Inventory Management

Multi-Items and Multi-Echelon

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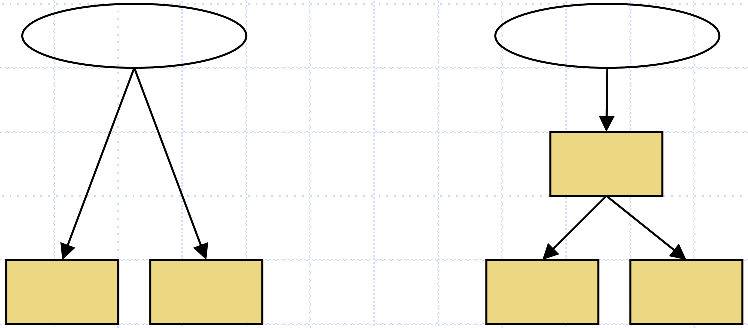
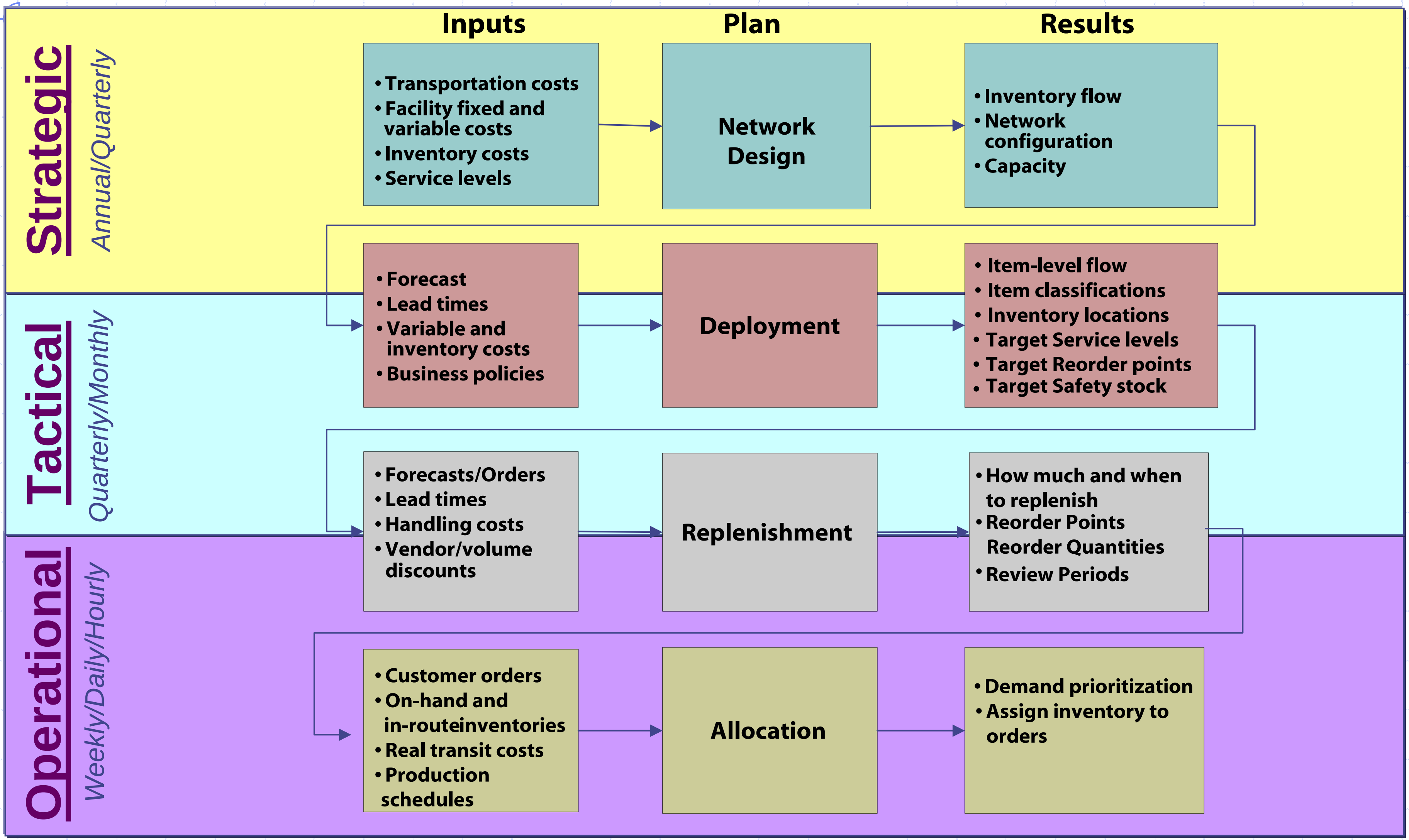
Advanced Topics

- So far, we have studied single-item single location inventory policies.
- What about . . .
  - Multiple Items
    - How do I set aggregate policies?
    - What if I have to meet a system wide objective?
  - Multiple Locations – Multi-echelon
    - Deterministic demand
    - Stochastic demand



Inventory Planning Hierarchy



Jeff Metersky, Vice President Chainalytics, LLC
Rosa Birjandi, Asst. Professor Air Force Institute of Technology

Inventory Policies for Multiple Items

- Aggregate constraints are placed on total inventory
  - Avg total inventory cannot exceed a certain budget ($ or Volume)
  - Total number of replenishments per unit time must be less than a certain number
- Inventory as a portfolio of stocks – which ones will yield the highest return?
- Cost parameters can be treated as management policy variables
  - There is no single correct value for holding cost, r.
  - Best r results in a system where inventory investment and service level are in agreement with overall strategy.
  - Cost per order, A, is also not typically known with any precision.
  - Safety factor, k, is set by management.
- Exchange Curves
  - Cycle Stock - Trade-off between total cycle stock and number of replenishments for different A/r values
  - Safety Stock – Trade-off between total safety stock and some performance metric for different k values

Exchange Curves

- Set notation for each item:
  - A = Order cost common for all items
  - r = Carrying cost common for all items
  - D_i = Demand for item i
  - v_i = Purchase cost of item i
  - Q_i = Order quantity for item i
- Need to find:

  Total average cycle stock (TACS) and Number of replenishments (N)

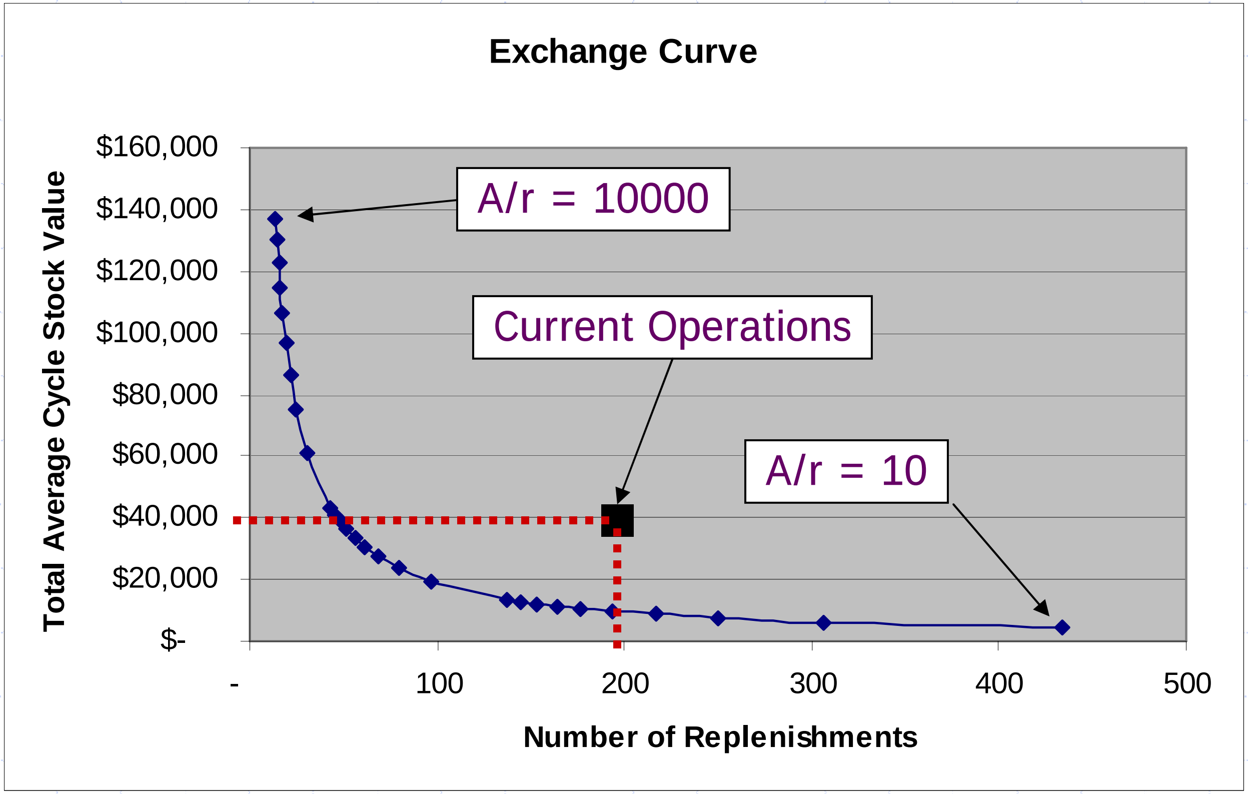
$$TACS = \sum_{i=1}^{n} \frac{Q_i v_i}{2} = \sum_{i=1}^{n} \frac{\left(\sqrt{\frac{2AD_i}{rv_i}}\right) v_i}{2}$$

$$TACS = \sum_{i=1}^{n} \sqrt{\frac{AD_i v_i}{2r}} = \sqrt{\frac{A}{r}} \frac{1}{\sqrt{2}} \sum_{i=1}^{n} \sqrt{D_i v_i}$$

$$N = \sum_{i=1}^{n} \frac{D_i}{Q_i} = \sum_{i=1}^{n} \frac{D_i}{\sqrt{\frac{2AD_i}{rv_i}}}$$

$$N = \sum_{i=1}^{n} \sqrt{\frac{rD_i v_i}{2A}} = \sqrt{\frac{r}{A}} \frac{1}{\sqrt{2}} \sum_{i=1}^{n} \sqrt{D_i v_i}$$

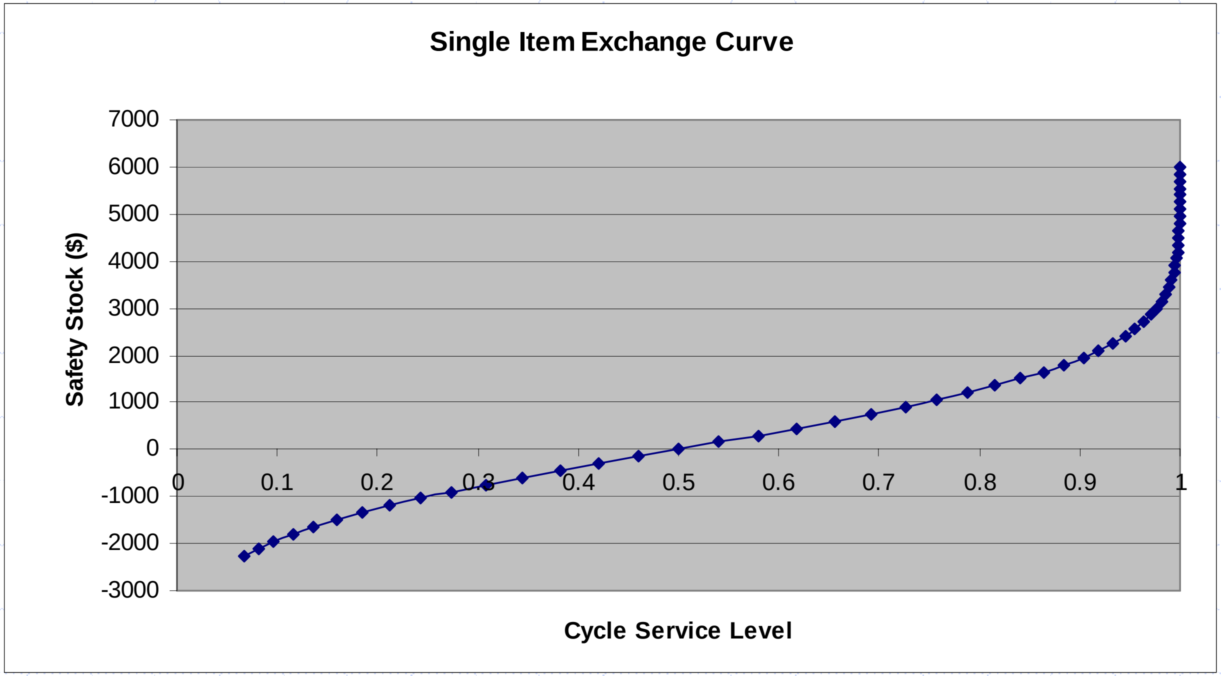
Exchange Curves



Exchange curve for 65 items from a hospital ward.
Current operations calculated from actual orders.
Allows for management to set A/r to meet goals or budget,
Suppose TACS set to $20,000 – we would set A/r to be ~100

Exchange Curves

- Now consider safety stock, where we are trading off SS inventory with some service metric
- Different k values dictate where we are on the curve
  - Suppose that we only have budget for $2000 in SS – what is our CSL?



Exchange Curves

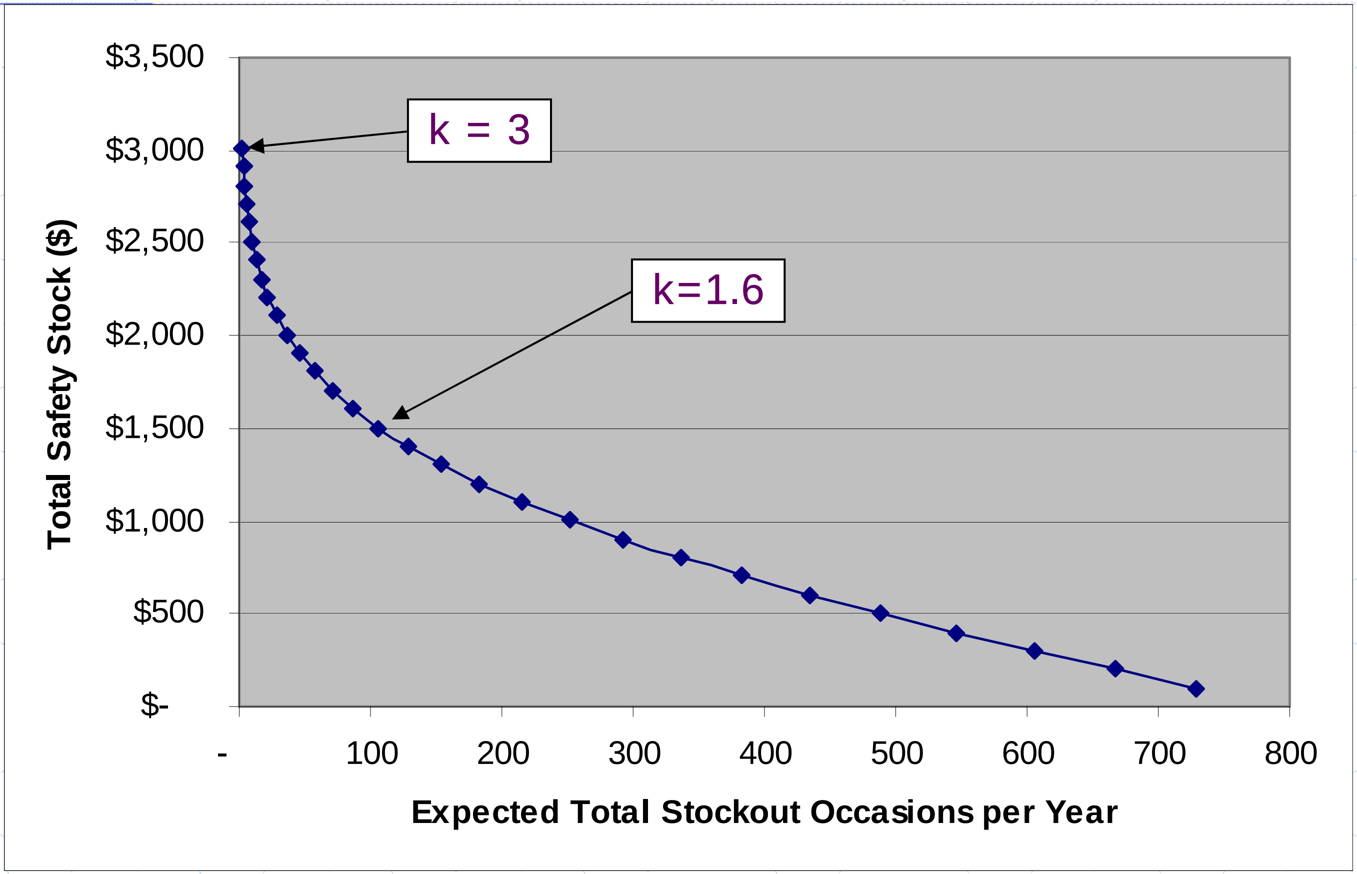
- Set notation for each item:
  - σ_{Li} = RMSE for item i
  - k_i = Safety factor for item i
  - D_i = Demand for item i
  - v_i = Purchase cost of item i
  - Q_i = Order quantity for item i
- Need to find:
  - Total safety stock (TSS) and
  - Some service level metric
    - Expected total stockout occasions per year (ETSOPY)
    - Expected total value short per year (ETVSPY)

$$TSS = \sum_{i=1}^{n} k_i \sigma_{Li} v_i$$

$$ETSOPY = \sum_{i=1}^{n} \frac{D_i}{Q_i} P[SO_i]$$

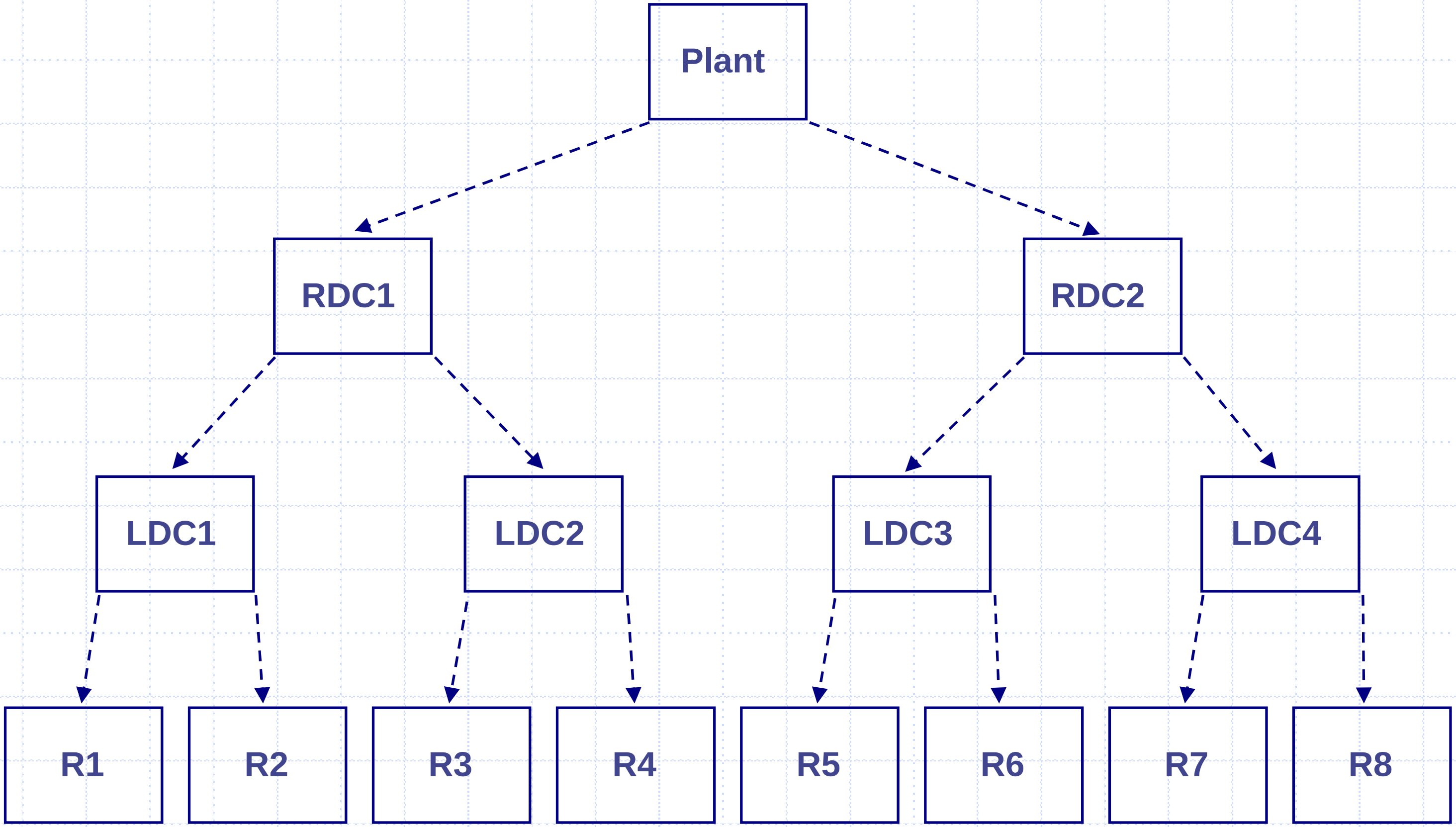
$$ETVSPY = \sum_{i=1}^{n} \frac{D_i}{Q_i} \sigma_{Li} v_i G(k_i)$$

Exchange Curves



- Exchange curve for same 65 items from a hospital ward.
- Allows for management to set aggregate k to meet goals or budget,
  - Suppose TSS set to $1,500 – we would expect ~100 stockout events per year and would set k= 1.6

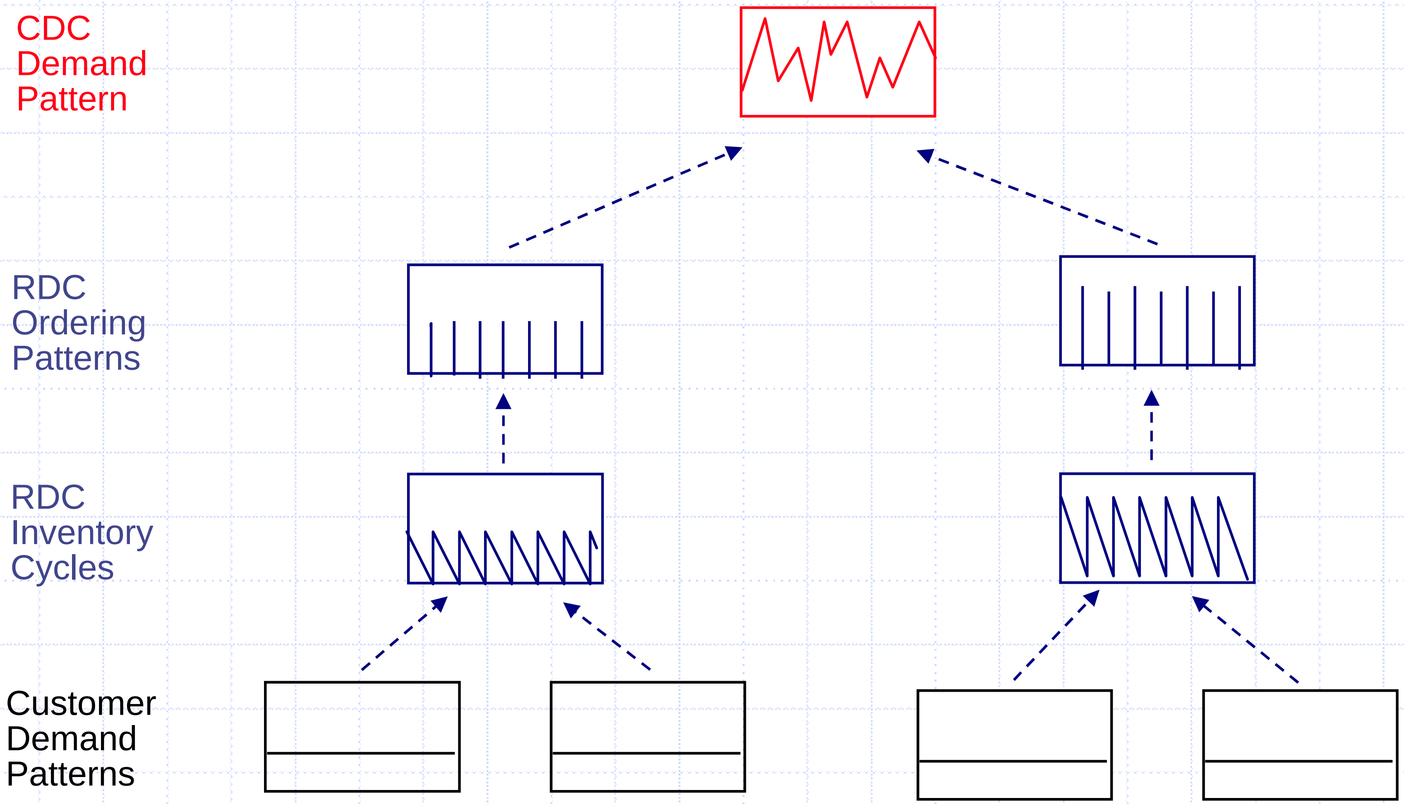
Replenishment in a Multi-Echelon System



What if I Use Traditional Techniques?

- In multi-echelon inventory systems with decentralized control, lot size / reorder point logic will:
  - Create and amplify "lumpy" demand
  - Lead to the mal-distribution of available stock, hoarding of stock, and unnecessary stock outs
  - Force reliance on large safety stocks, expediting, and re-distribution.

Impact of Multi-Echelons



Layers of Inventory Create Lumpy Demand

What does a DRP do?

- Premises
  - Inventory control in a distribution environment
  - Many products, many stockage locations
  - Multi-echelon distribution network
  - Layers of inventory create "lumpy" demand
- Concepts
  - Dependent demand versus independent demand
  - Requirements calculation versus demand forecasting
  - Schedule flow versus stockpile assets
  - Information replaces inventory

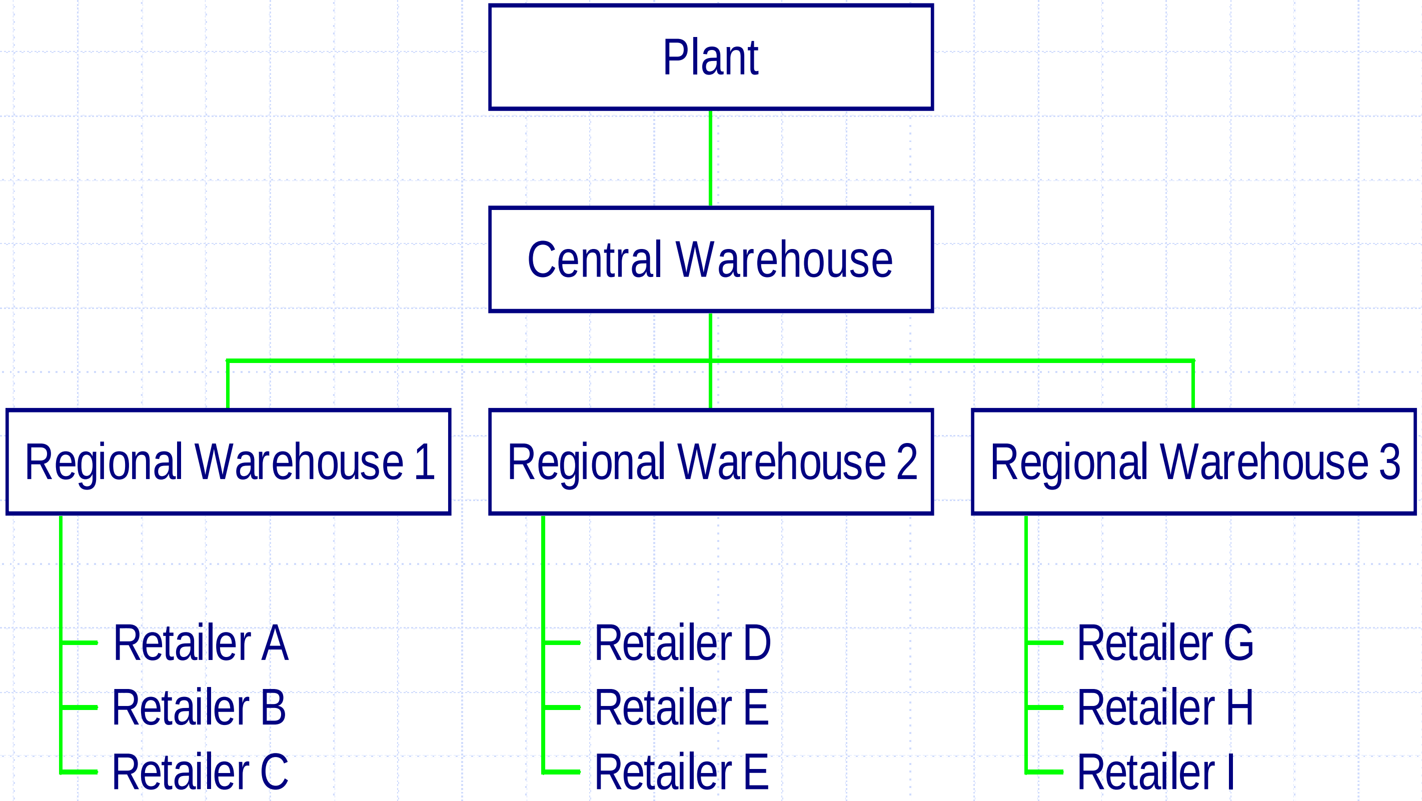
"DRP is simply the application
of the MRP principles and techniques
to distribution inventories“

Andre Martin

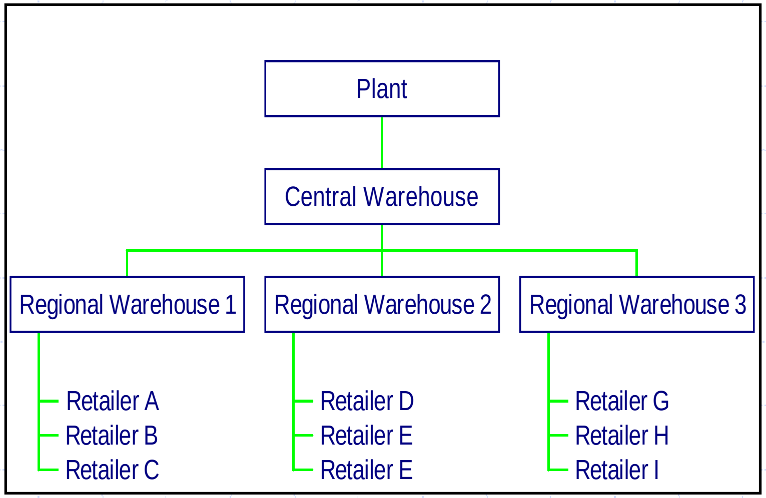
DRP Requirements

- Information Requirements:
  - Base Level Usage Forecasts
  - Distribution Network Design
  - Inventory Status
  - Ordering Data
- DRP Process:
  - Requirements Implosion
  - Net from Gross Requirements
  - Requirements Time Phasing
  - Planned Order Release

A Distribution Network Example



The DRP Plan



Note:
Gross Rqmt = Period Usage + SS

Central Warehouse Facility

Q=200, SS=0, LT=2	NOW	1	2	3	4	5	6	7	8
Period Usage		100	20	50	30	100	0	100	0
Gross Rqmt		100	20	50	30	100	0	100	0
Begin Inv		150	50	30	180	150	50	50	150
Sched Recpt		0	0	0	0	0	0	0	0
Net Rqmt		-	-	20	-	-	-	50	-
Planned Recpt		0		200	0	0	0	200	0
End Inv	150	50	30	180	150	50	50	150	150
Planned Order		200				200			

Regional Warehouse One

Q=50, SS=15, LT=1	NOW	1	2	3	4	5	6	7	8
Period Usage		25	25	25	25	25	25	25	25
Gross Rqmt		40	40	40	40	40	40	40	40
Begin Inv		50	25	50	25	50	25	50	25
Sched Recpt		0	0	0	0	0	0	0	0
Net Rqmt		-	15	-	15	-	15	-	15
Planned Recpt		0	50	0	50	0	50	0	50
End Inv	50	25	50	25	50	25	50	25	50
Planned Order		50		50		50		50	

Regional Warehouse Two

Q=30, SS=10, LT=1	NOW	1	2	3	4	5	6	7	8
Period Usage		10	10	10	10	20	20	20	20
Gross Rqmt		20	20	20	20	30	30	30	30
Begin Inv		20	10	30	20	10	20	30	10
Sched Recpt		0	0	0	0	0	0	0	0
Net Rqmt		-	10	-	-	20	10	-	20
Planned Recpt			30	0	0	30	30	0	30
End Inv	20	10	30	20	10	20	30	10	20
Planned Order		30			30	30		30	

Regional Warehouse Three

Q=20, SS=10, LT=1	NOW	1	2	3	4	5	6	7	8
Period Usage		5	15	10	10	0	15	0	15
Gross Rqmt		15	25	20	20	10	25	10	25
Begin Inv		15	10	15	25	15	15	20	20
Sched Recpt		0	0	0	0	0	0	0	0
Net Rqmt		-	15	5	-	-	10	-	5
Planned Recpt		0	20	20	0	0	20	0	20
End Inv	15	10	15	25	15	15	20	20	25

Example: The DRP Plan

Regional Warehouse One
Q=50 , SS=15 , LT=1

Forecast

	NOW	1	2	3	4	5	6	7	8
Period Usage		25	25	25	25	25	25	25	25
Gross Rqmt		40	40	40	40	40	40	40	40
Begin Inv		50	25	50	25	50	25	50	25
Sched Rcpt		0	0	0	0	0	0	0	0
Net Rqmt			15		15		15		15
Plan Rcpt		0	50	0	50	0	50	0	50
End Inv	50	25	50	25	50	25	50	25	50
POR		50		50		50		50	

Example: The DRP Plan

Regional Warehouse Two
Q=30 , SS=10 , LT=1

	NOW	1	2	3	4	5	6	7	8
Period Usage		10	10	10	10	20	20	20	20
Gross Rqmt		20	20	20	20	30	30	30	30
Begin Inv		20	10	30	20	10	20	30	10
Sched Rcpt		0	0	0	0	0	0	0	0
Net Rqmt			10			20	10		20
Plan Rcpt		0	30	0	0	30	30	0	30
End Inv	20	10	30	20	10	20	30	10	20
POR		30			30	30		30	

Example: The DRP Plan

Regional Warehouse Three
Q=20 , SS=10 , LT=1

	NOW	1	2	3	4	5	6	7	8
Period Usage		5	15	10	10	0	15	0	15
Gross Rqmt		15	25	20	20	10	25	10	25
Begin Inv		15	10	15	25	15	15	20	20
Sched Rcpt		0	0	0	0	0	0	0	0
Net Rqmt			15	5			10		5
Plan Rcpt		0	20	20	0	0	20	0	20
End Inv	15	10	15	25	15	15	20	20	25
POR		20	20			20		20	

The DRP Plan for All Locations

Rolling Up Orders

	NOW	1	2	3	4	5	6	7	8
CENTRAL									
Period Usage		100	20	50	30	100	0	100	0
POR		200				200			
REGION ONE									
Period Usage		25	25	25	25	25	25	25	25
POR		50		50		50		50	
REGION TWO									
Period Usage		10	10	10	10	20	20	20	20
POR		30			30	30		30	
REGION THREE									
Period Usage		5	15	10	10	0	15	0	15
POR		20	20			20		20	

Example: The DRP Plan

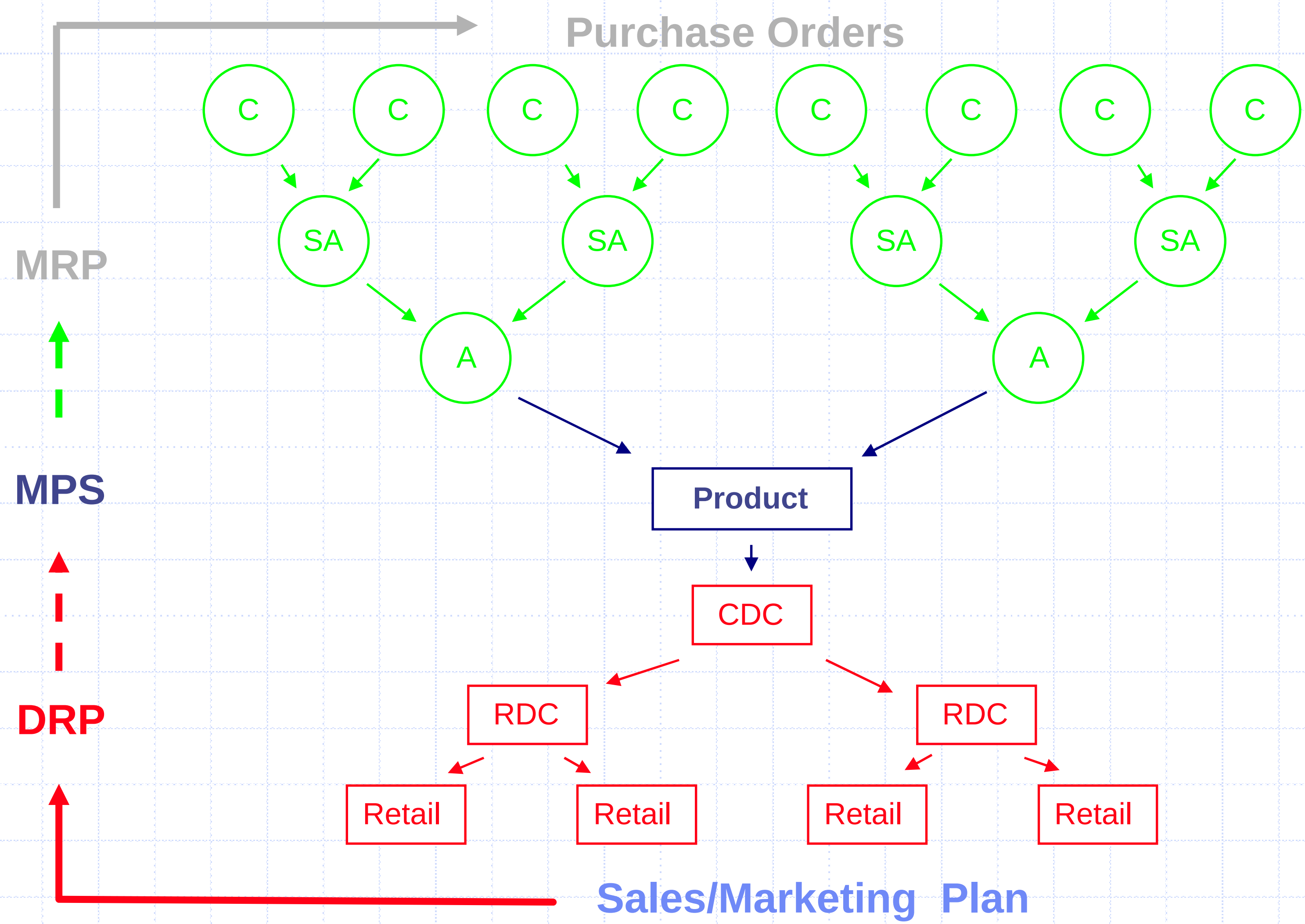
Central Warehouse
Q=200 , SS=0 , LT=2

	NOW	1	2	3	4	5	6	7	8
Period Usage		100	20	50	30	100	0	100	0
Gross Rqmt		100	20	50	30	100	0	100	0
Begin Inv		150	50	30	180	150	50	50	150
Sched Rcpt		0	0	0	0	0	0	0	0
Net Rqmt				20				50	
Plan Rcpt		0	0	200	0	0	0	200	0
End Inv	150	50	30	180	150	50	50	150	150
POR		200				200			

Results and Insights

- DRP is a scheduling and stockage algorithm
  -- it replaces the forecasting mechanism above the base inventory level
- DRP does not determine lot size or safety stock
  -- but these decisions must be made as inputs to the process
- DRP does not explicitly consider any costs
  -- but these costs are still relevant and the user must evaluate trade-offs
- DRP systems can deal with uncertainty somewhat
  -- using "safety time" and "safety stock"

MRP / DRP Integration



Evolution of Inventory Management

- Traditional Replenishment Inventory:
  - Lot Size/ Order Point Logic
  - Single item focus
  - Emphasis on cost optimization
  - Long run, steady state approach
- The MRP / DRP Approach:
  - Scheduling emphasis
  - Focus on quantities and times, not cost
  - Multiple, inter-related items and locations
  - Simple heuristic rules

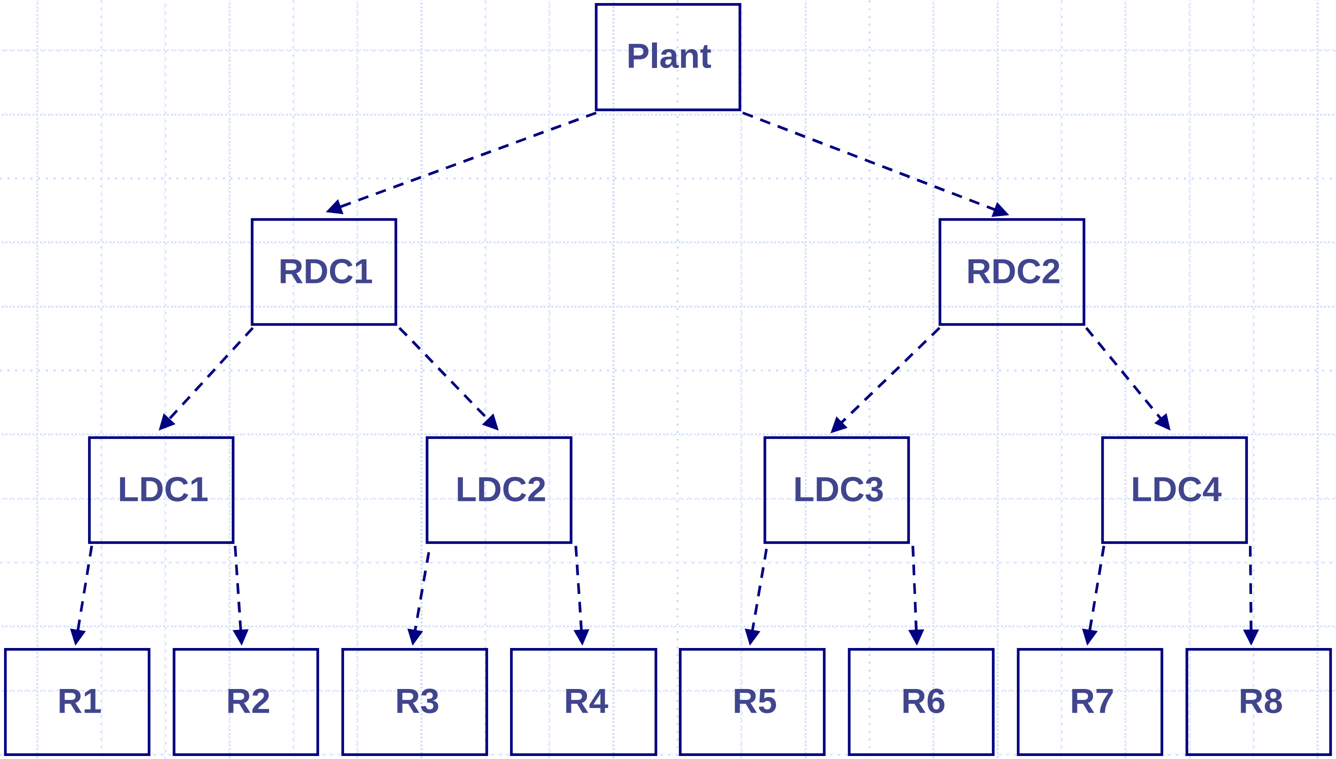
Evolution of Inventory Management

- MRP / DRP have limited ability to deal with:
  - Capacity restrictions in production and distribution
  - “set-up” costs
  - fixed and variable shipping costs
  - alternative sources of supply
  - network transshipment alternatives
  - expediting opportunities
- Next Steps in MRP/DRP
  - Establish a time-phased MRP/MPS/DRP network
  - Apply optimization tools to the network
  - Consider cost trade-offs across items, locations, and time periods
  - Deal with shortcomings listed above

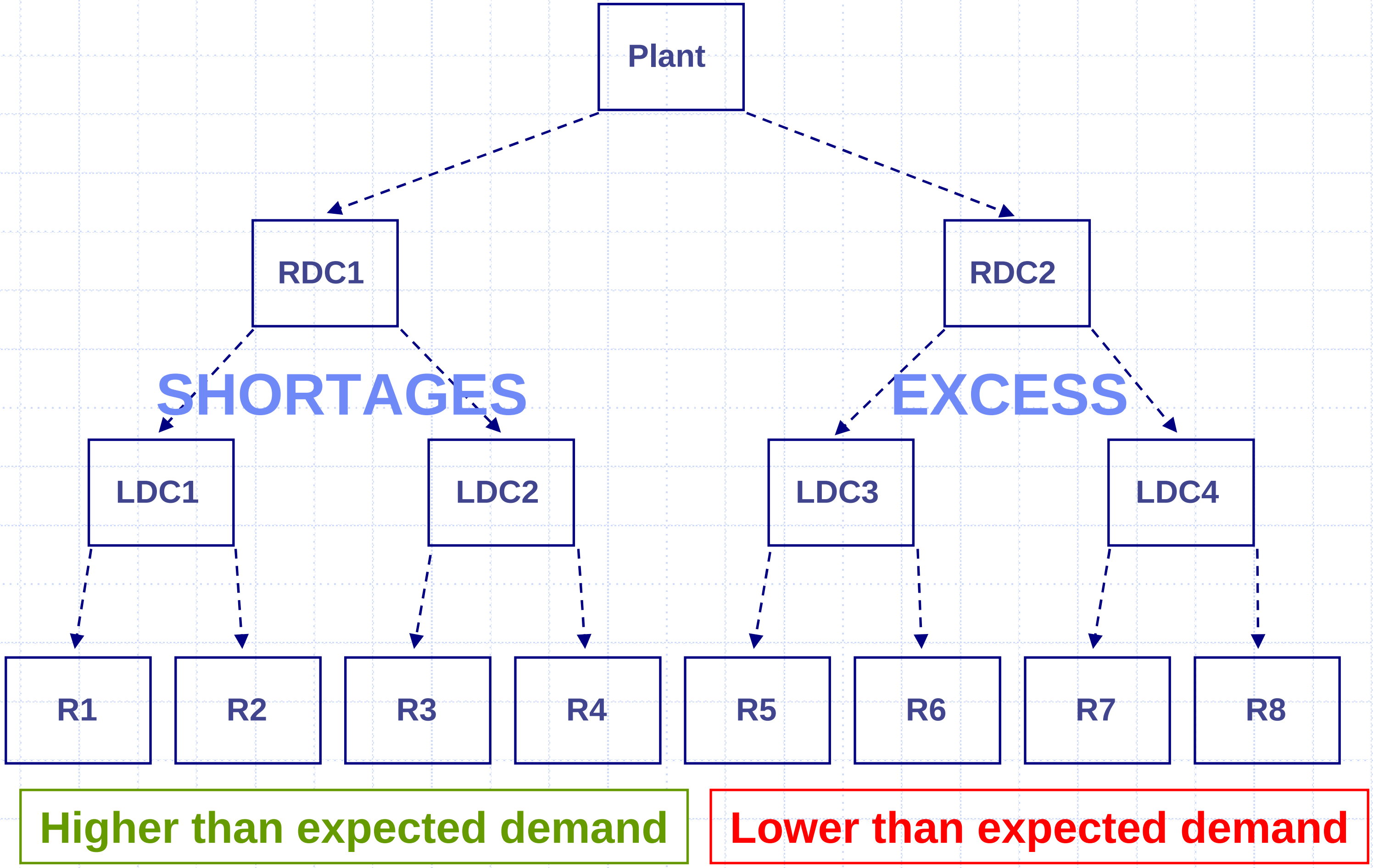
A DRP Network Plan

What happens when actual demand in the short term doesn't follow the forecast exactly.....

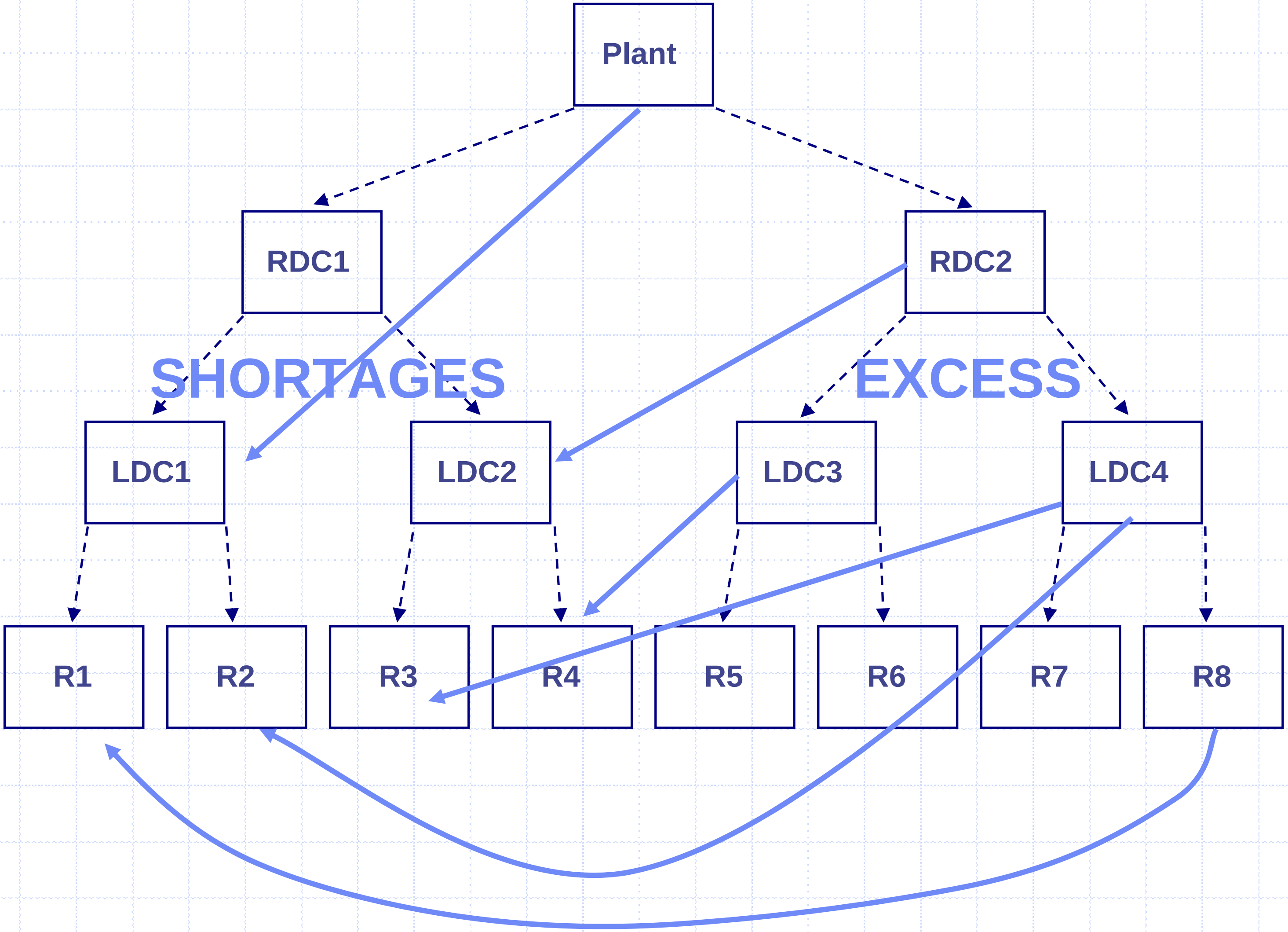
How should I re-deploy my inventory to take the maximum advantage of what I do have?



A DRP Network Reality



Optimal Network Utilization



Information and Control Impacts

	Centralized Control	Decentralized Control
Global Information	◆Vendor Managed Inventory (VMI) ◆DRP (some cases) ◆Extended Base Stock Control Systems	◆DRP (most cases) ◆Base Stock Control
Local Information	N/A	◆Standard Inventory Policies: (R,Q), (s,S) etc.

Questions?