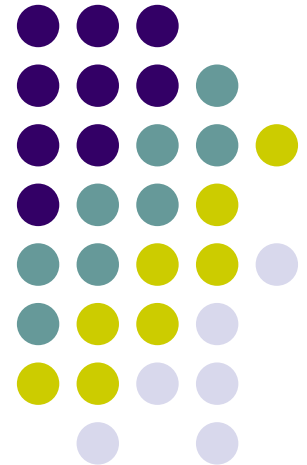


The Theory of Constraints approach to Supply Chain Management

Ensuring that the market is always supplied
on time and in full in terms of products and
service

Presented by Dr Ted Hutchin
Industrial Fellow University of Nottingham Business School





The goal of the session

- Apply the holistic approach of the Theory of Constraints systems to Logistics system
- Grasp the causalities within the Logistics system and between that system and the rest of the organisation
- Evaluate the applicability of this knowledge to the reality within Logistics



The five steps of focusing

- 1. Identify the constraint
 - Physical and policy constraints
- 2. Exploit the constraint
 - Maximise the performance of the constraint
- 3. Subordinate to the constraint
 - Everything works to the consumption of the constraint
- 4. Elevate the constraint
- 5. Prevent inertia – go back to step 1

Continuous Improvement Process



- **Step 1 - identify the system constraint:** the constraint determines the speed/flow of the entire process, improve the capability of the constraint and the whole supply chain is more effective
- **Step 2 - exploit the constraint:** maximise the constraint schedule, make sure that the proper volume/mix calculations have been done base on the contribution of the time on the constraint
- **Step 3 - subordinate all other operations to the constraint:** otherwise the whole system will choke with excess inventory, costs will go up, delivery performance will go down, lead-time will increase, bottom-line will go down etc
- **Step 4 - elevate the constraint:** either increase the capability of the constraint or keep the constraint where you want it to be, make sure that no other area will become the constraint and then elevate.
- **Step 5 - prevent inertia** – go back to step 1
- *Do not focus your people, time and money on a non-constraint operation within the process. It will only increase WIP prior to the constraint and it will not improve the profitability of the plant, in fact you will achieve the opposite*



The four main questions

- What to change?

.....

- What to change to?

.....

- How to cause the change?

.....

- POOGI?

.....

Boundaries of the Discussion



- All activities and functions related to making the finished goods products available to the market and raw materials available to production, including subcontracting

- Refer to the supply chain diagram



The goal of the session

- What is the goal of distribution?
 -
- How is distribution defined?
 -
- How do you know it is going well?
 -
- What are the key measures of performance?
 -



Problems/issues of the function

- List the key problems and issues relevant to the function

-
.....
.....

- What problems/issues are created for other departments?

-
.....
.....

The Current Reality Tree (CRT)



- Distribution Performance Measures:
 - Due date performance
 - Availability
 - Lead time
 - Inventory turns
 - Operating Cost
 - Quality
- Distribution Possible UDE's:
 - Too often there is a need for an urgent delivery,
 - Priorities constantly shift,
 - Too many shortages,
 - Too many inventory items have too high inventory levels,
 - Too many inventory items are obsolete,
 - Dead inventories level is too high,
 - There are too many cross-shipments,
 - There are too many customer returns,
 - Delivery costs are too high.

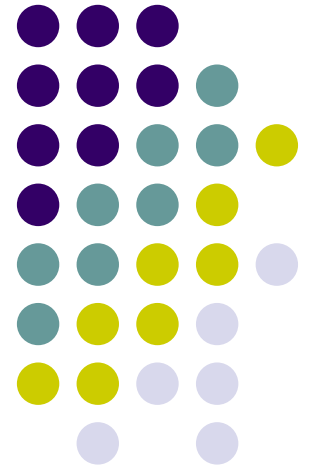


The CRT – Cont.

- Other Functions Possible UDE's:
 - Lost sales,
 - Introduction of new products is often delayed,
 - Reduced profit,
 - Too low ROI,
 - Lost customers,
 - Constant shift in priorities (OP's).

What is Distribution all about?

Aligning the global
supply chain





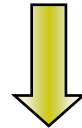
What is distribution?

- The consumption locations are remote from the production location
- The tolerance time of the buyer is much shorter than the time it takes to make the product available to the point of consumption
 - (If this is not the case then we are simply into a “Transportation” scenario)

What is distribution?



This normally leads us to conclude that we should hold material close to the point of consumption – so as not to lose the sale



Let's understand the problem in more detail

The Constraint of the System



The Constraint governs the throughput of a system.

In the case of Distribution the throughput is determined by the number of customers who come to buy, or consuming
-> more customers buying, more throughput



In order to “exploit” this constraint of the system we should ensure that we have the right inventory, at the right place at the right time



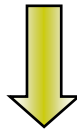
The key is, then, managing the distribution system so that we have the right inventory, at the right place at the right time

Considerations



Replenishment time: the longer the replenishment time – the more inventory the selling point should hold
The distribution system has inventory on the way + inventory at the site

Factors which impact Replenishment time: Batching which impact; order lead time (e.g. at the selling point), production lead time, transportation lead time



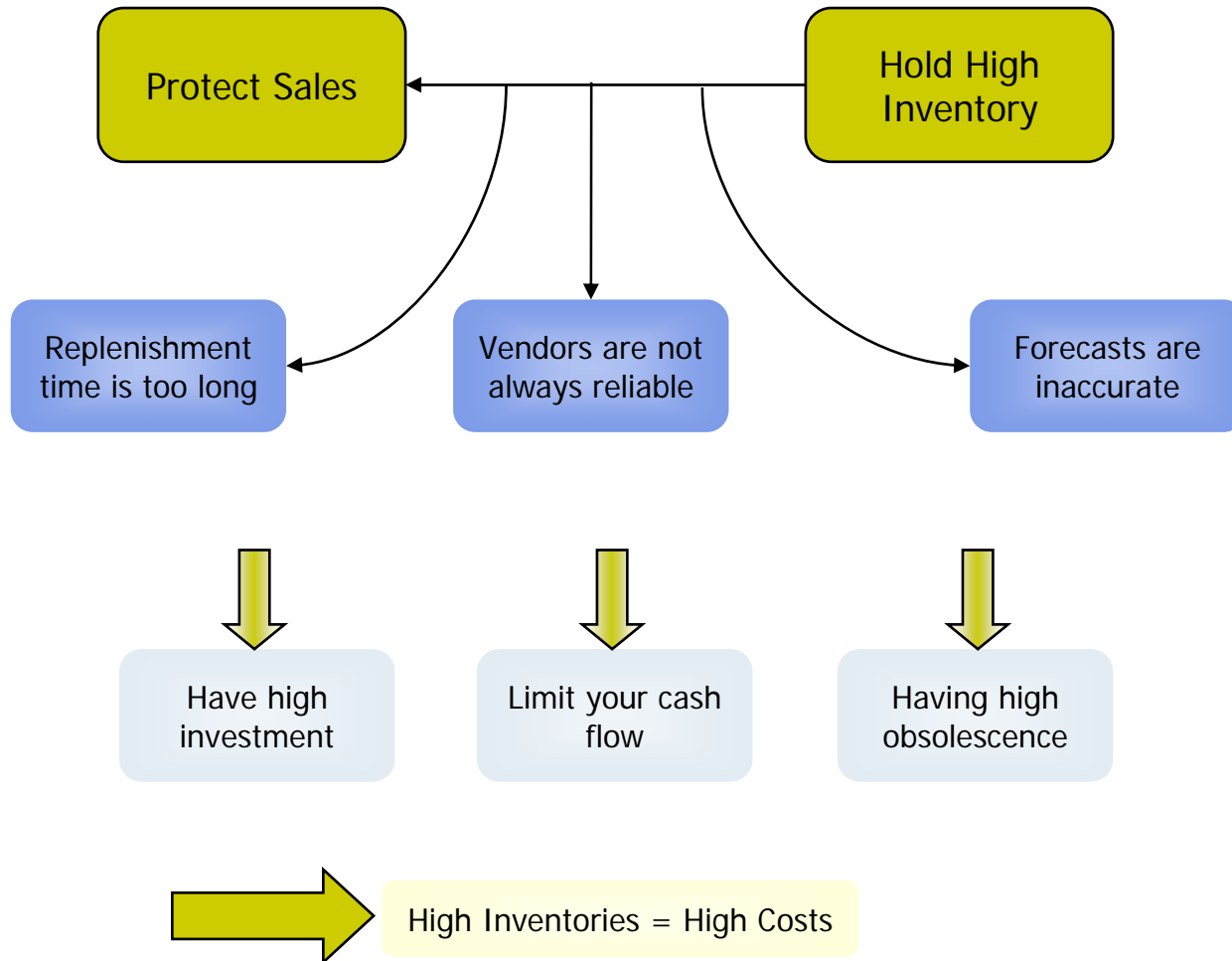
Long replenishment lead time results in higher inventories in the system. It also results in poorer forecast accuracy (and a greater reliance on forecasts)

Furthermore the true level of shortages is not known;

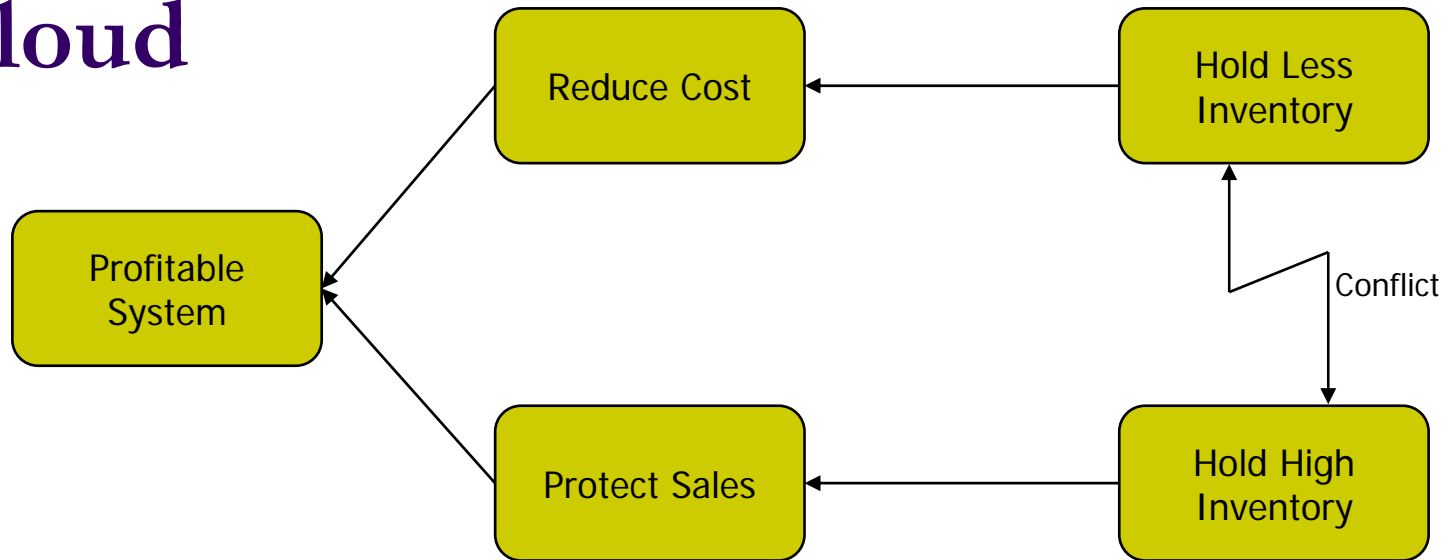
- customers do not complain to the seller every time an item is not found
- when they do, the sales person will not always register the shortage in the system
- when they do, the warehouse will not always register that an order was not placed

This means that the true level of shortages is likely to be 20% rather than the 2-3% that most systems report...

One solution – hold high levels of inventory



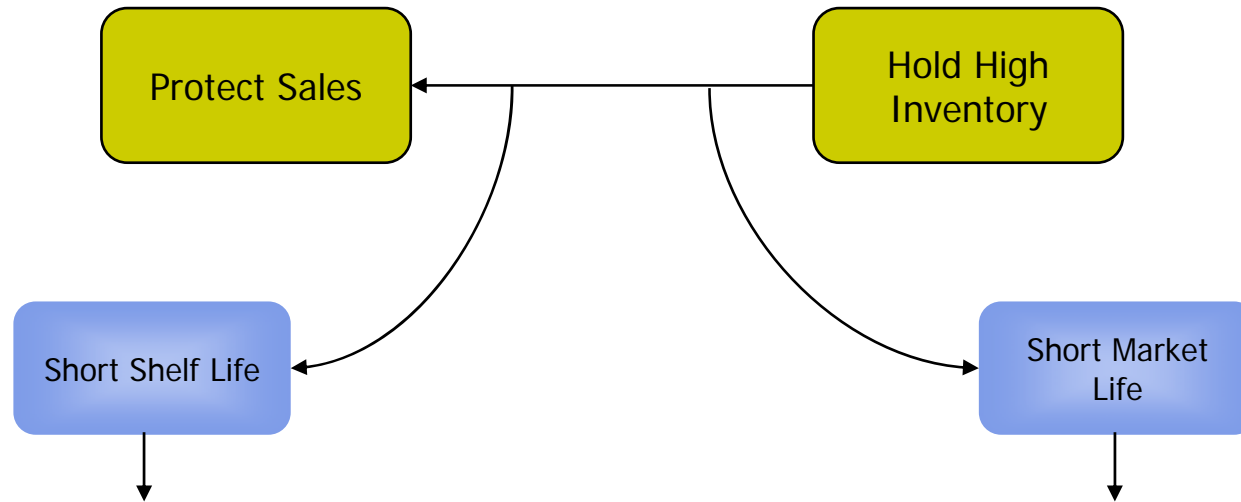
High Inventory – resulting conflict cloud



Most solutions to this problem estimate the expected consumption (e.g. per year) and then set a target level for each item according to the forecasted consumption per month (for example) – this ignores the replenishment time completely.

As a result, performance is measured using terminology such as total stock turns per year -> ignoring that some items may have zero inventory whilst others may have enough inventory for a year for others.

High Inventory – can jeopardise sales



Where the items have a short shelf life, the long lead times (that result from high inventory, batches, etc) will mean that many items are offered to the customer close to the expiry dates – this could impact future sales if quality is reduced and will put some customers’ off making the purchase in the first place

In this scenario, newer version of our own product, or competing products will be entering the market soon after introduction of the existing product.

There are a number of impacts of this:

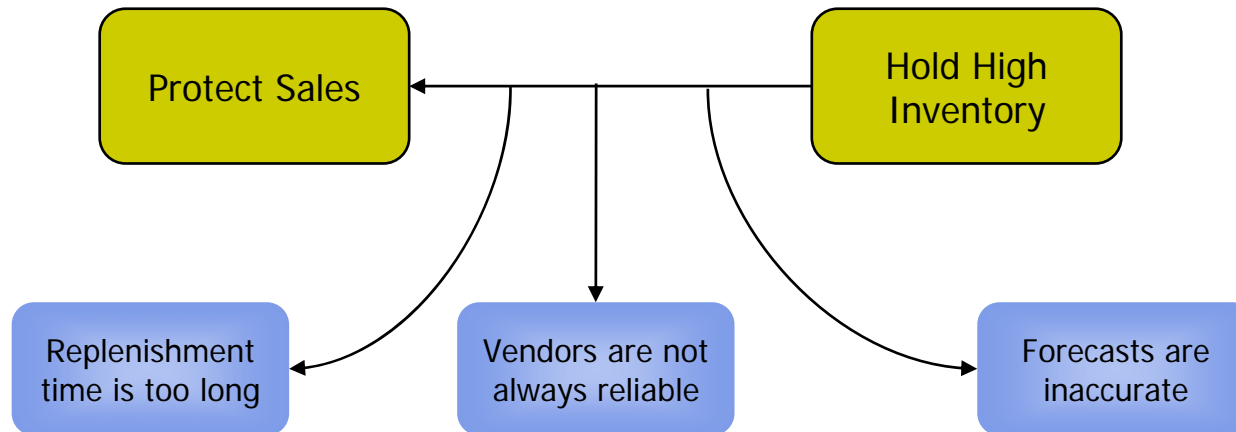
- Obsolescence due to the release of more advanced products;
- Loss of income due to “end of line” sales of the old products;
- Loss of market share due to delaying new product introduction whilst existing stocks are sold.

The required solution must meet a number of criteria



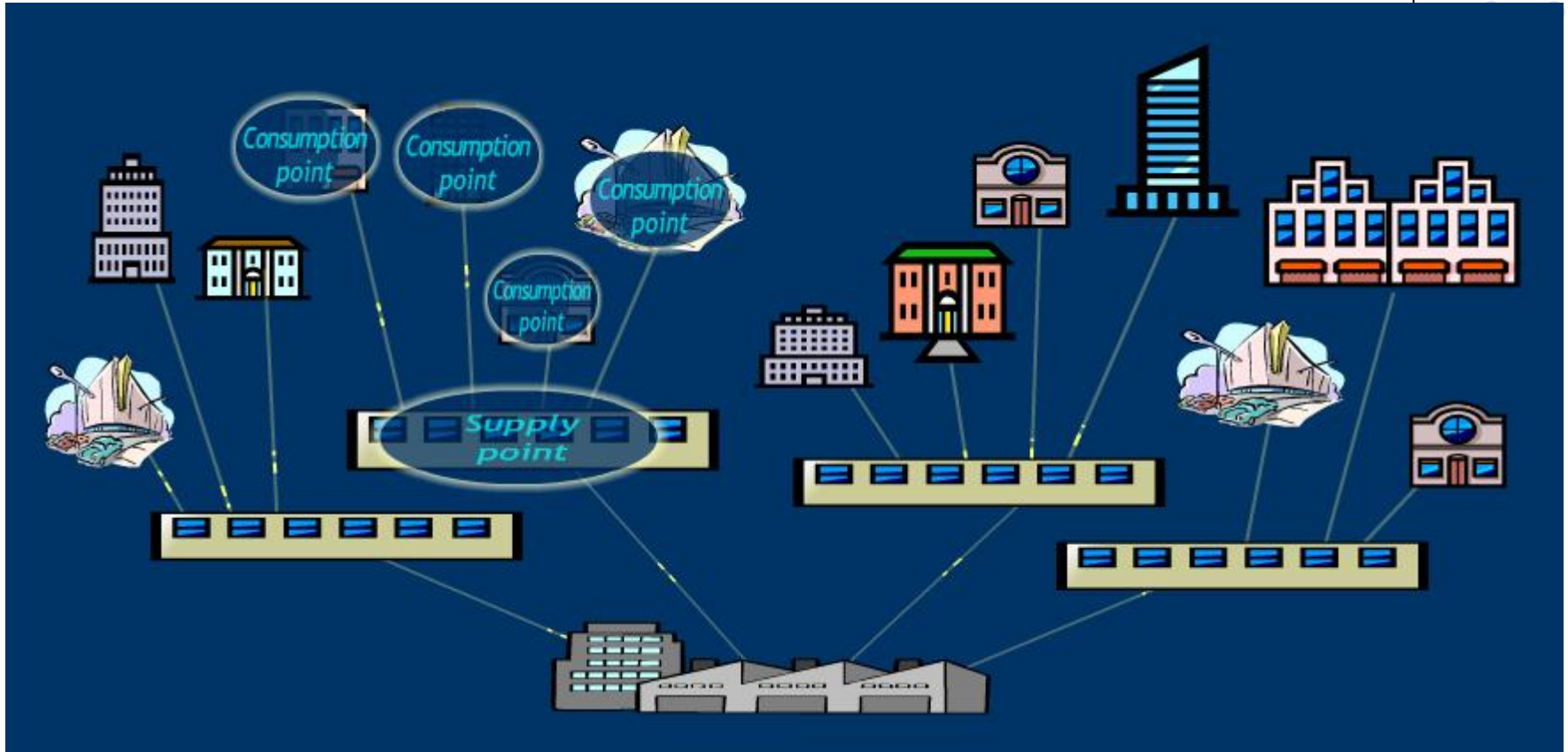
Any solution must improve the distribution system by:

- Drastically reducing shortages
- Reduce the high levels of inventory



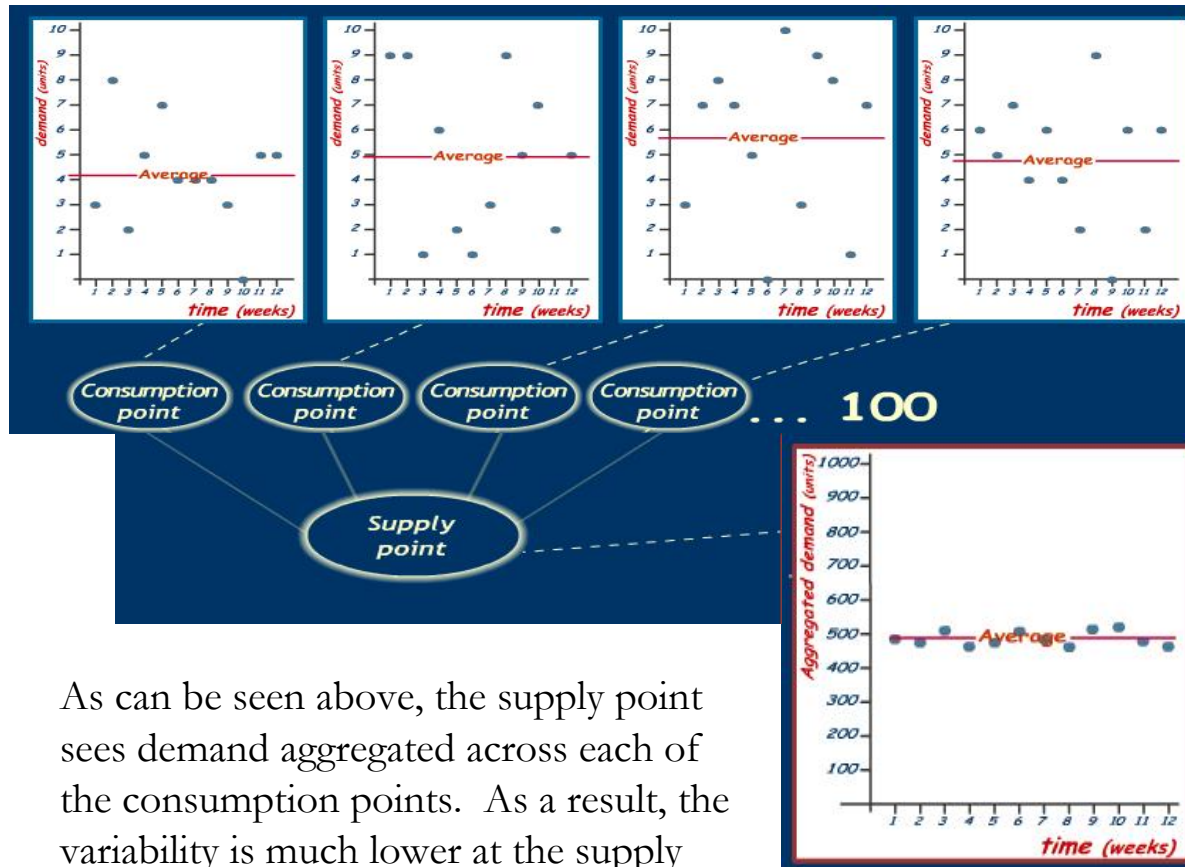
At the same time, it is impractical to invalidate any of the underlying assumptions, above.

Is the relative accuracy of a supply point the same as a consumption point?



The manufacturing plant (in this scenario) is also a supply point, with each of the regional warehouses being a consumption point to it...

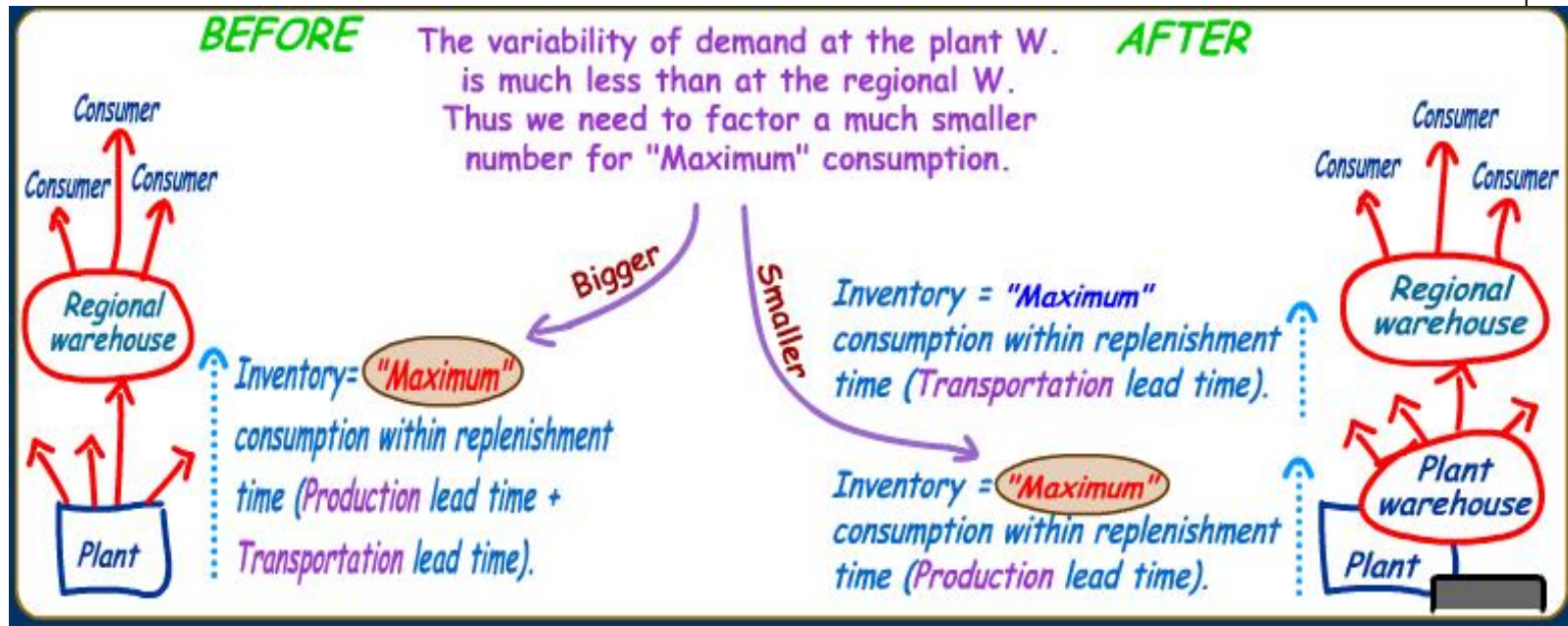
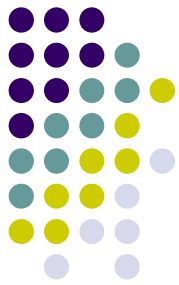
Is the relative accuracy of a supply point the same as a consumption point?



Example: a supply point, aggregating across 100 consumption points

As can be seen above, the supply point sees demand aggregated across each of the consumption points. As a result, the variability is much lower at the supply point than at each of the consumption points above

The Solution, Part 1: Introduce a Plant Warehouse



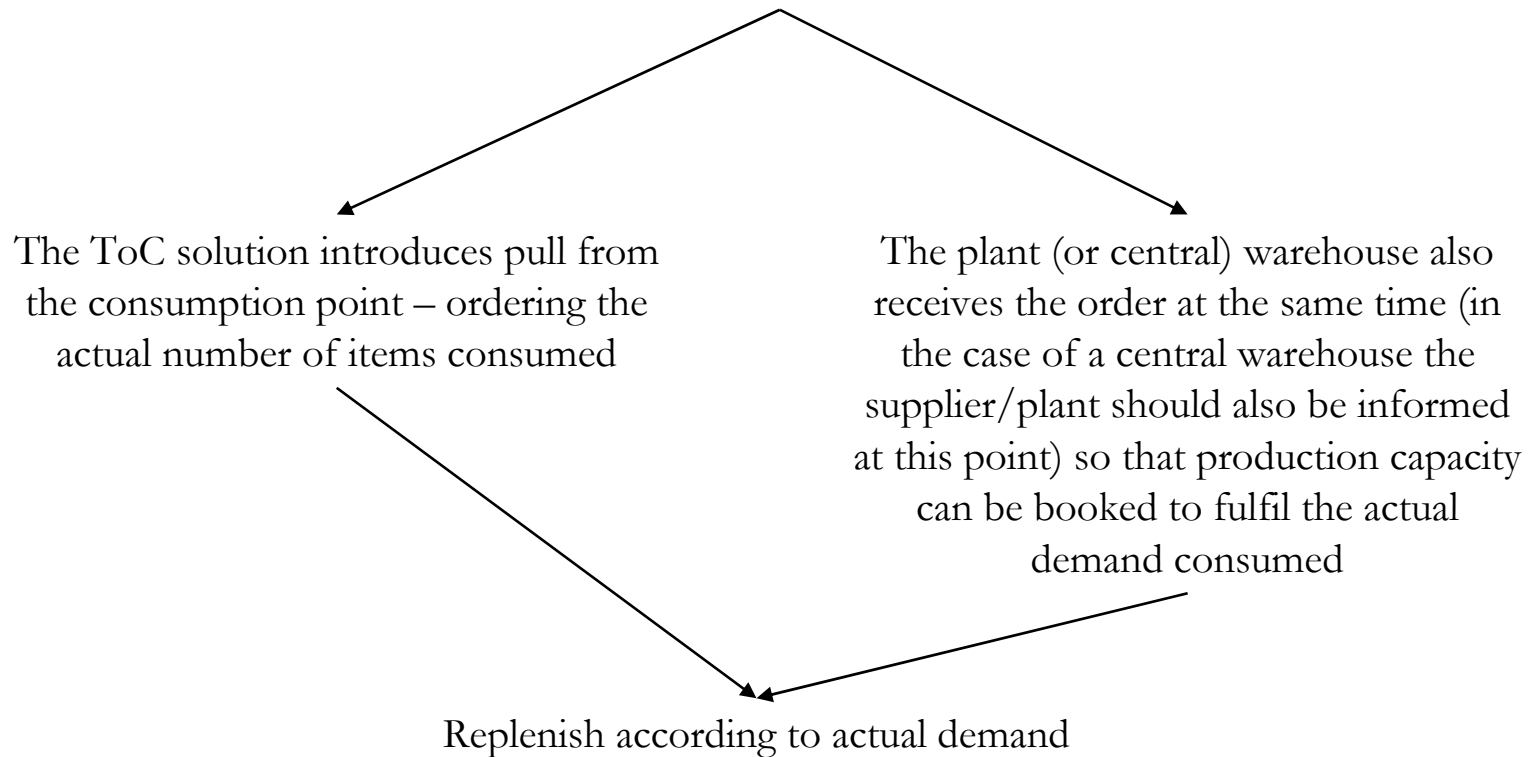
The introduction of a plant warehouse ensures that the variability in the demand for each item is kept to a minimum.

The plant warehouse also means that we can hold inventory of every item at this central location and *guarantee* its' supply to every consumption point within the replenishment time only.

The Solution, Part 2: Move from Push to pull



Long lead times and batching throughout the supply chain almost necessitate that items are made to a forecast and pushed through the supply chain



The Solution, Part 3: Order daily replenish frequently



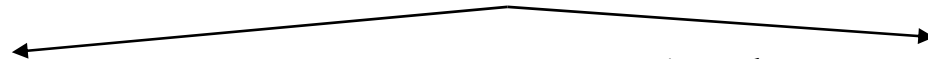
Long lead times and batching throughout the supply chain almost necessitate that items are made to a forecast and pushed through the supply chain



We have already described the move from push to pull



We should also order daily – that is at the end of each day place the order for the actual items consumed that day



We should aim to replenish daily



In most circumstances this will simply require changing the mix of items that are delivered each day – instead of delivering a batch of items forecast to be enough for e.g. 1 month, we will be delivering the items actually consumed

Actual consumption will not have changed

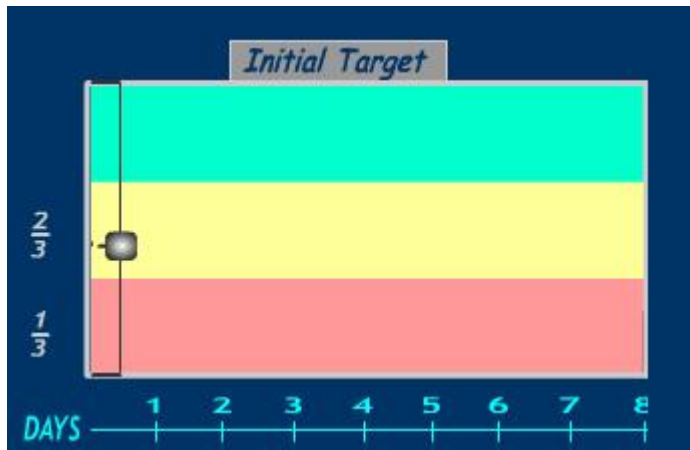


The total number of items delivered will not change – if there are currently daily deliveries, the number delivered per day will also not change (except for the adjustment period where stock is removed from the system)

The Solution, Part 4: react to changes in demand without a forecast



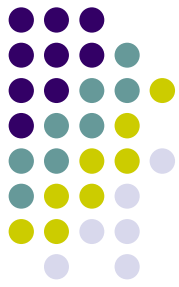
An initial target inventory is set:



The Red Zone indicates low Inventory

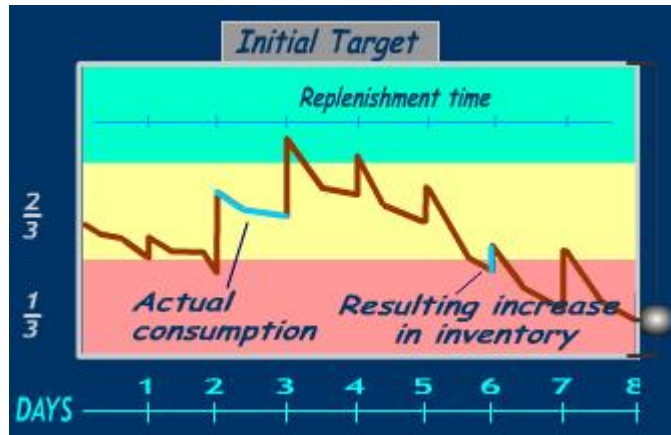
The Yellow Zone indicates normal Inventory

The Green Zone indicates high Inventory

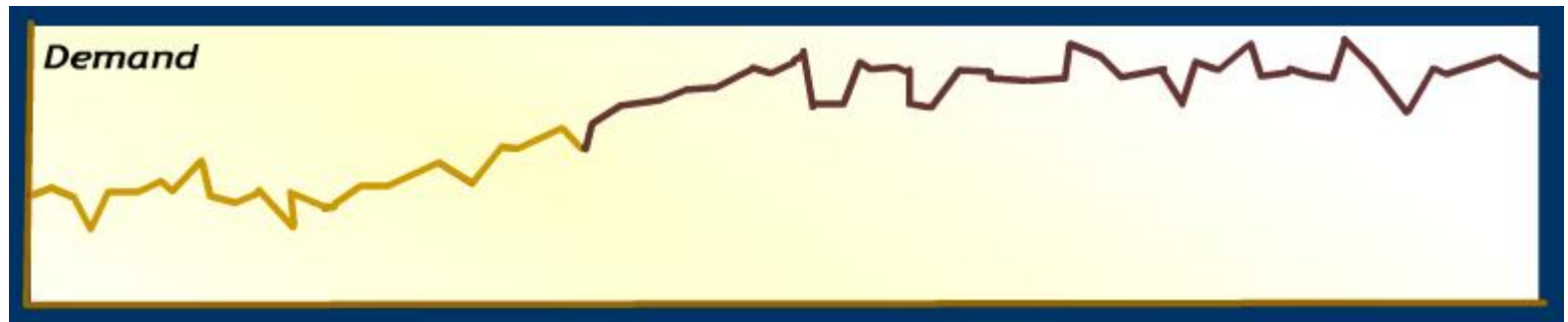


The Solution, Part 4: react to changes in demand without a forecast

The Inventory level is plotted:



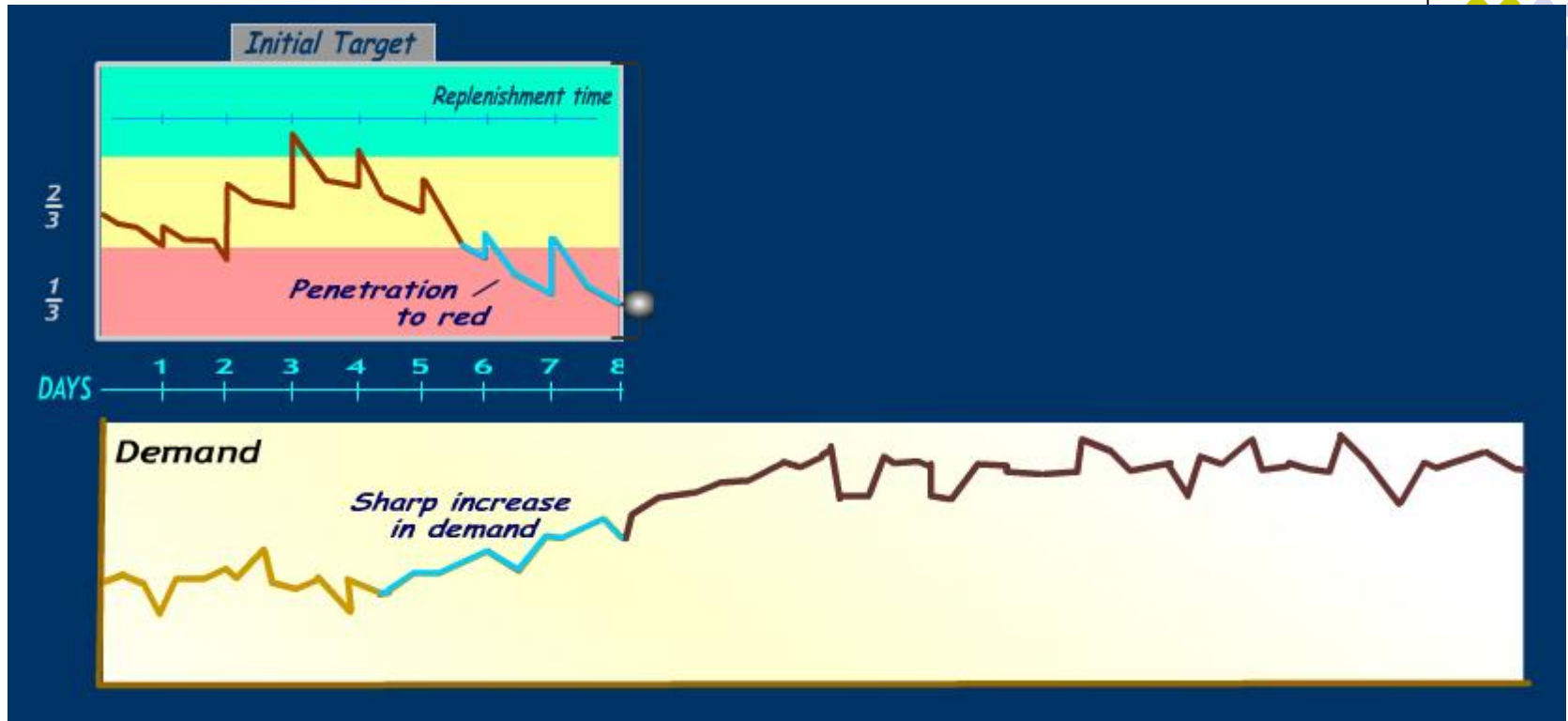
Inventory is consumed according to the demand profile
Inventory is replenished daily (in this example)



The Solution, Part 4: react to changes in demand without a forecast



As a result of a sharp increase in demand the Red Zone is penetrated, repeatedly.

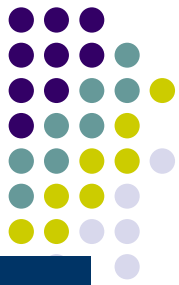


The target is then increased in value by a full zone

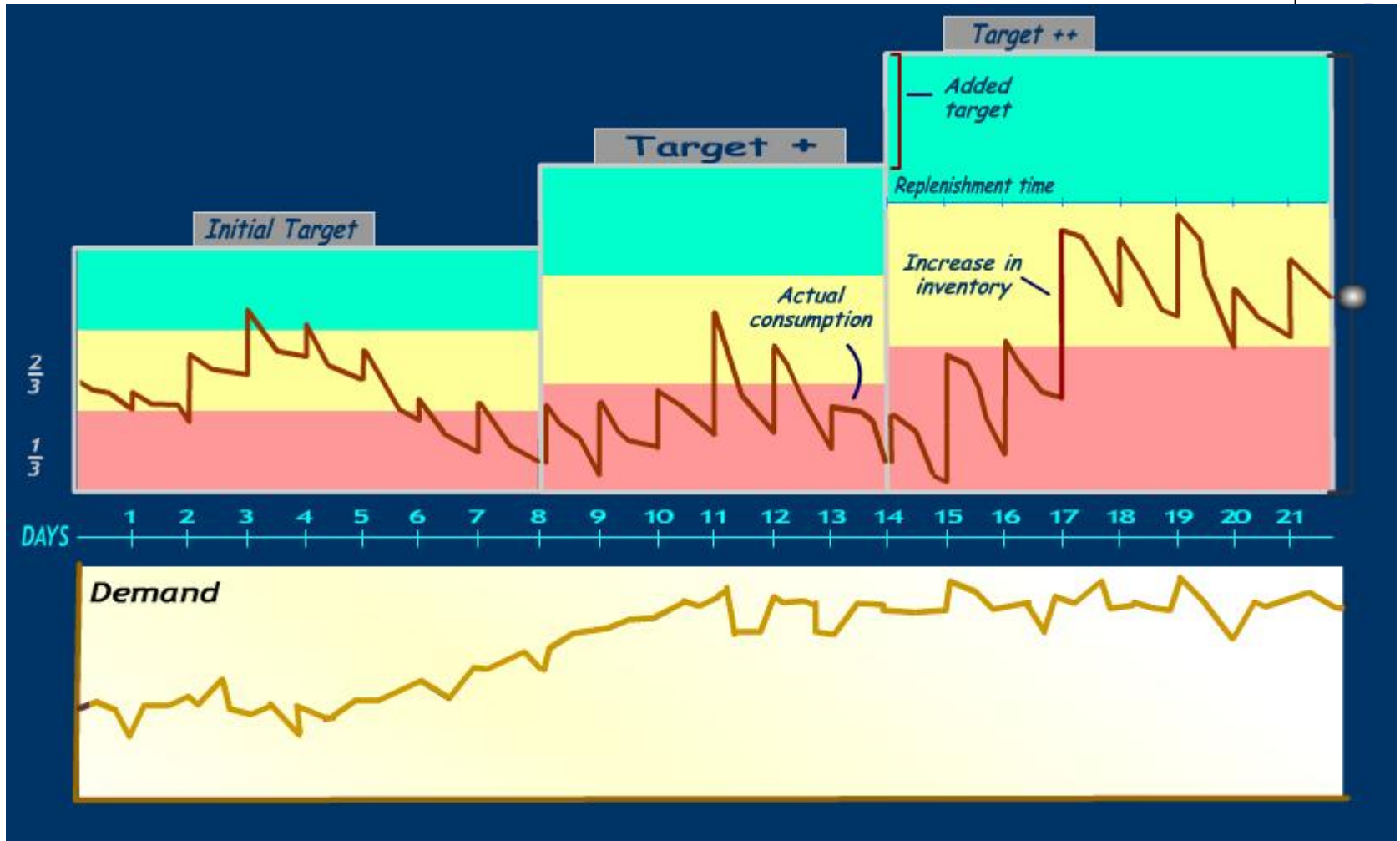
The inventory is also increased by the additional amount added to the target

It may be necessary to repeat the procedure if the Red Zone continues to be penetrated

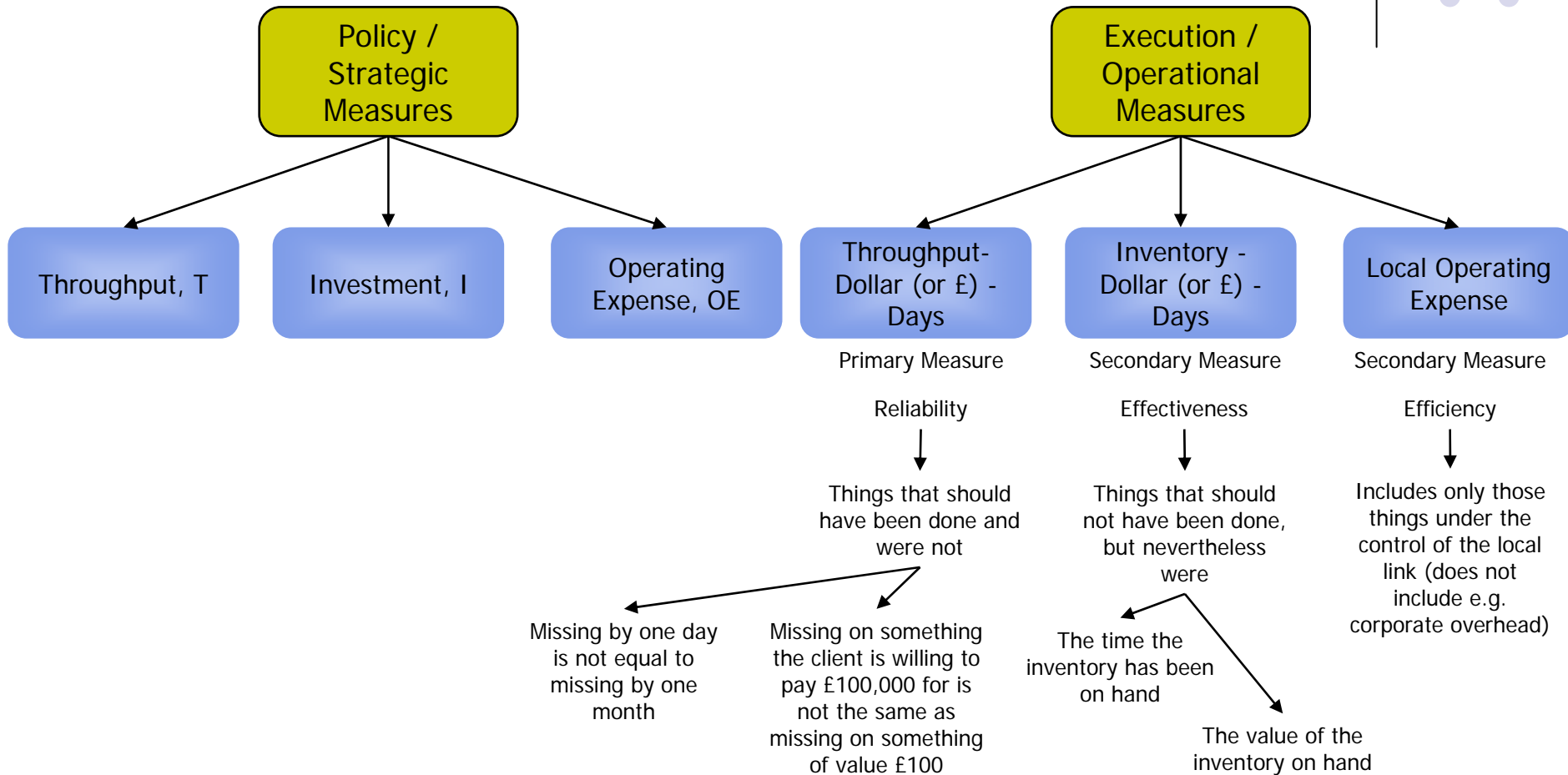
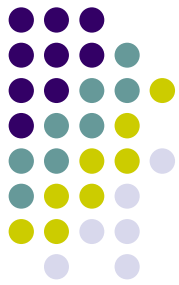
The Solution, Part 4: react to changes in demand without a forecast



The final plot shows that a further increase in the Target was required. The profile has now stabilised within the Yellow Zone



The Solution, Part 5: change the measures away from those of local optima



Expected benefits from adopting the full solution



- Inventory in the system decreases (typically by 50%)
- Sales increase (typically by 20%)
- Inventory turns increase (typically more than double)
- Internal transfers between regional warehouses drop (typically to almost zero)
- Obsolescence drops (typically to less than half)
- Operating expense stays about the same
- Relationships with suppliers and clients significantly improve

Reliability – Throughput-Dollar-Days



RELIABILITY

Measuring things that should have been done and were not.

Throughput-Dollar-Days

$$\Sigma (\text{Value}) \times (\text{days of delay})$$

Summation of all commitments not delivered on time in the measured period.

The dollar value of not meeting the commitment (As first approximation use the sales price to the next link - if available use the price of final product to end consumer).

The time since the commitment was due until it was delivered (or until the present if not yet delivered).

We should strive to have ZERO Throughput-Dollar-Days!

Effectiveness – Inventory-Dollar-Days



EFFECTIVENESS

Things that should not have been done but nevertheless were.

Inventory-Dollar-Days

$$\Sigma (\text{Inventory value}) \times (\text{days on hand})$$

The dollar value of the inventory at hand.

The time since the inventory entered the responsibility of the link.

To simplify matters we measure all existing inventory (rather than just excess inventory) and we do not strive to reduce Inventory-Dollar-Days to zero.

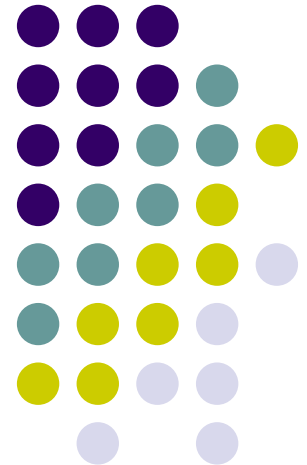
We should strive to have the minimum Inventory-Dollar-Days needed to ensure Reliability.

Understanding replenishment in more detail

TOC Replenishment Basics

With thanks to:

Bert Husken
Red Curve Institute B.V.
Tel. +31 74 2771627
e-mail: rcibv@planet.nl



Viability Vision

VMI: Ability to provide

- 100% Availability
- Zero financial cost of inventory
- Guaranteed with penalties

Function Goal

Right Product, at right place, at the right time

DE's

Availability of Product
is near perfect

Limited Stock-outs occur

X ship cost are
significantly reduced

Buffer are
correctly Sized
and Stabilized

Inv. Buffers adjust
according to
actual Demand

LT are reduced
to 3 days

DIST VMI - OEM

DBR

Solution Injections

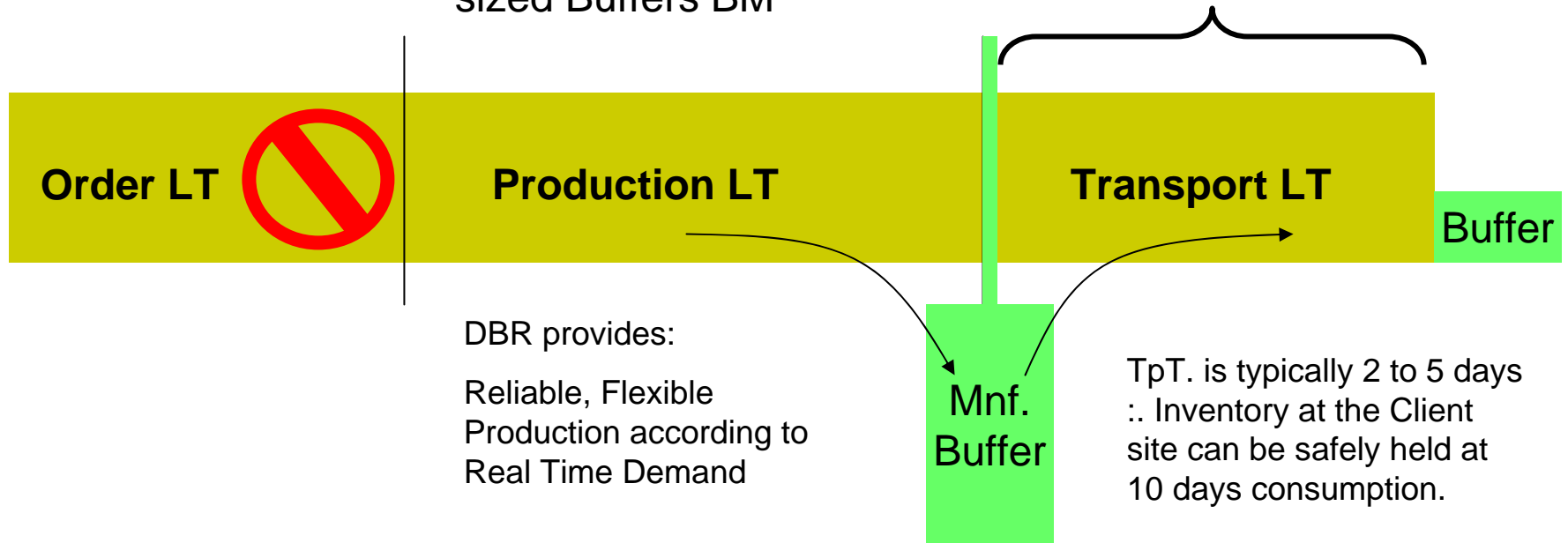
Lead Time is reduced to Transport Time only



Order Lead Time is reduced to ZERO.

Production builds product according to the correctly sized Buffers BM

Replenishment Time is reduced to be only the Transport Lead Time

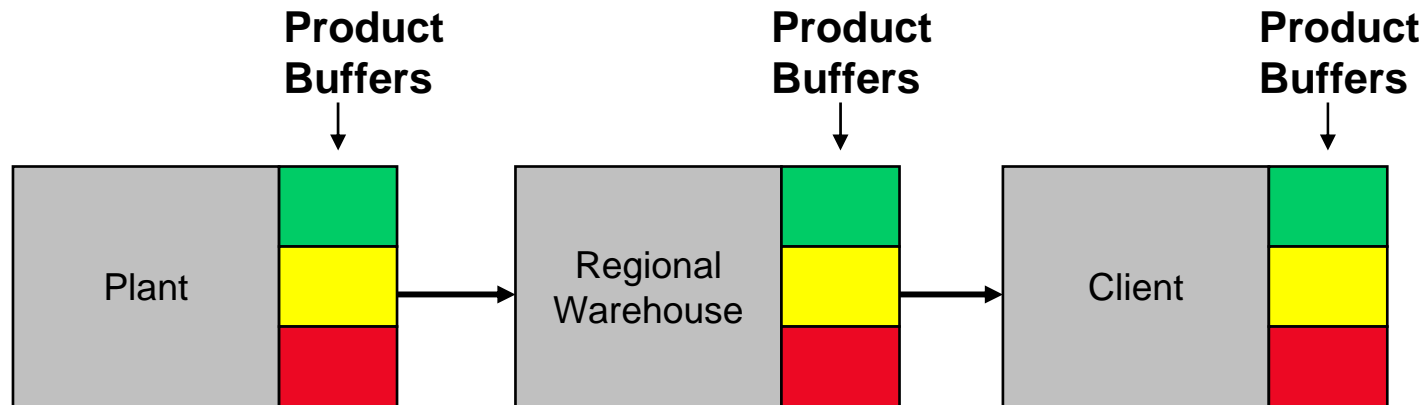


DBR provides:
Reliable, Flexible
Production according to
Real Time Demand

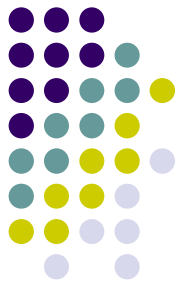
TpT. is typically 2 to 5 days
∴ Inventory at the Client
site can be safely held at
10 days consumption.

Mnf. Buffer will
DECOUPLE the
Production LT from
the Delivery LT.

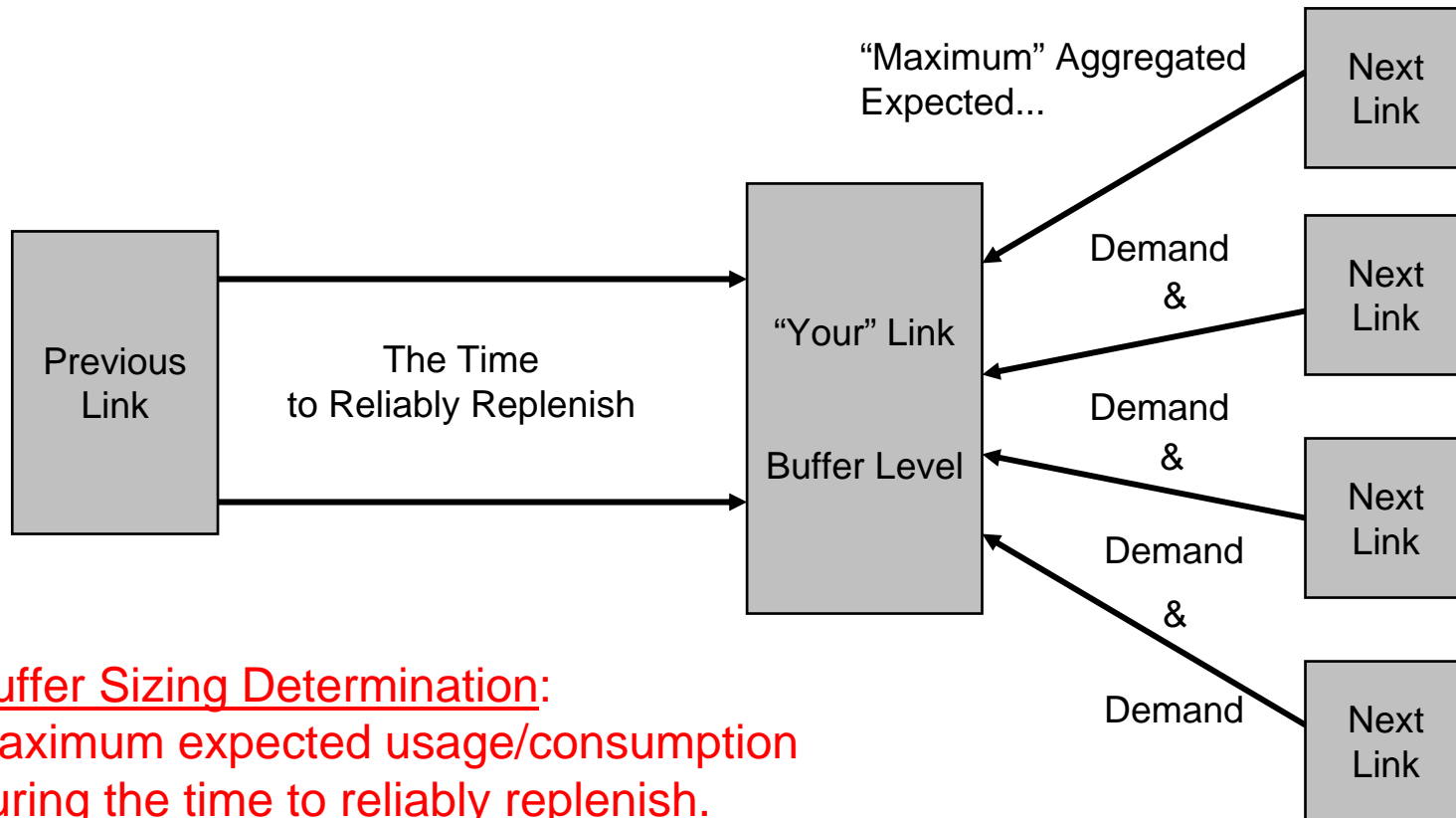
Managing Uncertainty by De-coupling the Links



In order to protect the distribution chain from disruptions that may occur at any of the links, it is necessary to de-couple the links from each other by placing properly sized *inventory buffers* at each link.



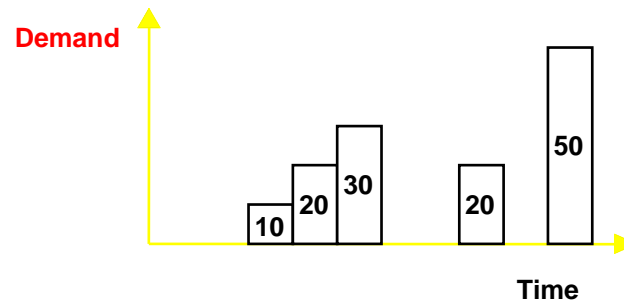
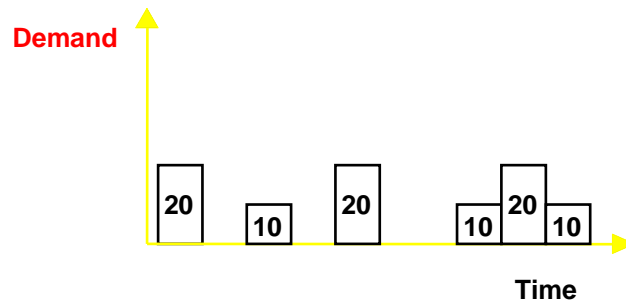
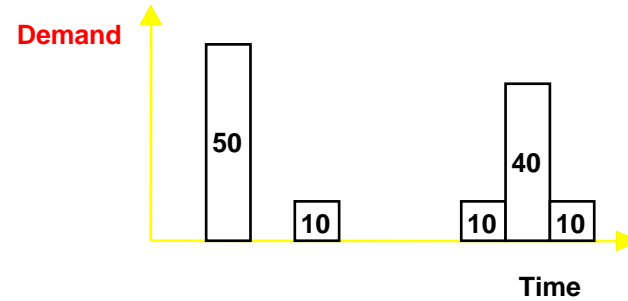
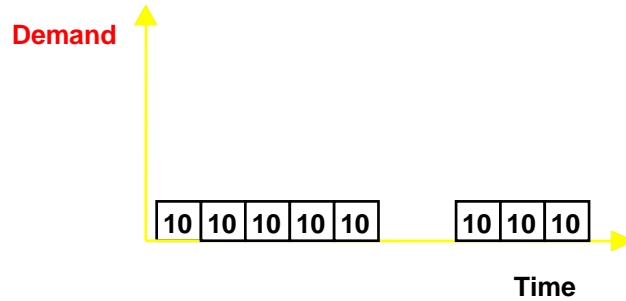
Factors that Determine Buffer Size



Buffer Sizing Determination:
Maximum expected usage/consumption during the time to reliably replenish.

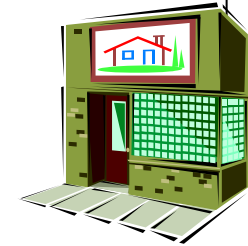
Question: Is the accuracy of the forecast the same for every stage of the distribution system?

Aggregate Demand

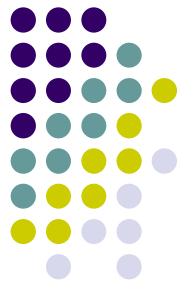


- Demand patterns differ.
- Aggregate demand is variable over time.
- Peak must be covered during time it takes for reliable replenishment.

Frequency of Replenishment



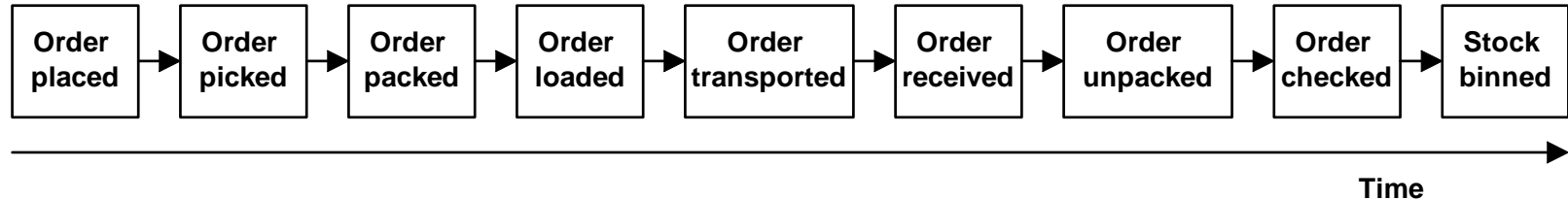
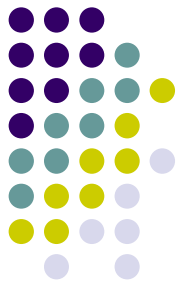
Three Weeks



If the ship sails once every three weeks, what level of stock will we need to hold?

If a ship sails every week, what level of stock do we need to hold?

Reliable Replenishment Time

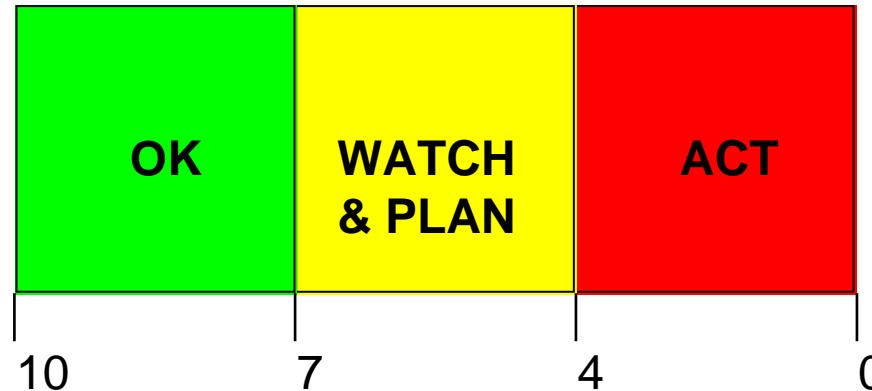


- It is likely that the above activities have variation in their expected times.
- The reliability of the source of supply must be considered.
- There is a need to determine and use the “maximum” time for reliable replenishment in determining the buffer levels.

Controlling the Buffers



Inventory Buffer for Item XYZ

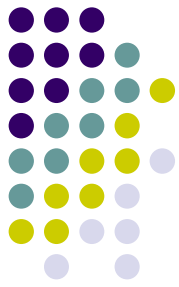


Days of aggregate demand in the buffer before next replenishment.

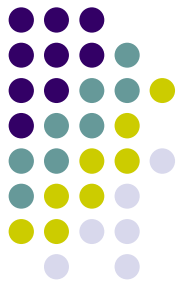
Time from last replenishment: (10 day replenishment frequency)



Buffer Management - Fine Tuning



- The trends of the rate of consumption/depletion of the buffers are monitored.
- Never depleting more than the “**OK**” level of the buffer indicates an over-estimation of the buffer size.
- Frequently having to “**ACT**” to urgently replenish the buffer indicates an under-estimation of the required buffer size.
- Corrective action is taken to decrease or increase the buffer size.

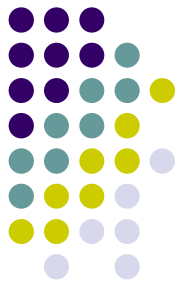


Market-Driven Replenishment Solution

Summary

- We hold enough product inventory at each link to satisfy the greatest demand, during the time it takes to reliably replenish from the previous link.
- Links only order to replenish.
- Each product buffer is properly monitored.
- Proper measurement and corresponding education are given to all personnel to guarantee that the proper buffer levels are maintained, and that protecting the buffers against depletion is given first priority.
- Corrective action is taken to replenish and, if necessary, the buffers are resized.

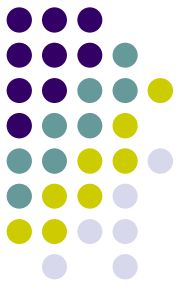
Required Paradigm Shifts



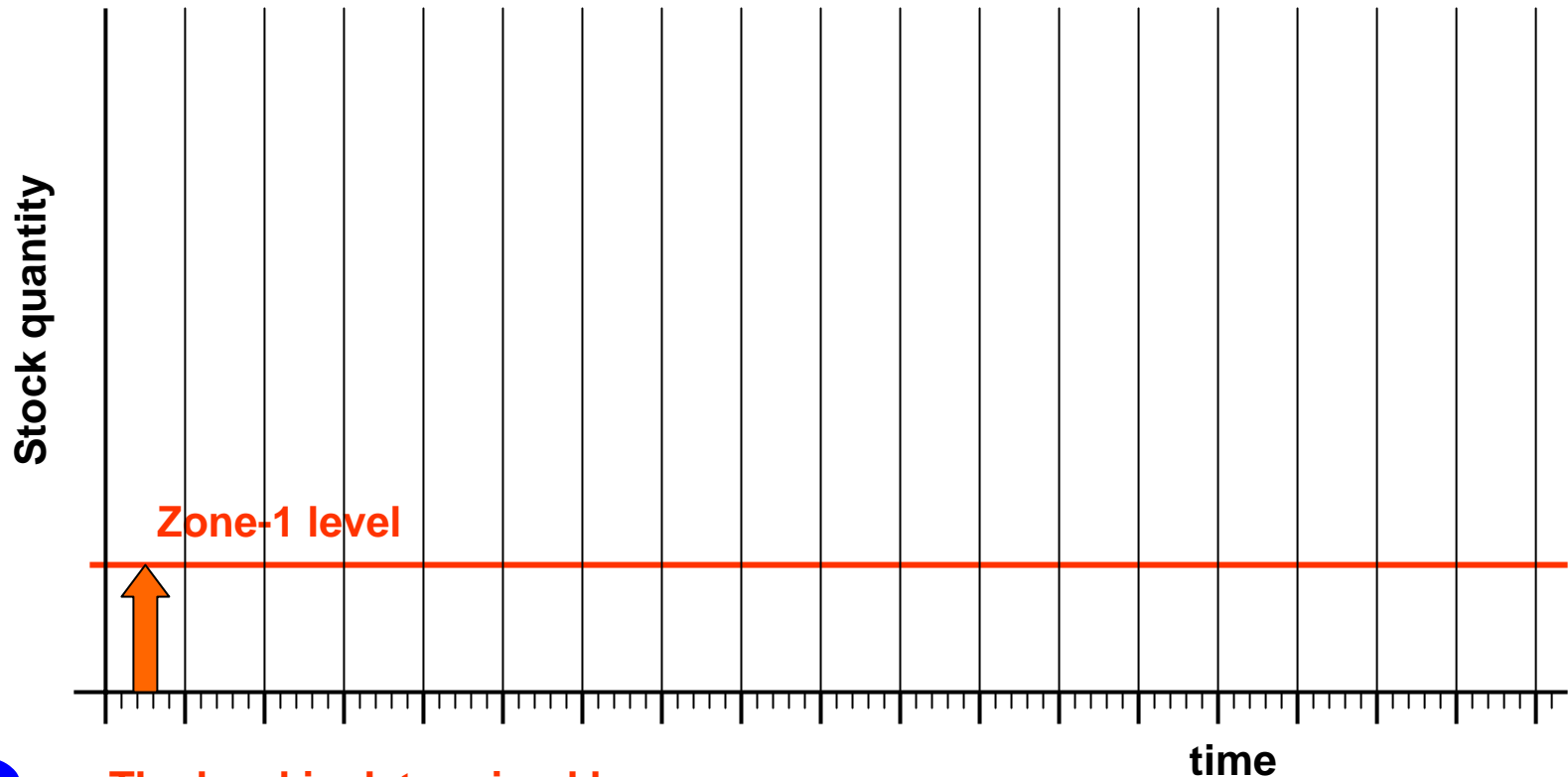
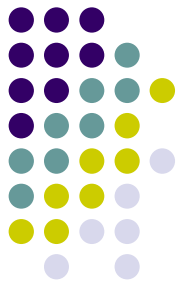
1. Use available capacity and energy to achieve actual demand instead of long-range forecasts.
2. Stop the push-syndrome.
3. Stop the long-run syndrome.
4. Stop the economic-batch-size syndrome.
5. Stop the economic-order-size syndrome.
6. Understand that each link must subordinate it's efforts to the overall success of the chain as a whole.

Symptoms

- Out of stock situations
- Too high inventory levels
- No accurate forecast
- Inventory data is not reliable



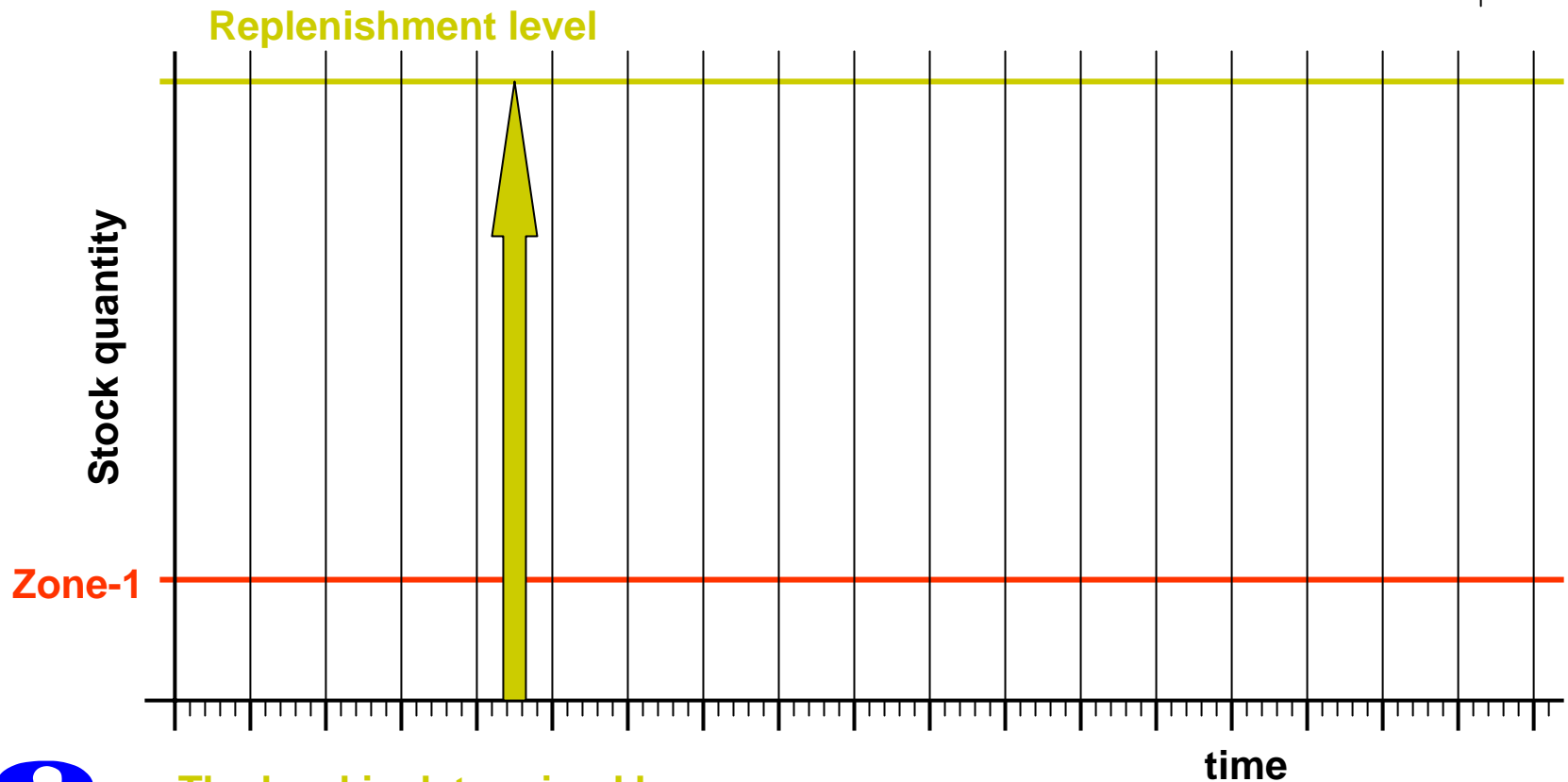
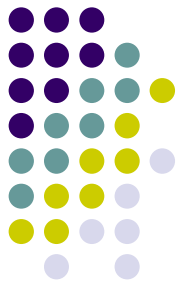
Replenishment basics



The level is determined by:

- Expedited minimum leadtime of delivery
- Worst case consumption during this time

Replenishment basics



The level is determined by:

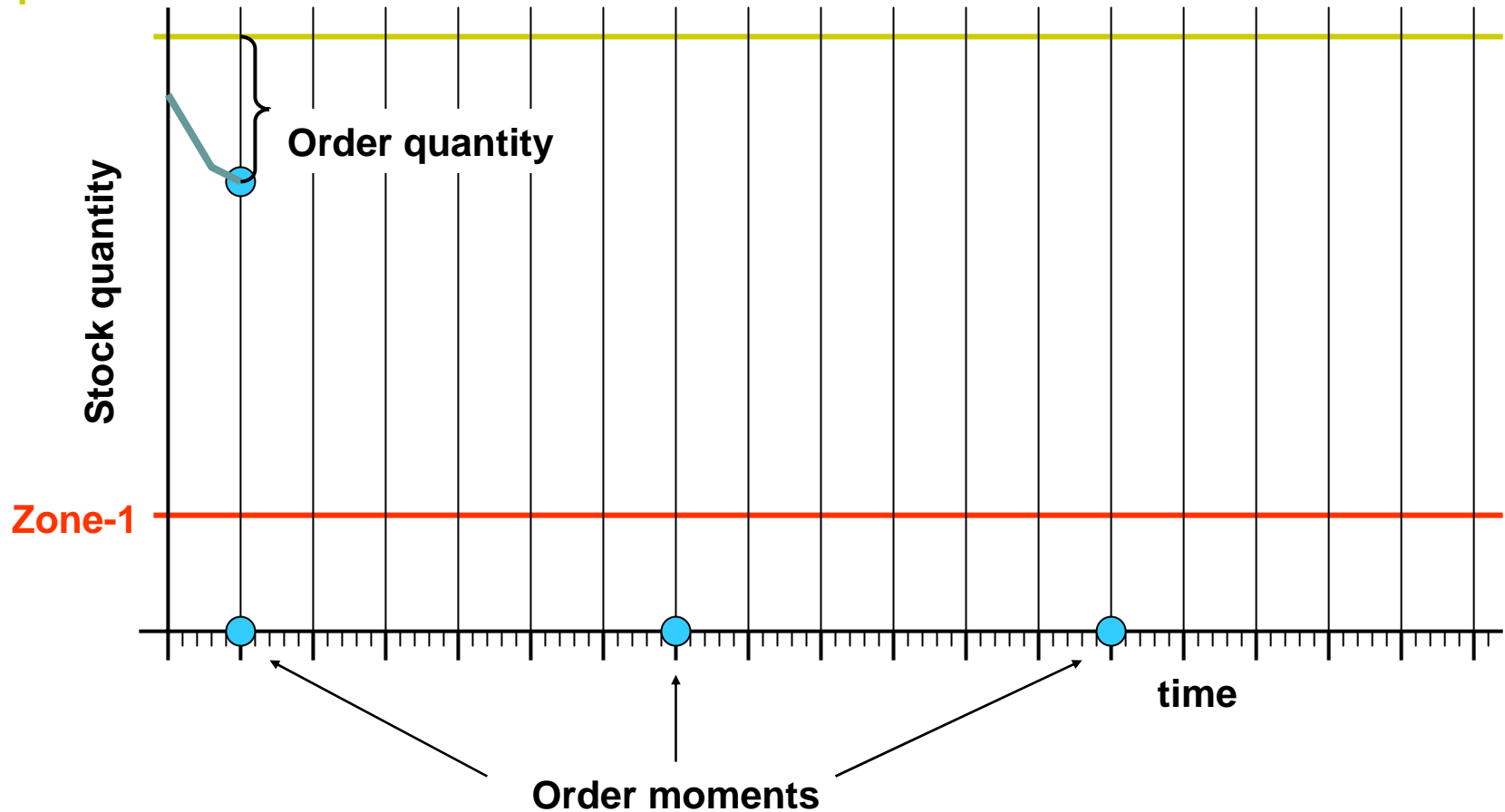
- Be paranoid
- Don't be hysteric



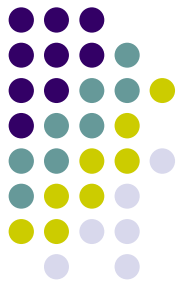
Replenishment basics

$$\text{Order quantity} = \text{Replenishment level} - \text{Stock}$$

Replenishment

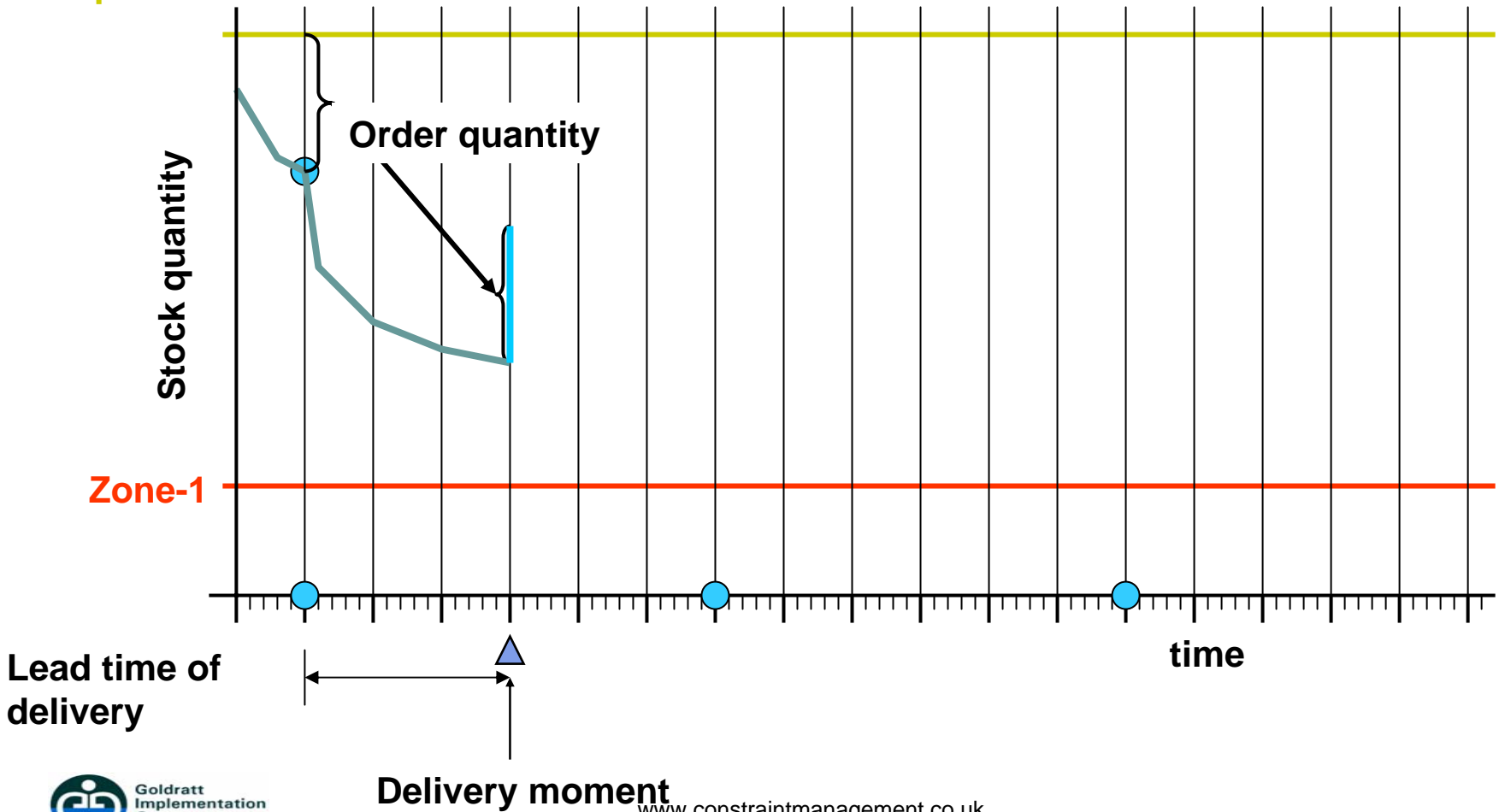


Replenishment basics



$$\text{Order quantity} = \text{Replenishment level} - \text{Stock}$$

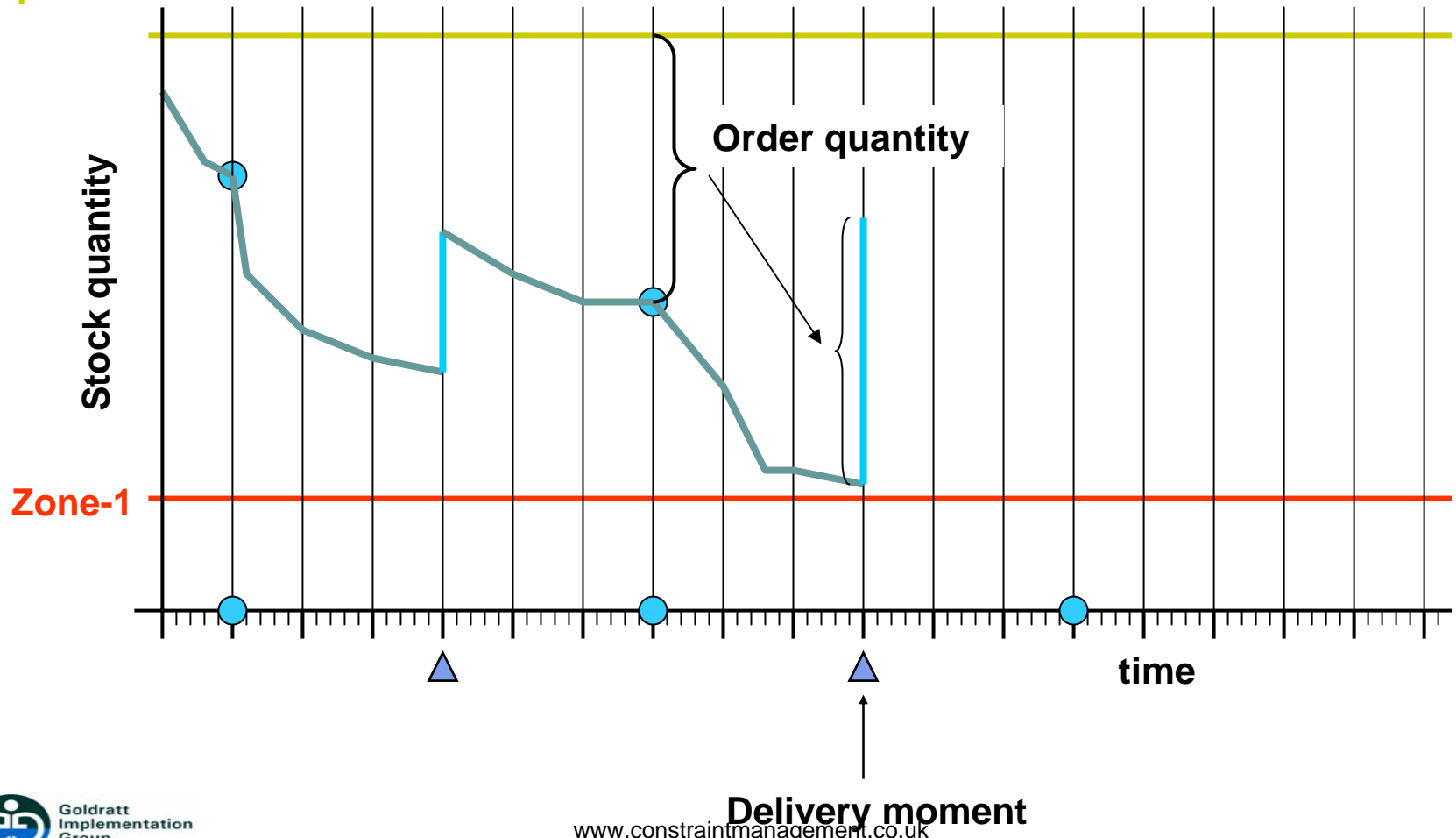
Replenishment



Replenishment basics



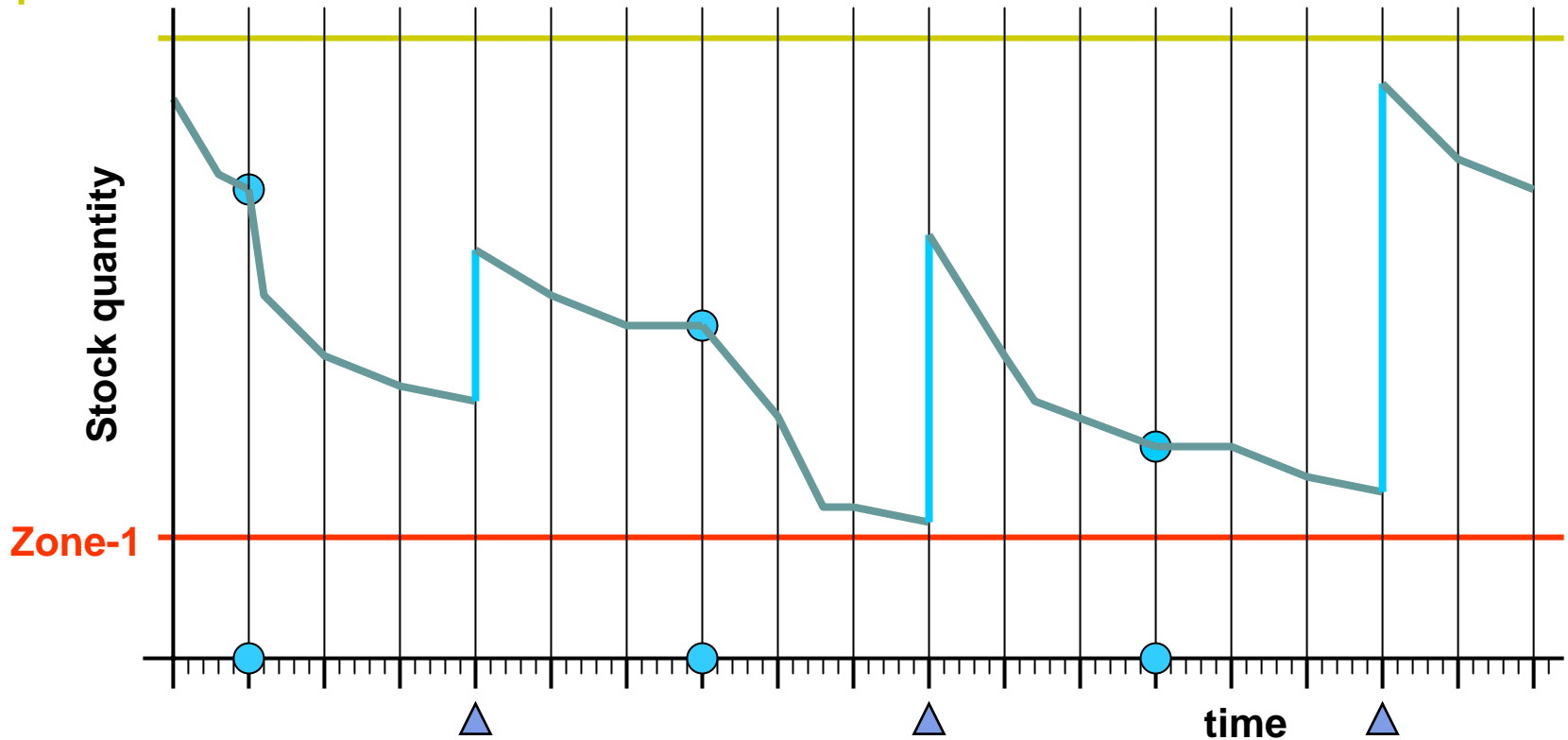
Replenishment



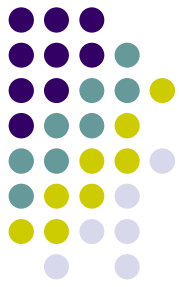
Replenishment basics



Replenishment

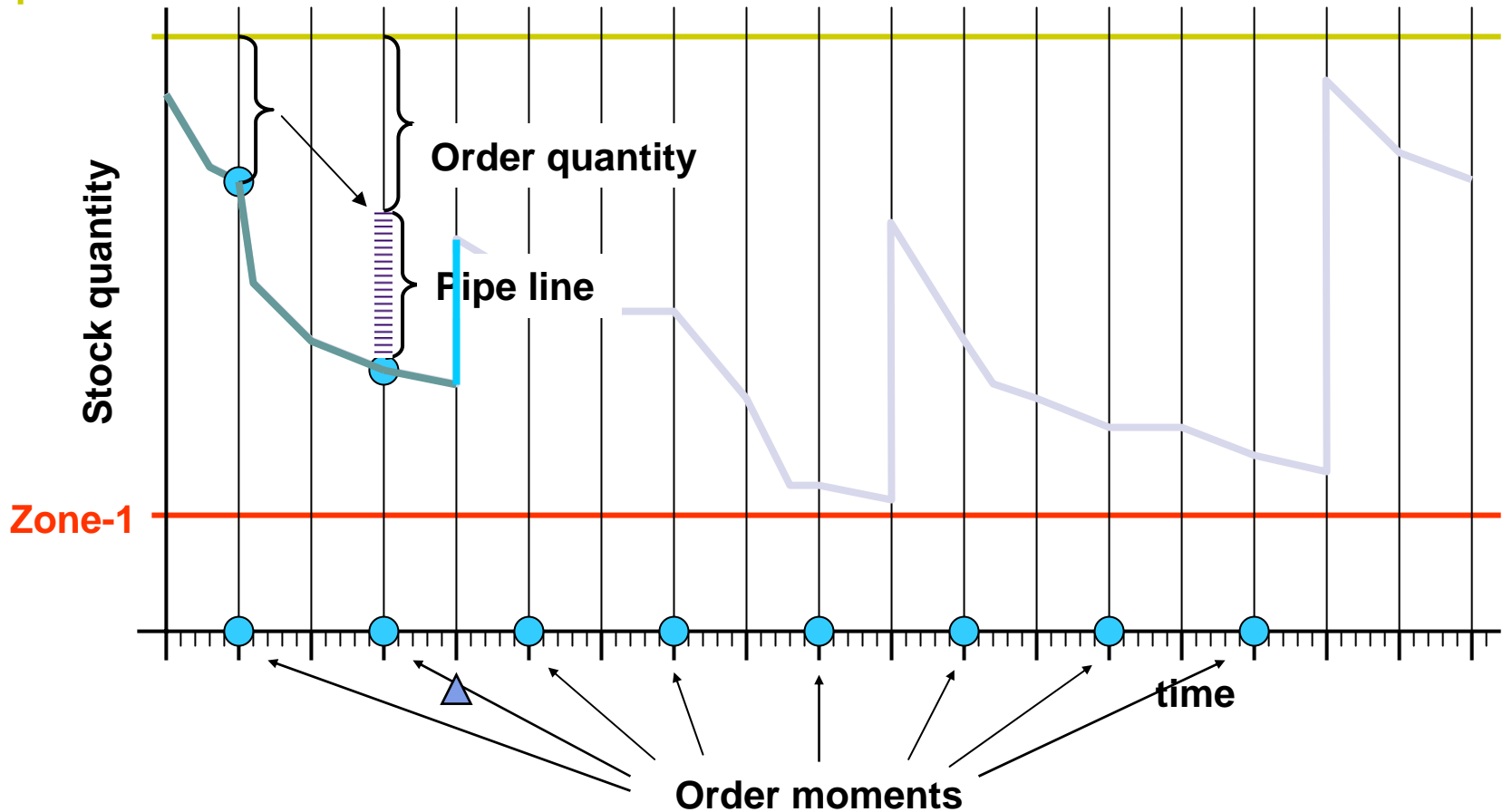


Replenishment basics: pipe line effect



$$\text{Order quantity} = \text{Replenishment level} - \text{Stock} - \text{Pipe line quantity}$$

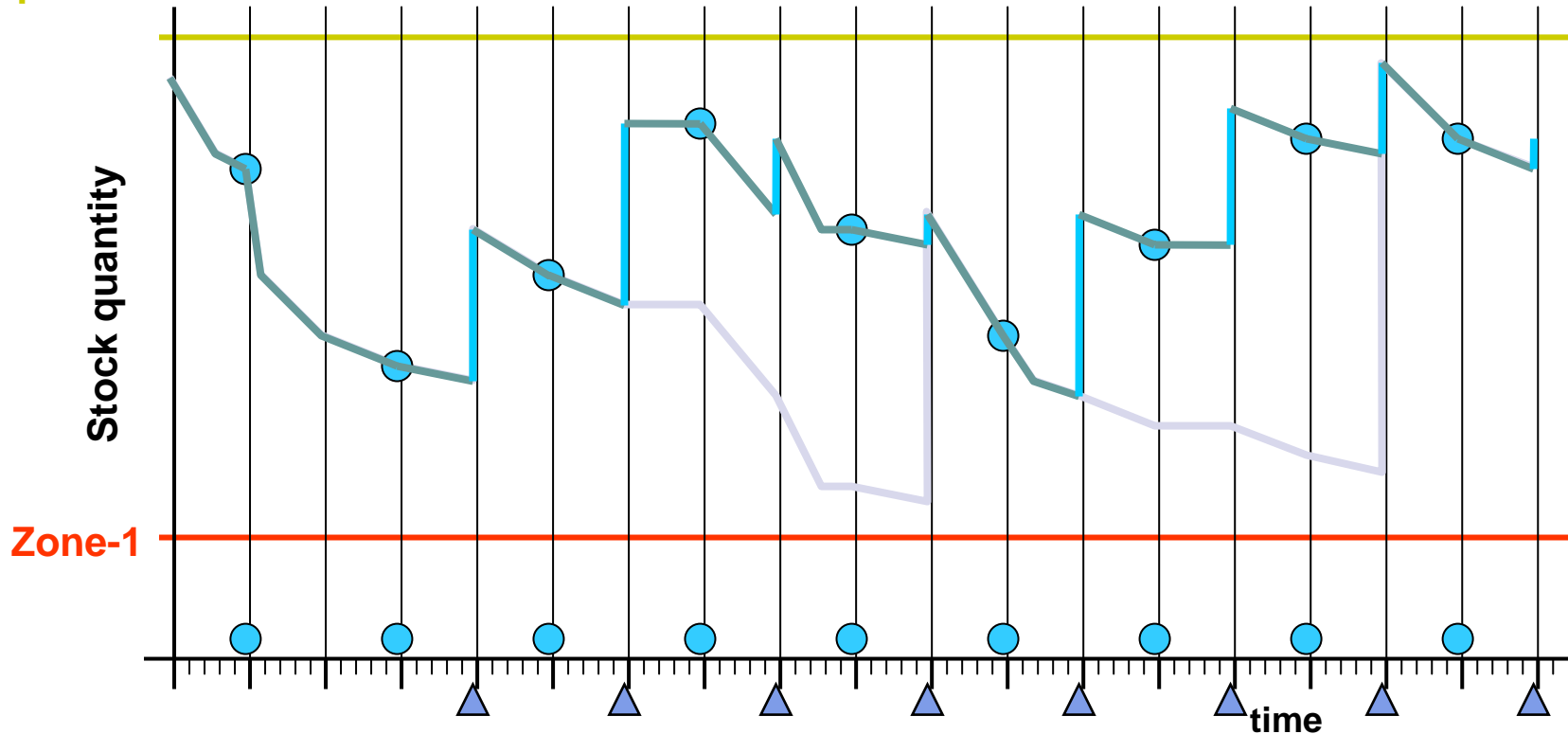
Replenishment



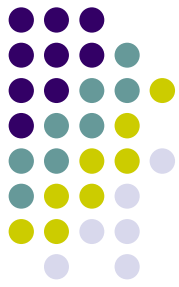
Replenishment basics: pipe line effect



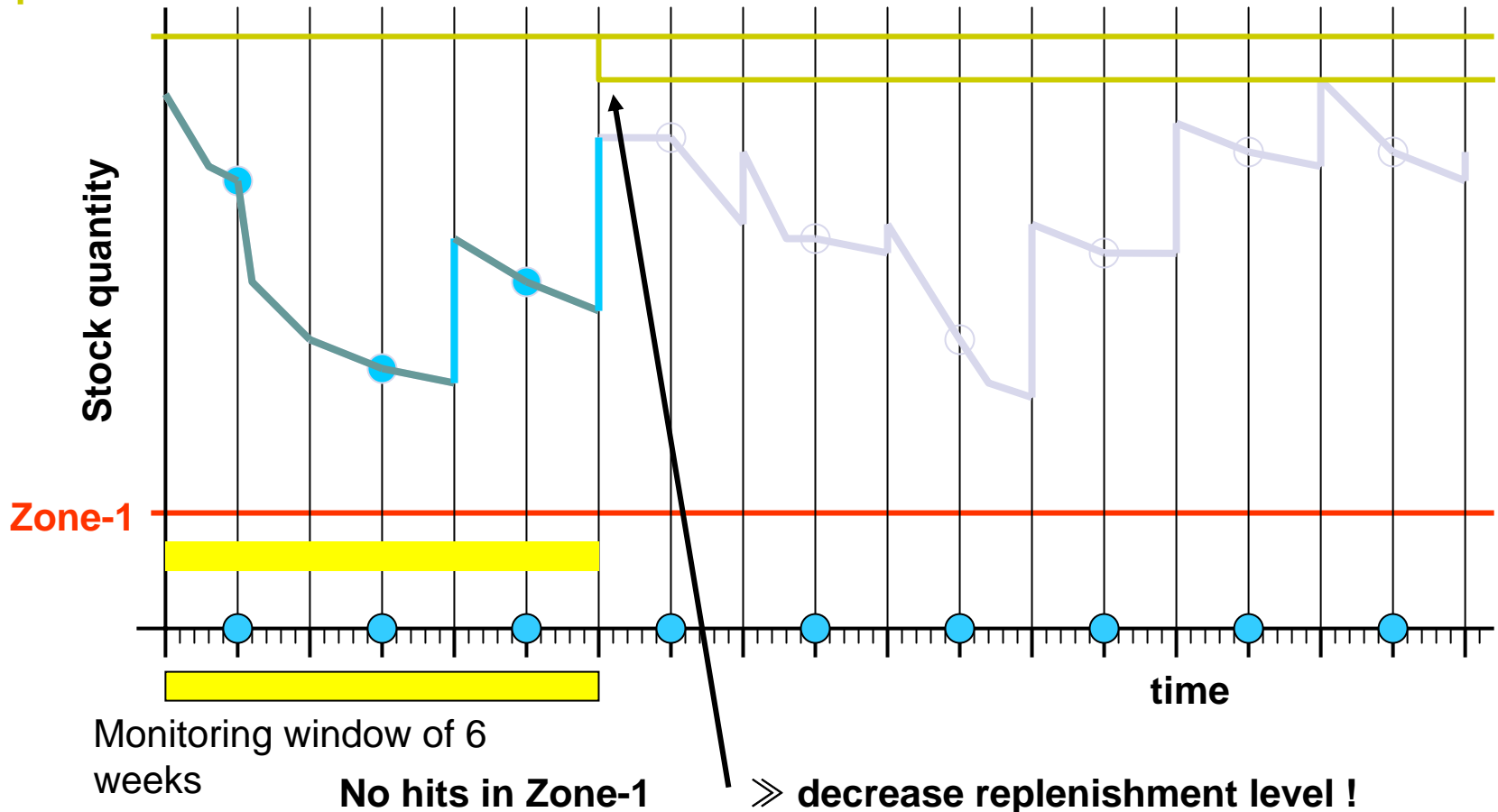
Replenishment



Replenishment basics: adjustment of replenishment level



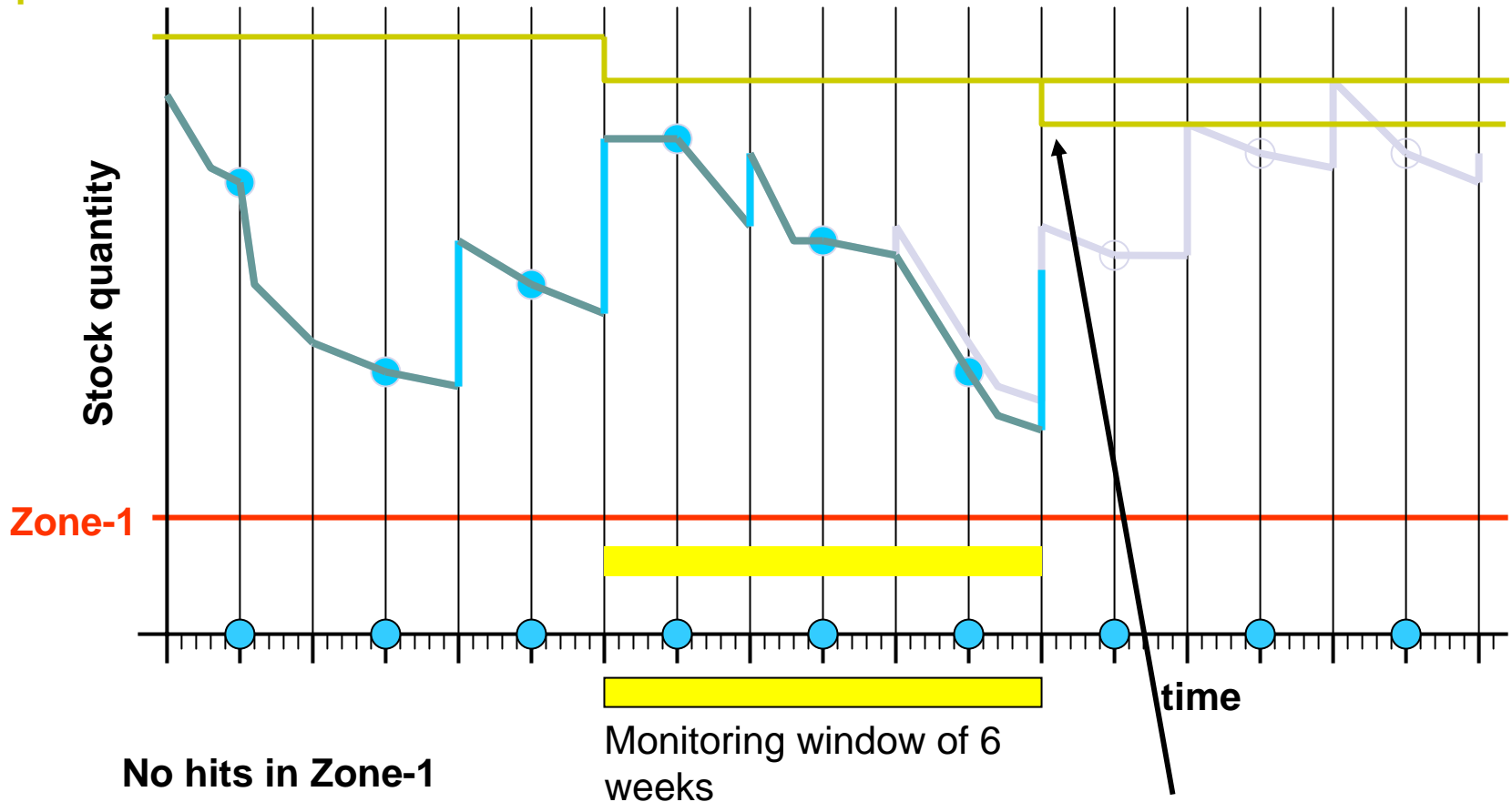
Replenishment



Replenishment basics: adjustment of replenishment level

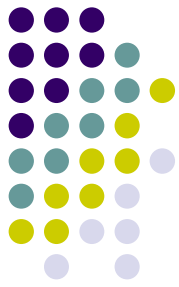


Replenishment

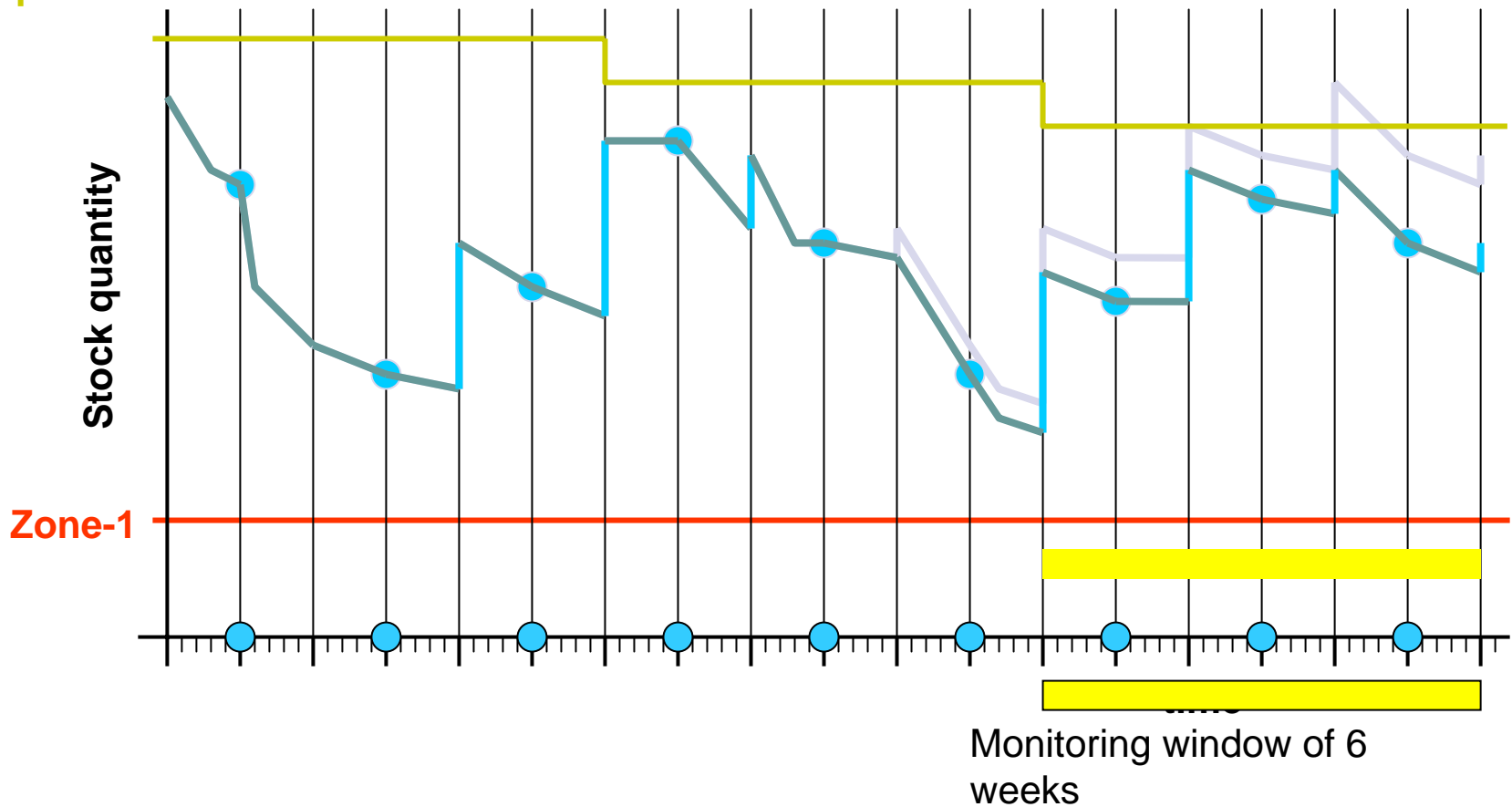


» decrease replenishment level !

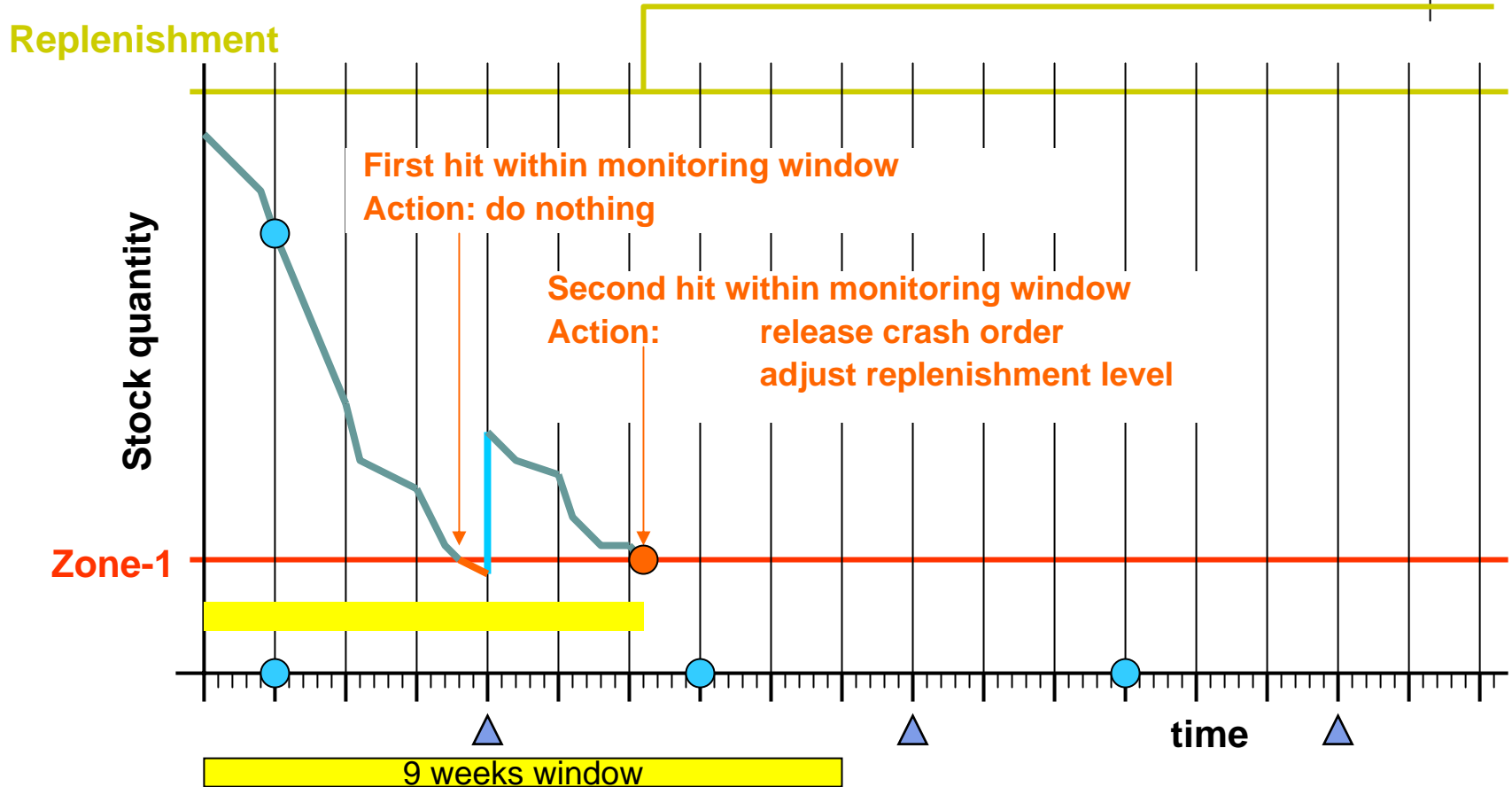
Replenishment basics: adjustment of replenishment level



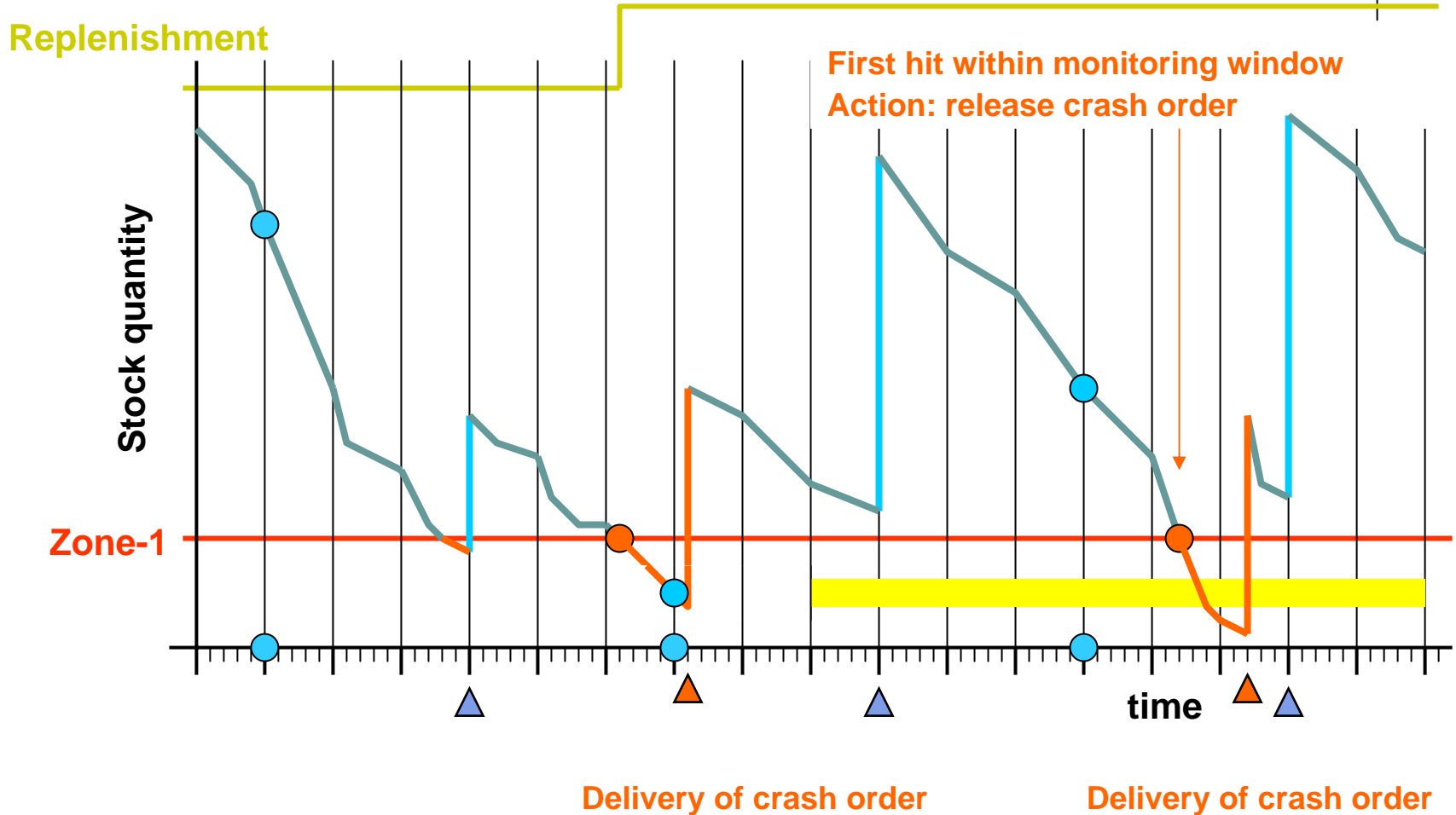
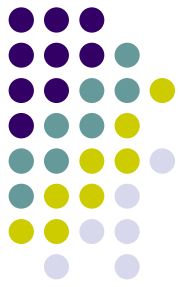
Replenishment



Replenishment basics: Zone-1 hit



Replenishment basics: Zone-1 hit

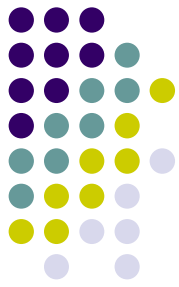


Summarizing – the 4 Questions



- What to change?
 - Replenishment time is long
- What to change to?
 - Distribution the TOC way
- How to cause the change?
 - Establish the plant (Central) warehouse
 - At each place and for each product establish the inventory target according to the formula
 - Move to ‘Order daily – Replenish periodically’
 - Monitor the inventory targets according to the zones
 - Re-examine policies of make to stock – make to order
 - Educate sub-systems to monitor execution using Dollar days measurements
- What creates the POOGI?
 - The buffer management statistics

Summarizing – the Future Reality Tree (FRT)



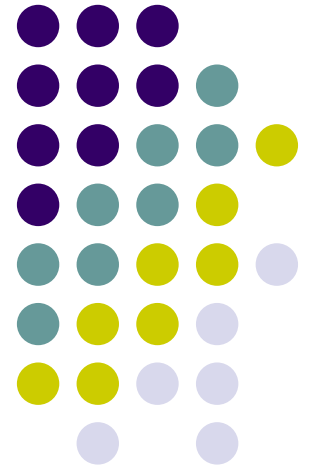
- Distribution Possible DE's:
 - There is less & less need for urgent deliveries,
 - Priorities are known and more & more stable,
 - There are less & less shortages,
 - There are less & less inventory items that have too high inventory levels,
 - There are less & less inventory items that are obsolete,
 - There are less & less dead inventories,
 - There are less & less cross-shipments,
 - There are less & less customer returns,
 - Delivery costs are controlled.
- Distribution Performance Measures:
 - Improved due date performance
 - Improved availability
 - Reduced lead time
 - Increased inventory turns

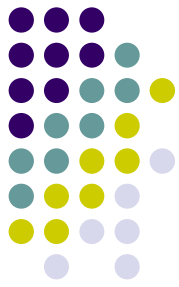
Summarizing – the FRT



- Other Functions DE's:
 - Increased sales,
 - Introduction of new products is smoother,
 - Improved profit,
 - Improved ROI,
 - Customers loyalty is enhanced,
 - Priorities are known and more & more stable.

Appendices





Contact Details

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