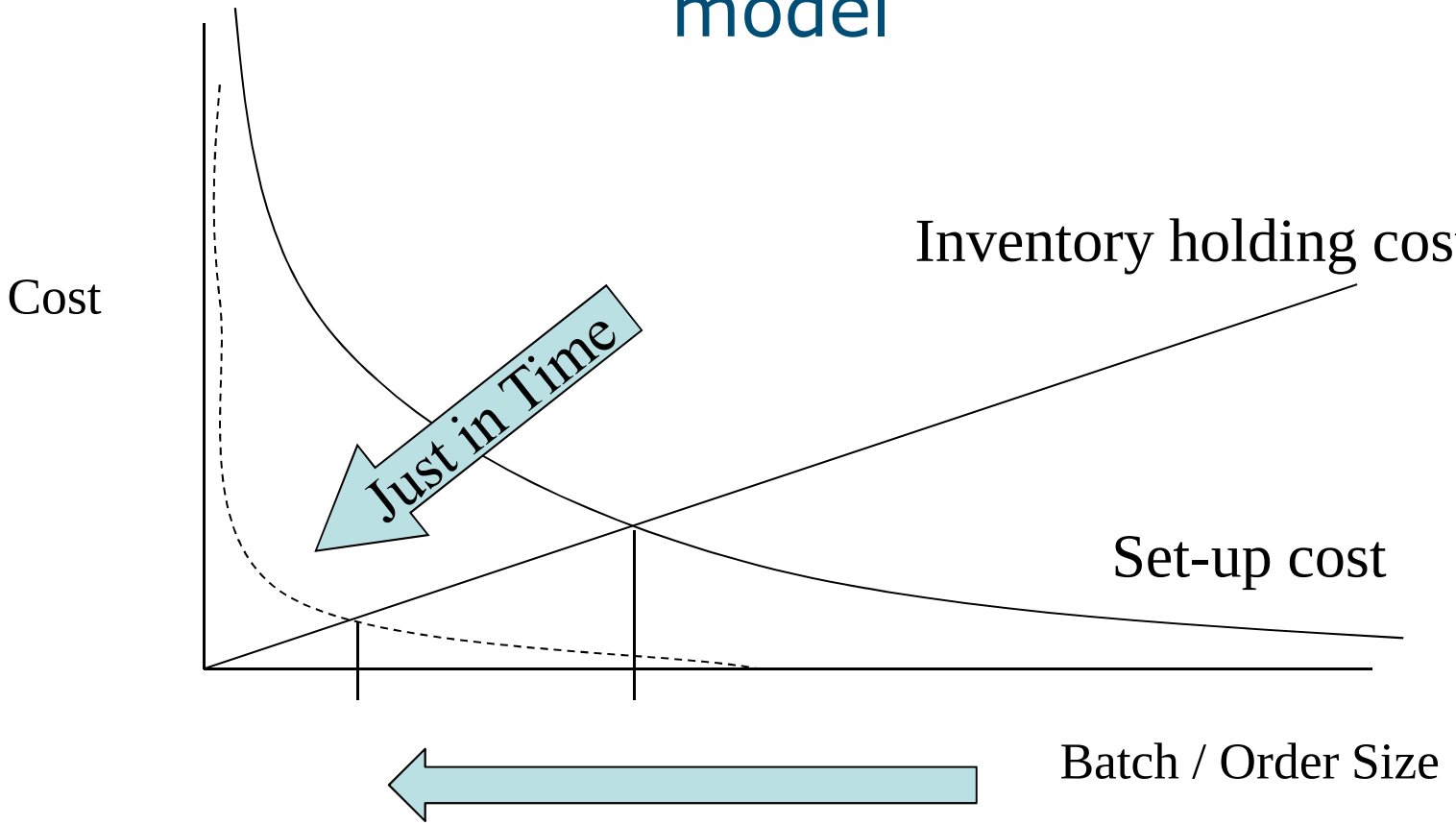


Economic Batch Quantity

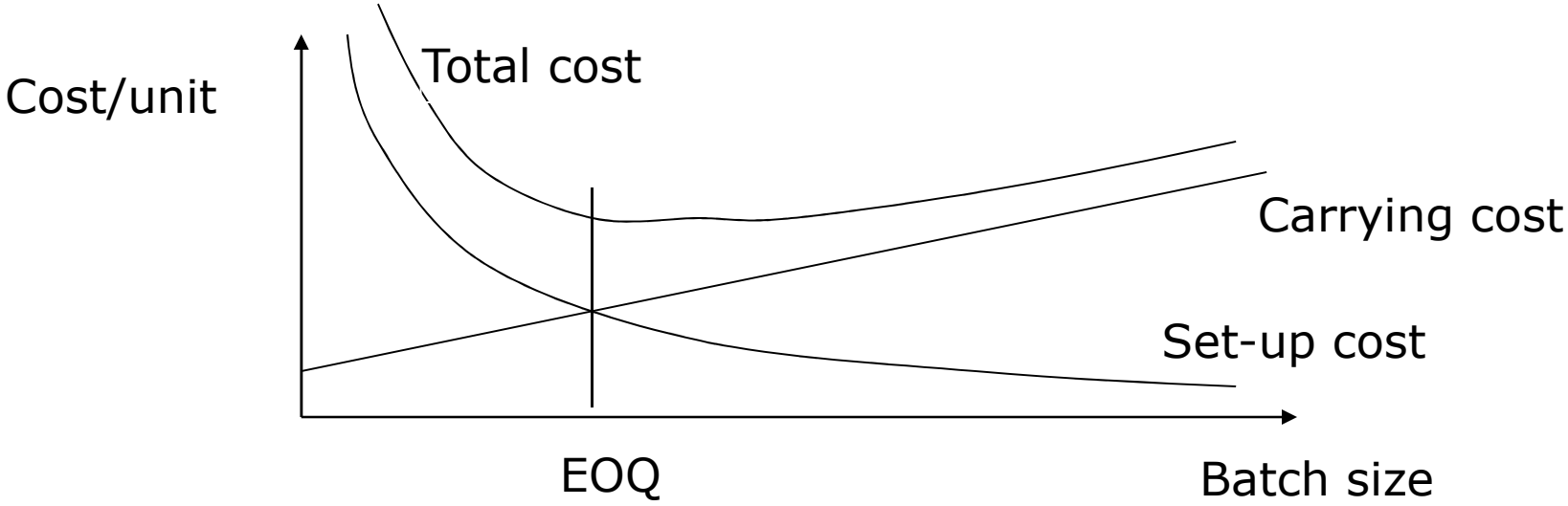
Effects of JIT Production (Schonburger, 1982, p26)

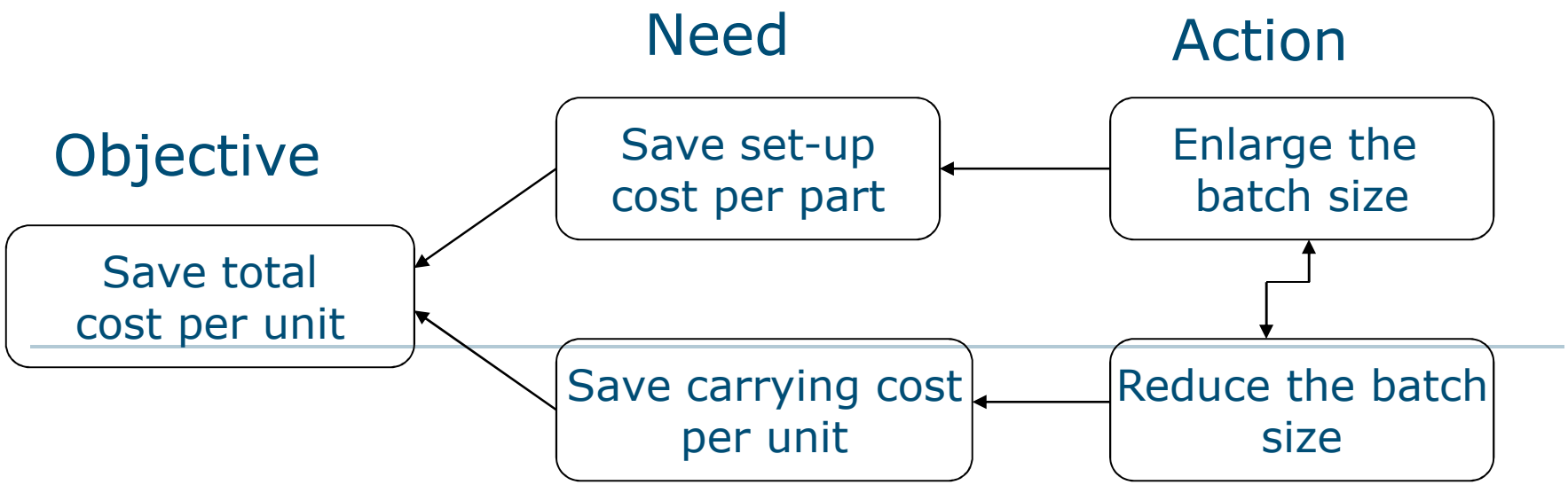


The Lean (JIT) challenge to the batching cost model

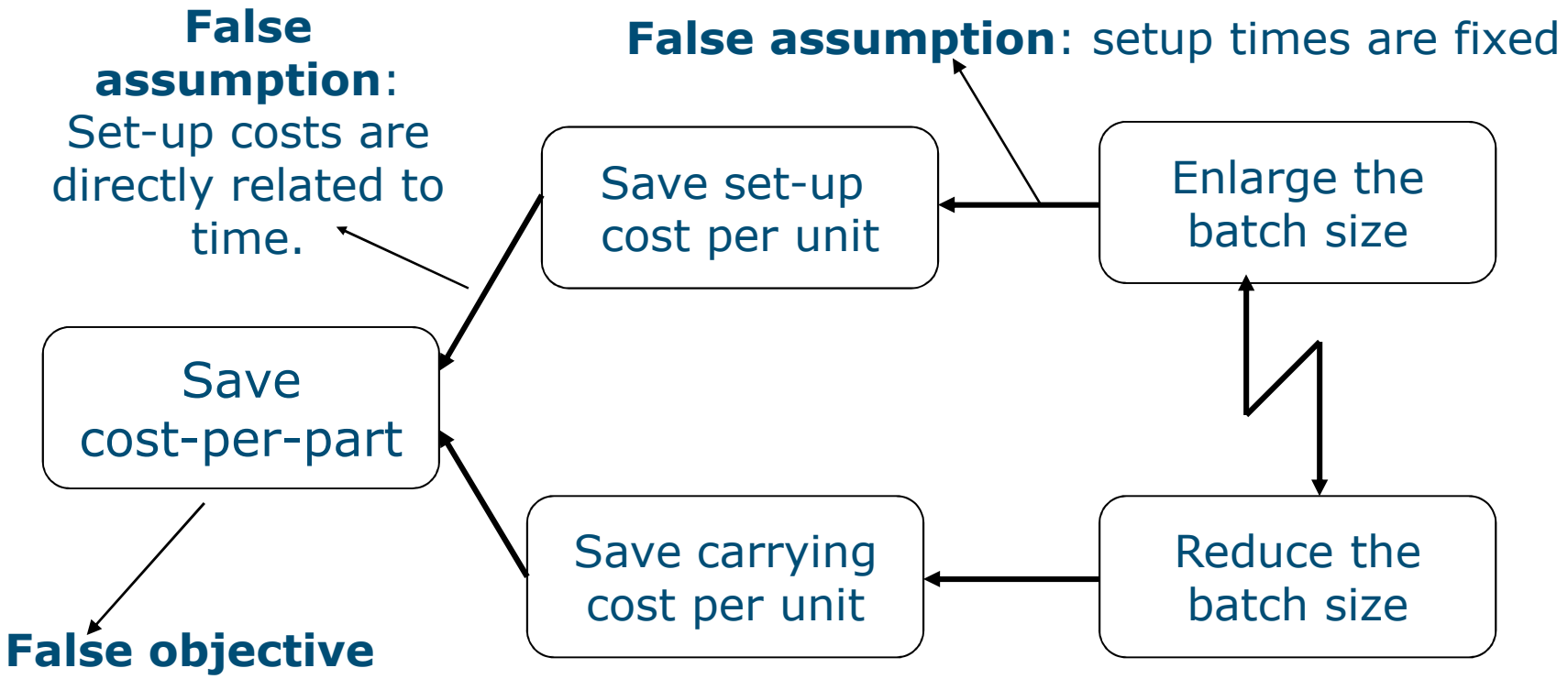


A TOC interpretation (Cloud diagram)





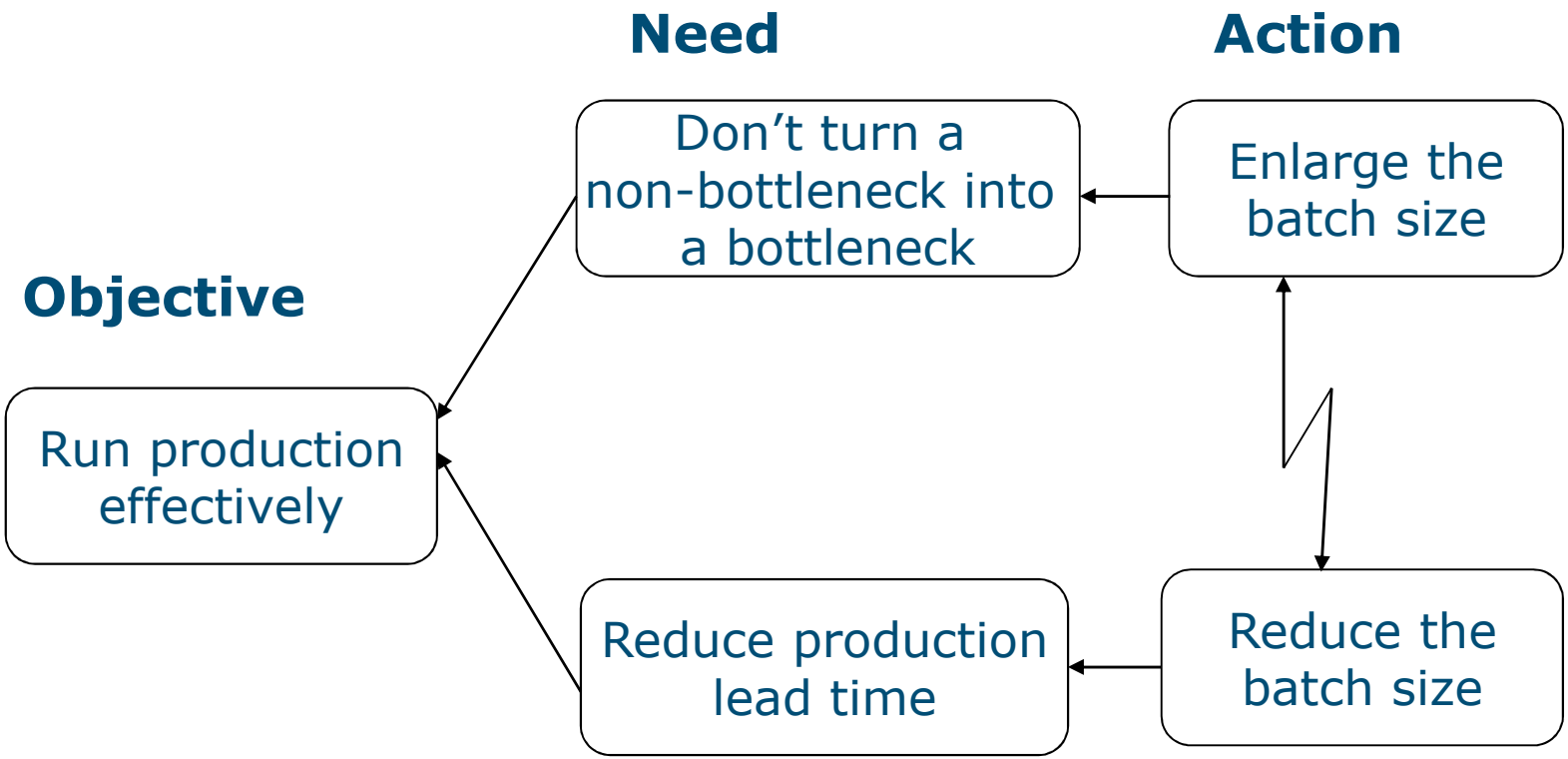
Challenging the assumptions underpinning the batching cost model



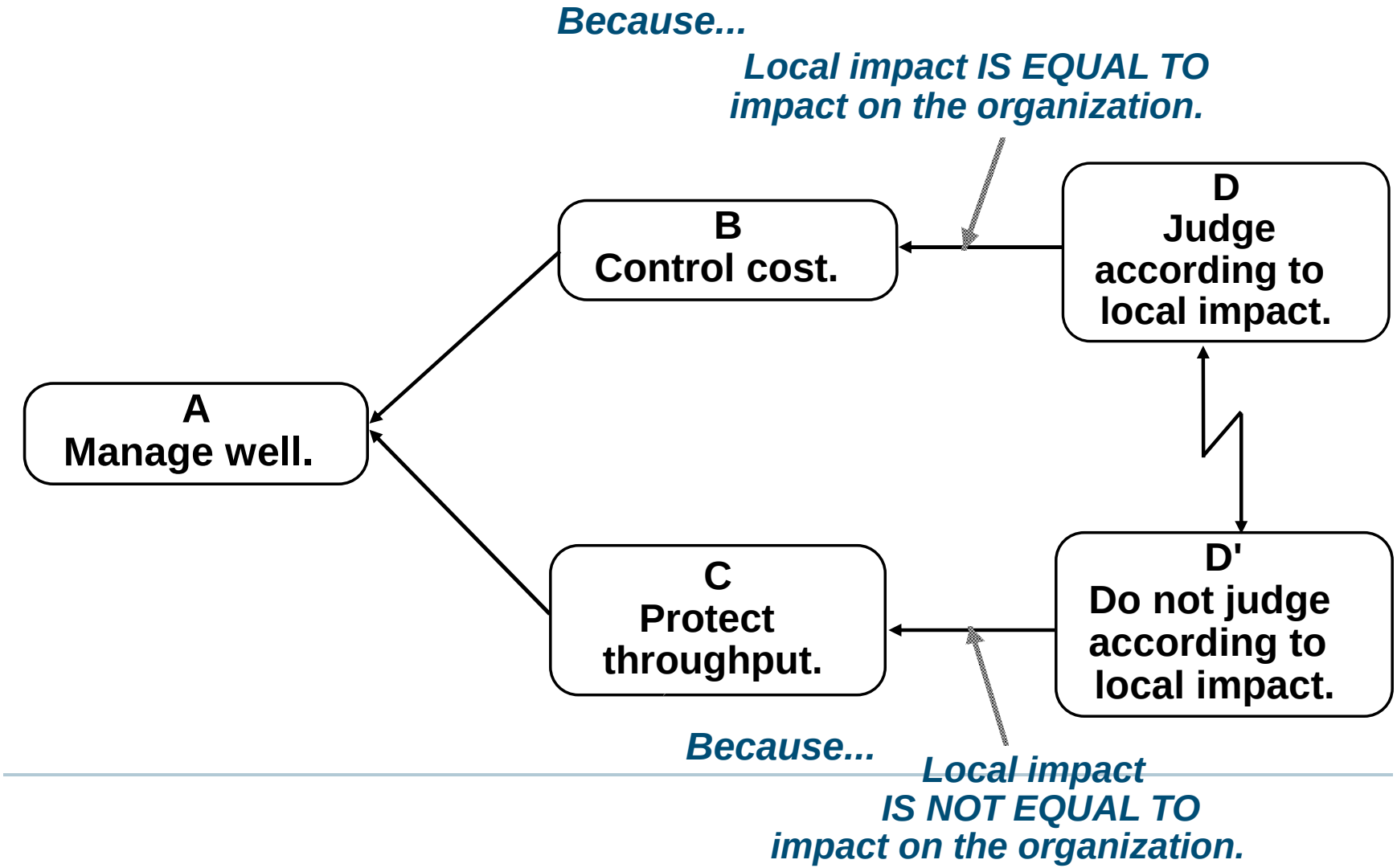
A cost world view

The Reconstructed cloud

A Throughput world view



The generalised cloud of managers



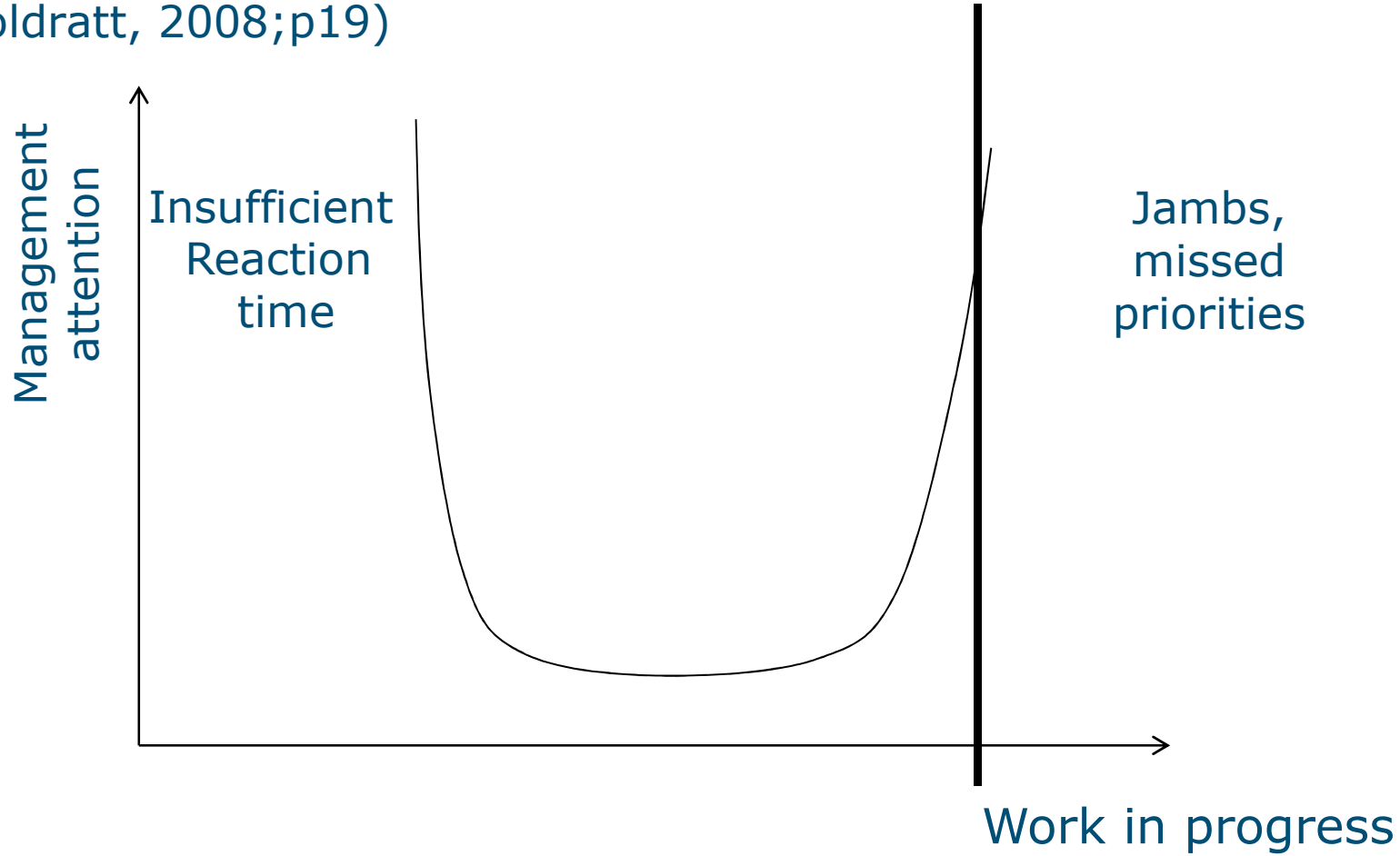
Goldratt (TOC), Ohno (lean) and Ford (flow line) in context

Underlying guidelines for 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).**
  - Ford used space; Ohno used inventory; Goldratt used time and inventory.
- **3. Local efficiencies must be abolished.**
- **4. A focusing process to balance flow must be in place.**
  - Ford used direct observation.
  - Ohno used the gradual reduction of the number of containers and then gradual reduction of parts per container.
  - Goldratt used red zone buffer penetration signals.

The effects of choking the release of work

(Goldratt, 2008;p19)



TOC – challenging the management rules!

Buffer aggregation

Buffer management

‘Scissors’ jump Olympic winner 1928

Straddle high jump technique

Bundesarchiv, Bild 183-S0305-0030
Foto: Mittelstädt, Rainer | 5. März 1977

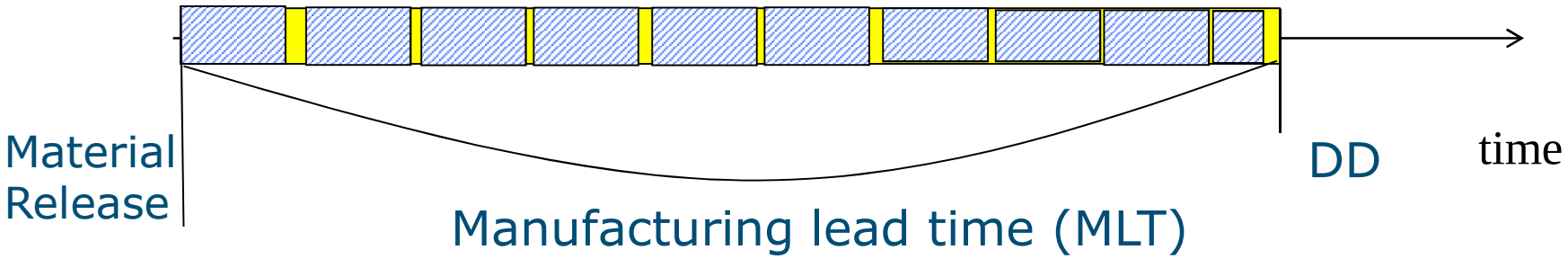
Rule changes enable step change improvements

Dick Fosbury's 1968 Olympic record was
65mm higher than the 1964 Olympic record

Buffer aggregation and Drum-Buffer-Rope

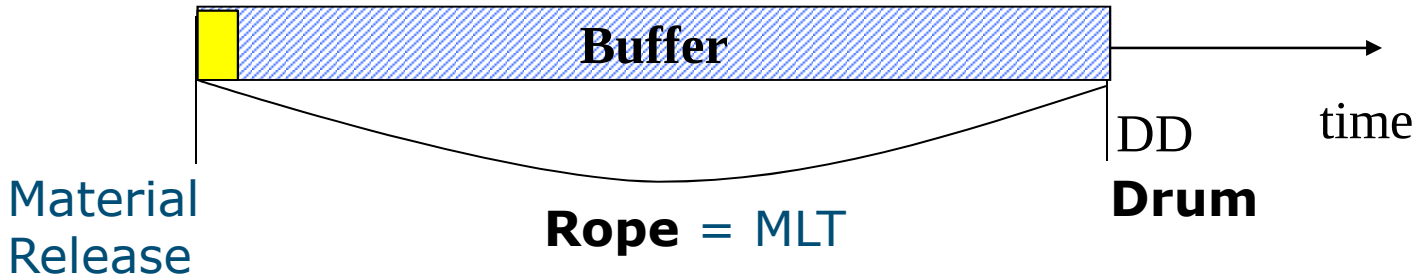
Traditional Make To Order

Intermediate due dates protected by separate queues



DBR

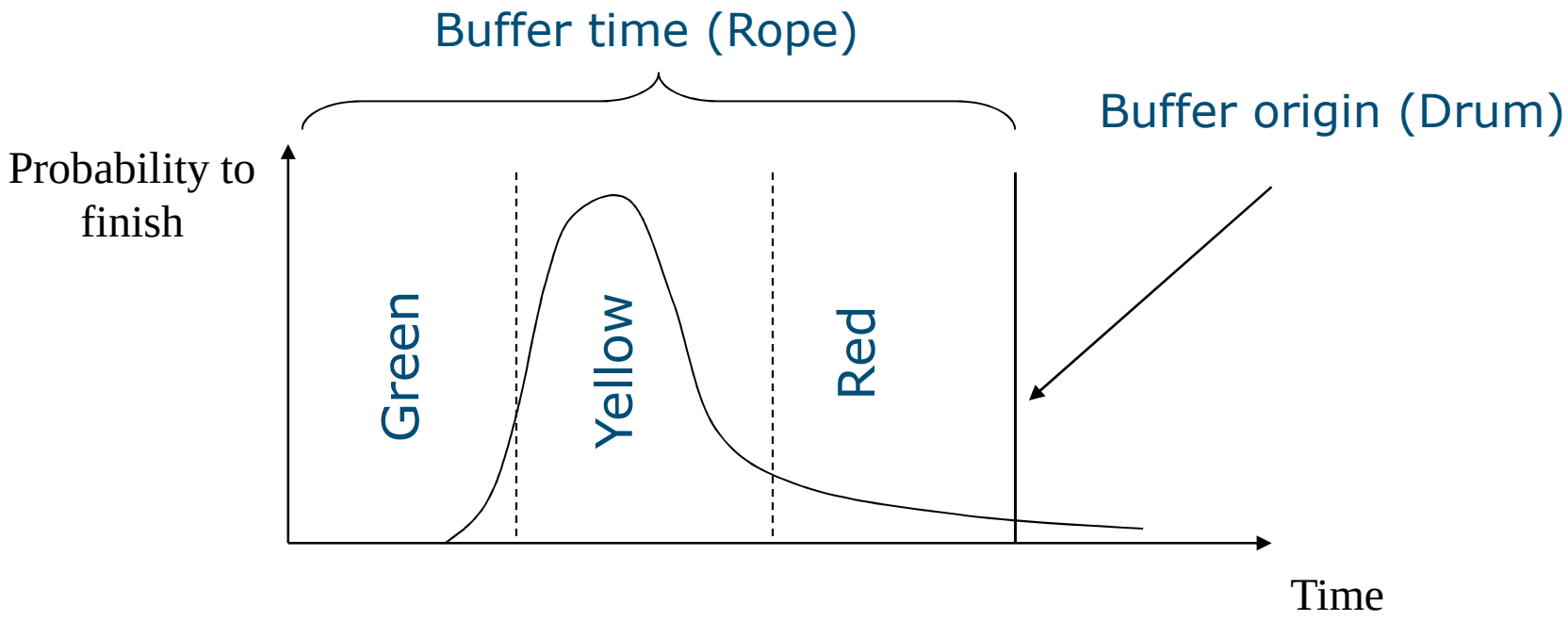
Buffer is aggregated: No intermediate due dates
(Assumes touch time is insignificant <10%)



Touch time: Buffer:

Flow related distribution

DBR and buffer management

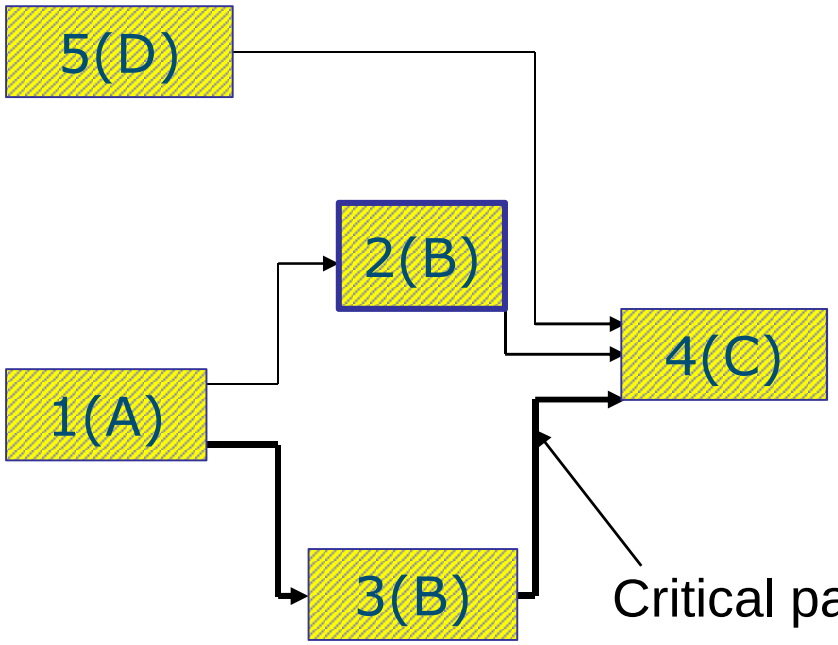


The functions of buffer management applied to Make to Order (DBR)

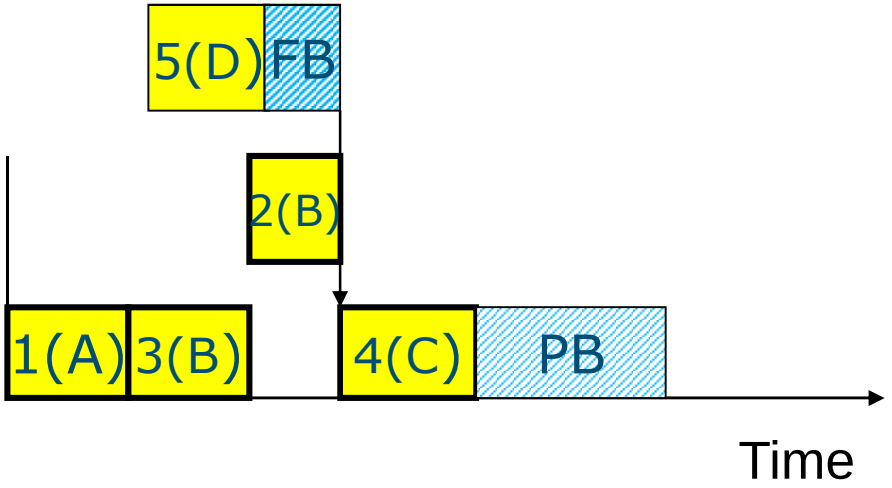
- ***Prioritise*** *the flow of work*
  - *buffer penetration*
- *Identify when to* ***expedite*** *potential delays.*
  - *Respond to individual red zone penetration*
- *Signals when there is a need to* ***escalate*** *intervention.*
  - *Respond to significant and growing red zone penetration*
- *Identify and* ***target*** *main sources of delay for improvement*
  - *Pareto analysis causes of red zone penetration*

Buffer Aggregation and Critical Chain

Critical Path Method



Critical Chain



Resources: A,B,C,D

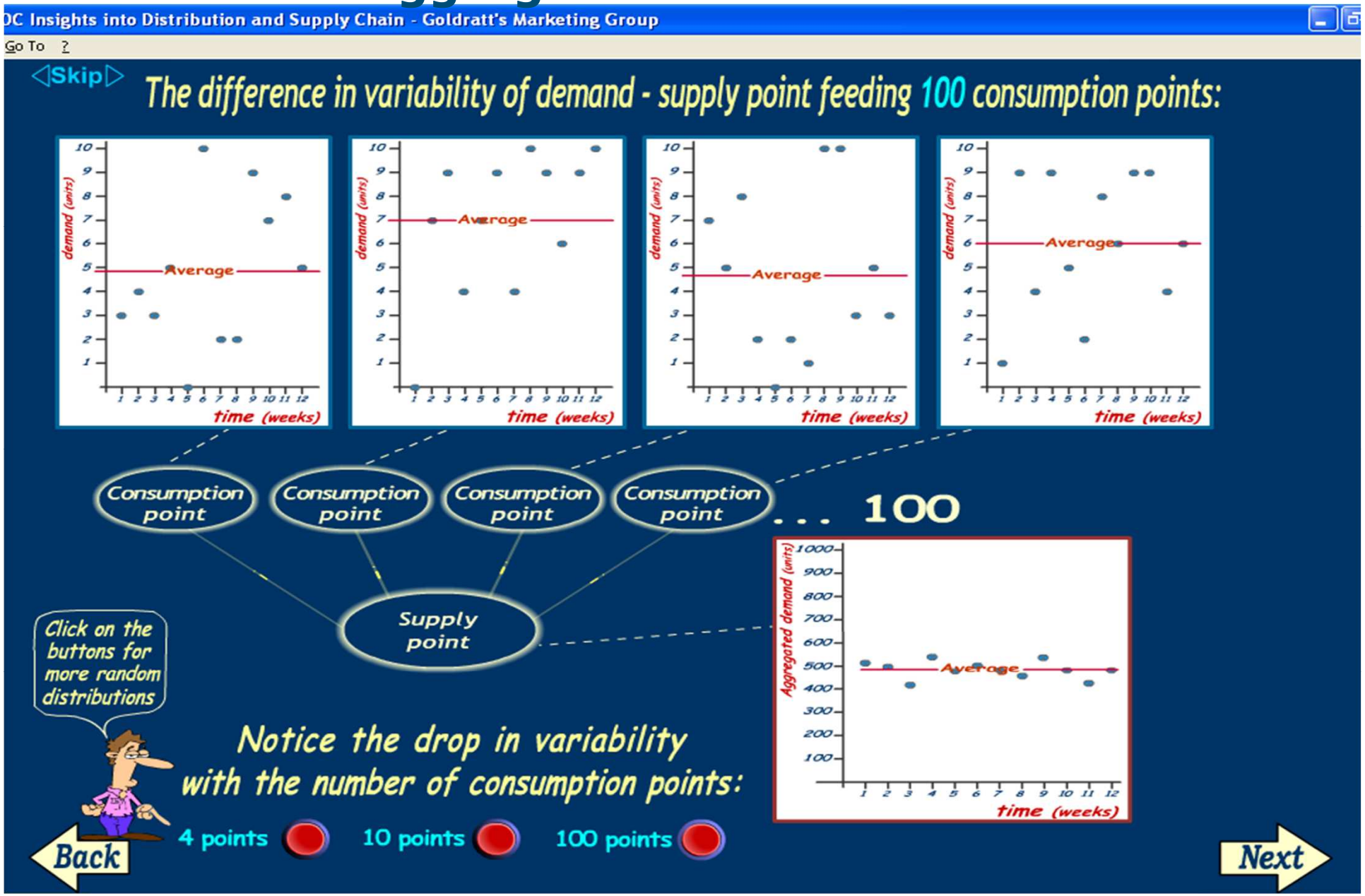
FB: Feeding Buffer
PB: Project Buffer

Touch time: Buffer: Mixed:

Functions of Buffer Management applied to Project Management

- ***Prioritise*** *the flow of work*
  - *Based on a ratio of buffer penetration to project CC completions*
- *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*
  - *Respond to red zone penetration at the project/programme level.*
- *Identify and* ***target*** *main sources of delay for improvement*
  - *Pareto analyse causes of red zone penetration.*

Buffer Aggregation in a distribution network



Functions of Buffer Management applied to MTA and Distribution

- ***Prioritise*** *the flow of work*
  - *% Buffer penetration*
- *Identify when to* ***expedite*** *potential delays.*
  - *If the stock buffer availability shows red the next order is chased*
- *Signals when there is a need to* ***escalate*** *intervention*
  - *If the red zone is repeatedly in the red increase the target level*
- *Identify and* ***target*** *main sources of delay for improvement*
  - *Pareto analyse causes of red zone penetration due to supply.*

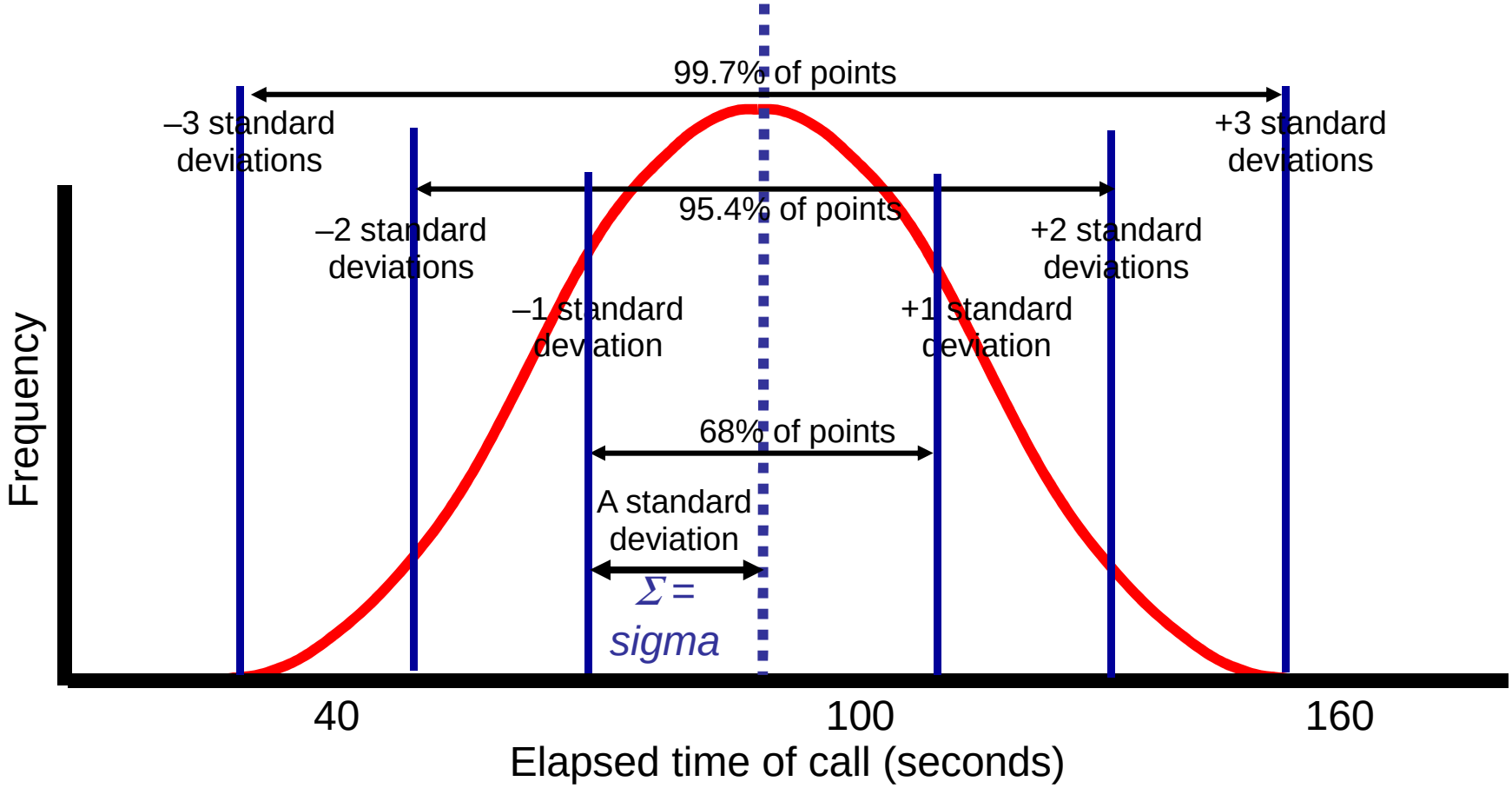
Statistical Process Control and Buffer Management

Variation has wide consequences!

'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.'

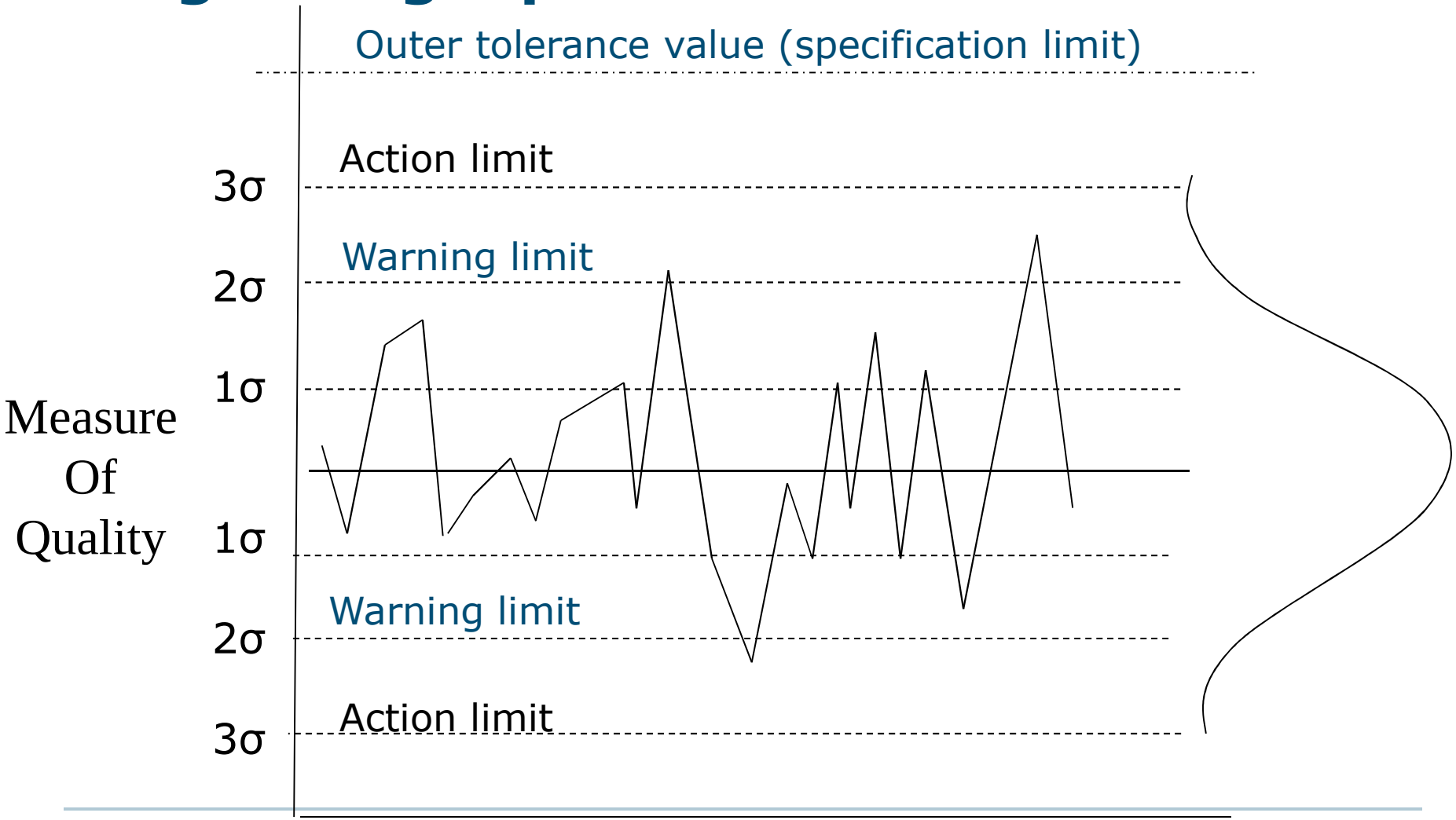
Deming, 1986, p20

Process control charting



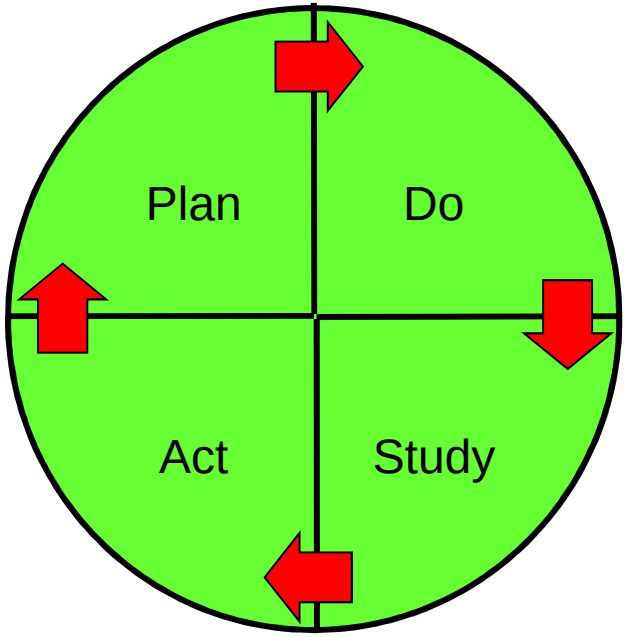
The chances of measurement points deviating from the average are predictable in a normal distribution

Signalling: special and common cause

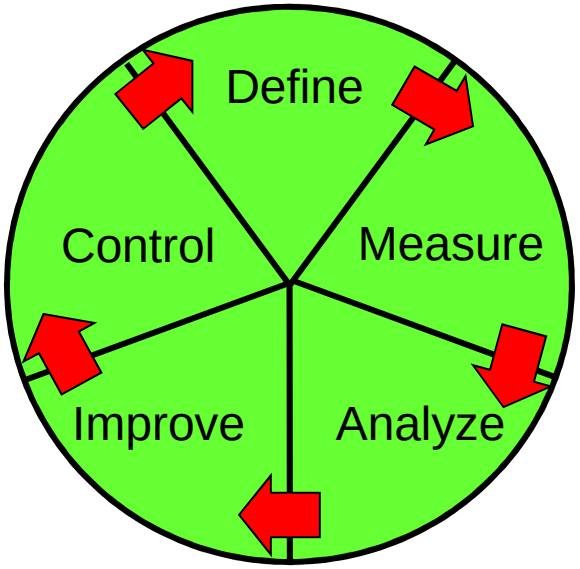


Statistical Process Control Chart

Shewhart Cycle



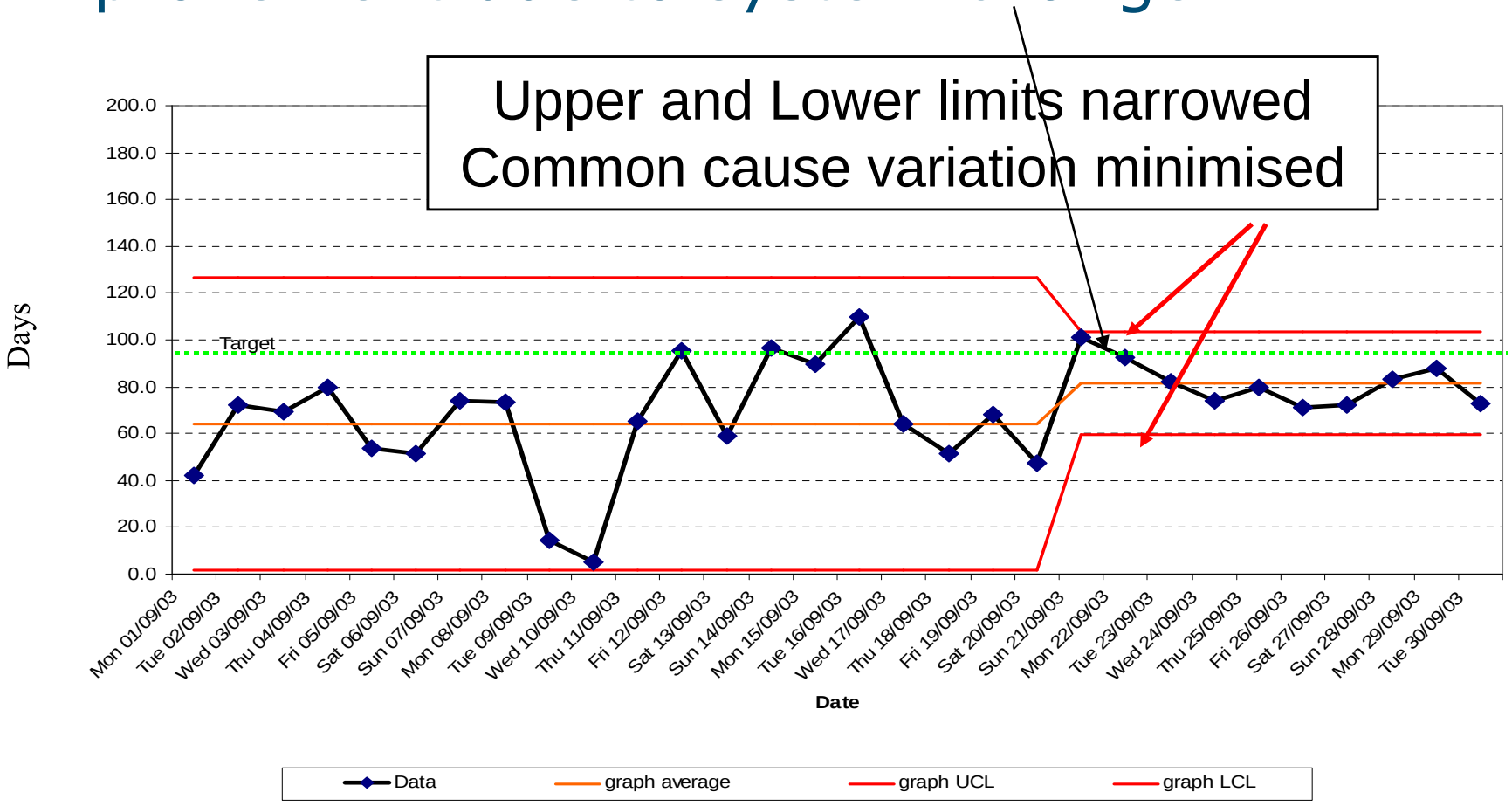
Six Sigma Cycle



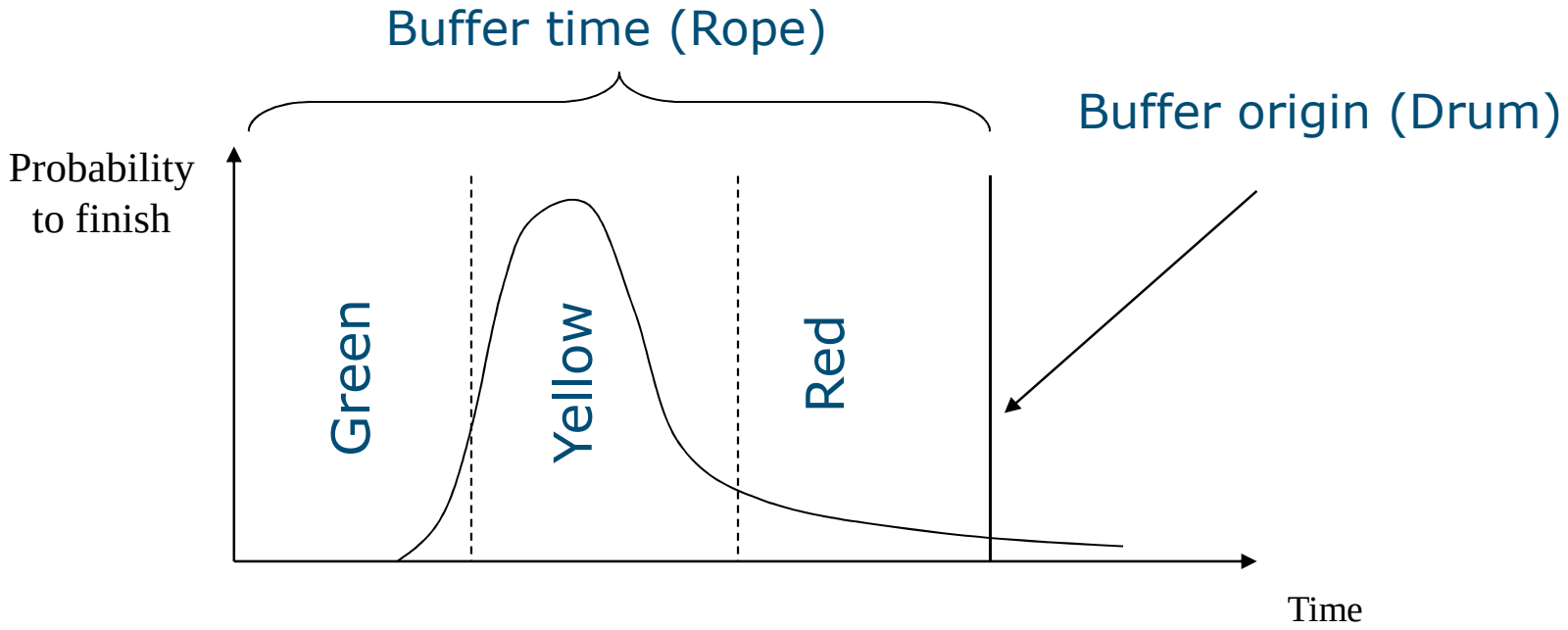
Outline: http://www.youtube.com/watch?v=xzAp6ZV5ml4

Detail: http://www.youtube.com/watch?v=QgmtXRoVVc0&feature=related

Evidence of common cause variation improvement due to system change



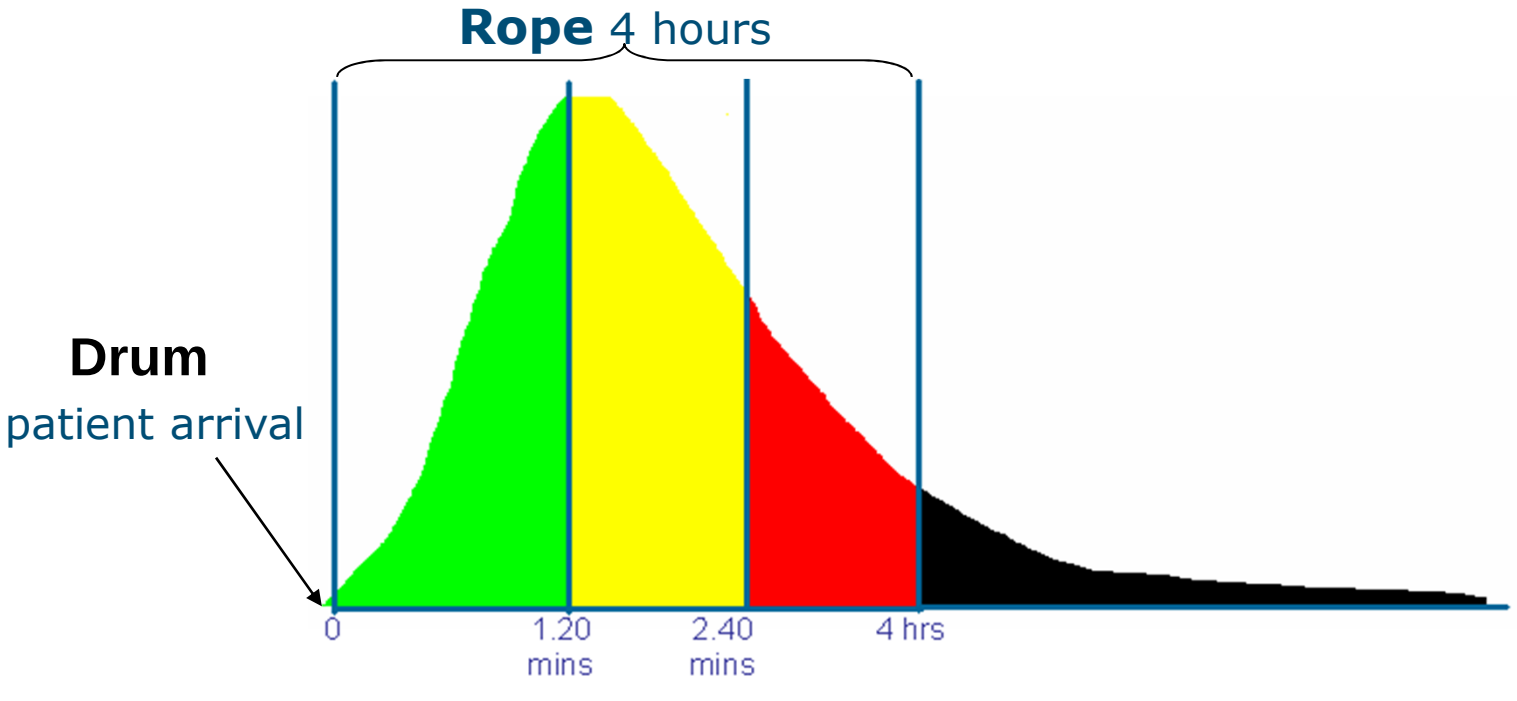
Buffer Management also provides signals to support statistical control



Functions of BM: Prioritise; Expedite; Escalate; Target

Time Buffer Management signals in emergency care

Split the 4 hour process into 3 zones: green, yellow and red.



4 Functions of BM

Prioritise patients**; Expedite** in red zone**; Escalate** instability**; Target** causes of delay**.**

Functions of Buffer Management

- ***Prioritise** the flow of work*
  - *% buffer penetration (green / yellow)*
- *Identify when to **expedite** potential delays.*
  - *Respond to individual red zone penetration*
- *Signals when there is a need to **escalate** increased capacity.*
  - *Respond to significant and growing red zone penetration*
- *Identify and **target** main sources of delay for improvement*
  - *Pareto analysis and target improvement activities*

How do SPC and BM relate?

- The need to gain statistical control also applies to operations flow.
- We need **signals** to predict if the delivery system is becoming unstable.
- 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 **signal** that an order needs to be monitored to ensure there isn't a 'special' cause and ensure it is expedited if necessary.
- Experience has shown the red zone penetration is expected to be around 5% if the system is to remain in control the equivalent of 2 sigma.

How do SPC and BM relate?

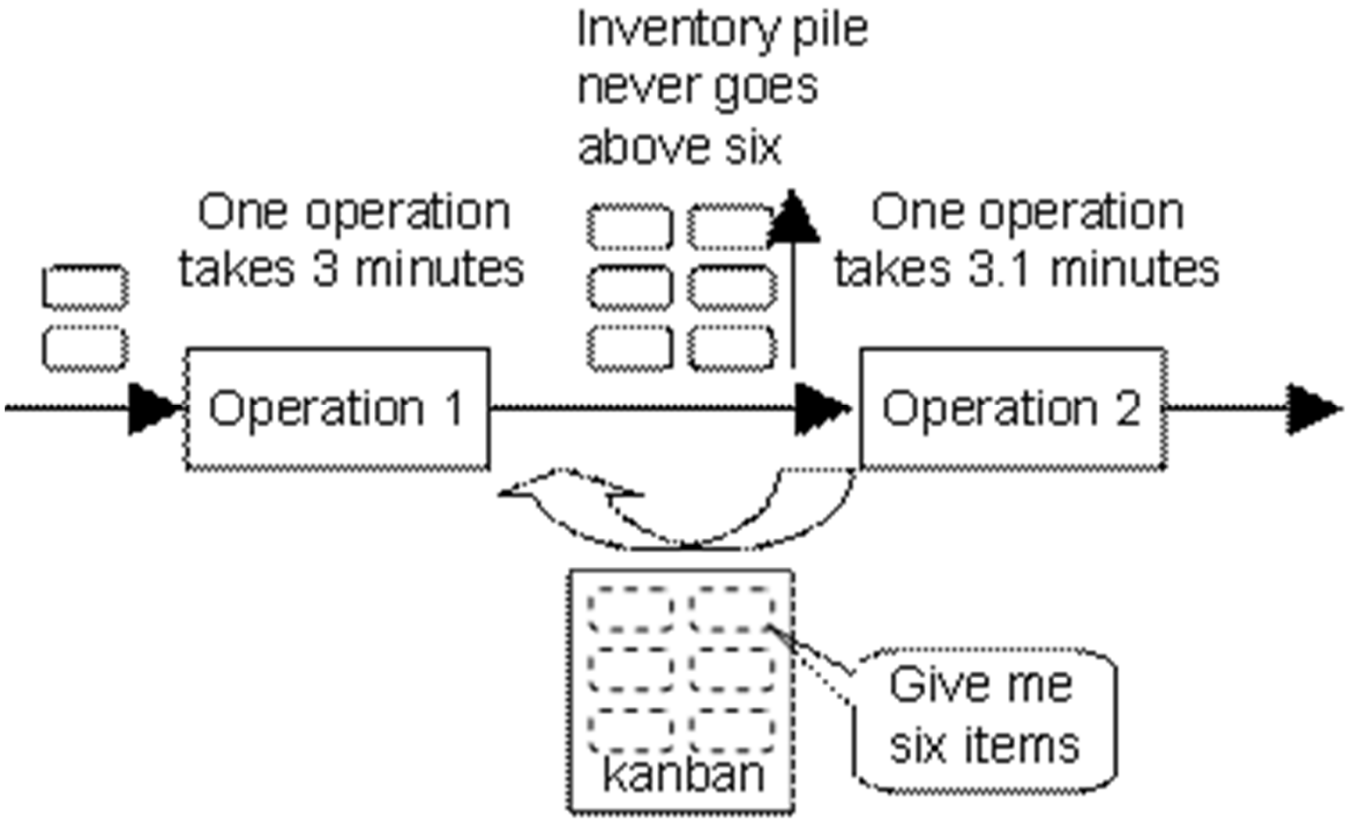
- If the protective inventory and capacity is too high or too low the buffers will need corresponding adjustment.
  - This would also appear to corresponds to a 3-sigma buffer size in SPC terms with the red zone starting at 2-sigma.
- Growing red zone penetration (typically over 5-10%) **signals** the system was going out of control.
- As with '**common cause**' variation, analysis of the causes of red zone penetration over time enables focused improvement effort **utilising lean and 6 sigma tools** (e.g. set-up reduction, machine availability, process reliability, etc).

Kanban Control and Time Buffer Management

TPS kanban management system

- *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 illustration



Kanban functions/rules

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.	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 sesitivity.

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

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

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.

Conclusion

Attribute	Approach / Theory / Philosophy		
	Six sigma	**Lean**	**TOC**
Environment	All processes	Inherently stable flow	Complex flow
Key word	Variation	Flow	Focus
Key assumption	Process variation drives the cost vs. quality trade-off	Batching drives buffering and waste	Buffers need to be strategically managed
Distinguishing Methodology	Plan, Do, Study, Act	Value stream mapping	Cause & Effect mapping / Conflict resolution
What to change	Specific Processes	Process flow	Management Rules
Distinguishing improvement concept/tool	Statistical Process Control	Kanban control	Buffer management
Application sequence?	2	2	1


Questions