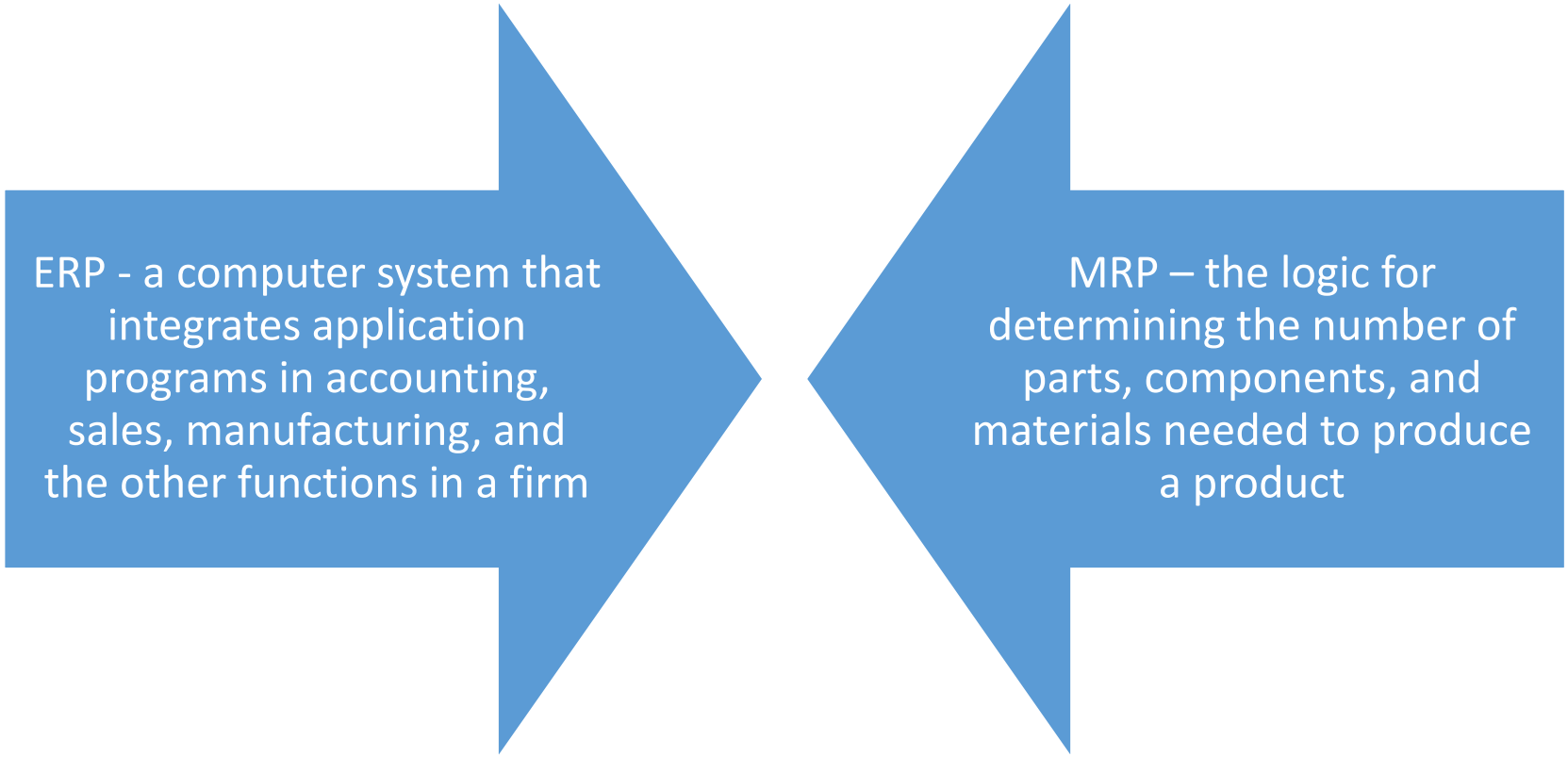
Material requirements planning

Chapter 9

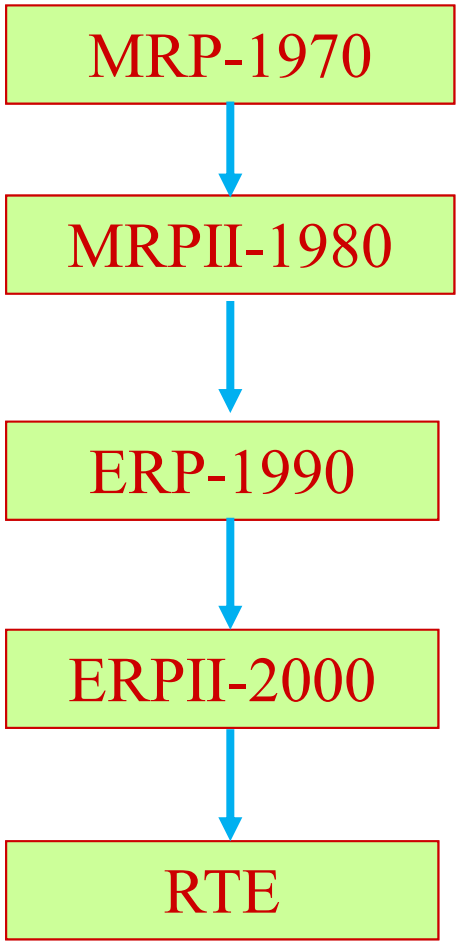
Learning Objectives

1. Describe what material requirements planning (MRP) is.
2. Understand how the MRP system is structured.
3. Analyze an MRP problem.
4. Evaluate and compare MRP lot-sizing techniques.

Enterprise Resource Planning (ERP) and Material Requirements Planning (MRP)



ERP的資訊系統的演進過程



Material Requirement Planning

Manufacturing Resource Planning

Enterprise Resource Planning

Extended ERP
(包含ERP+CRM+SCM+EC+MES+BI+KM等)

Real Time Enterprise

MRP（物料需求規劃）

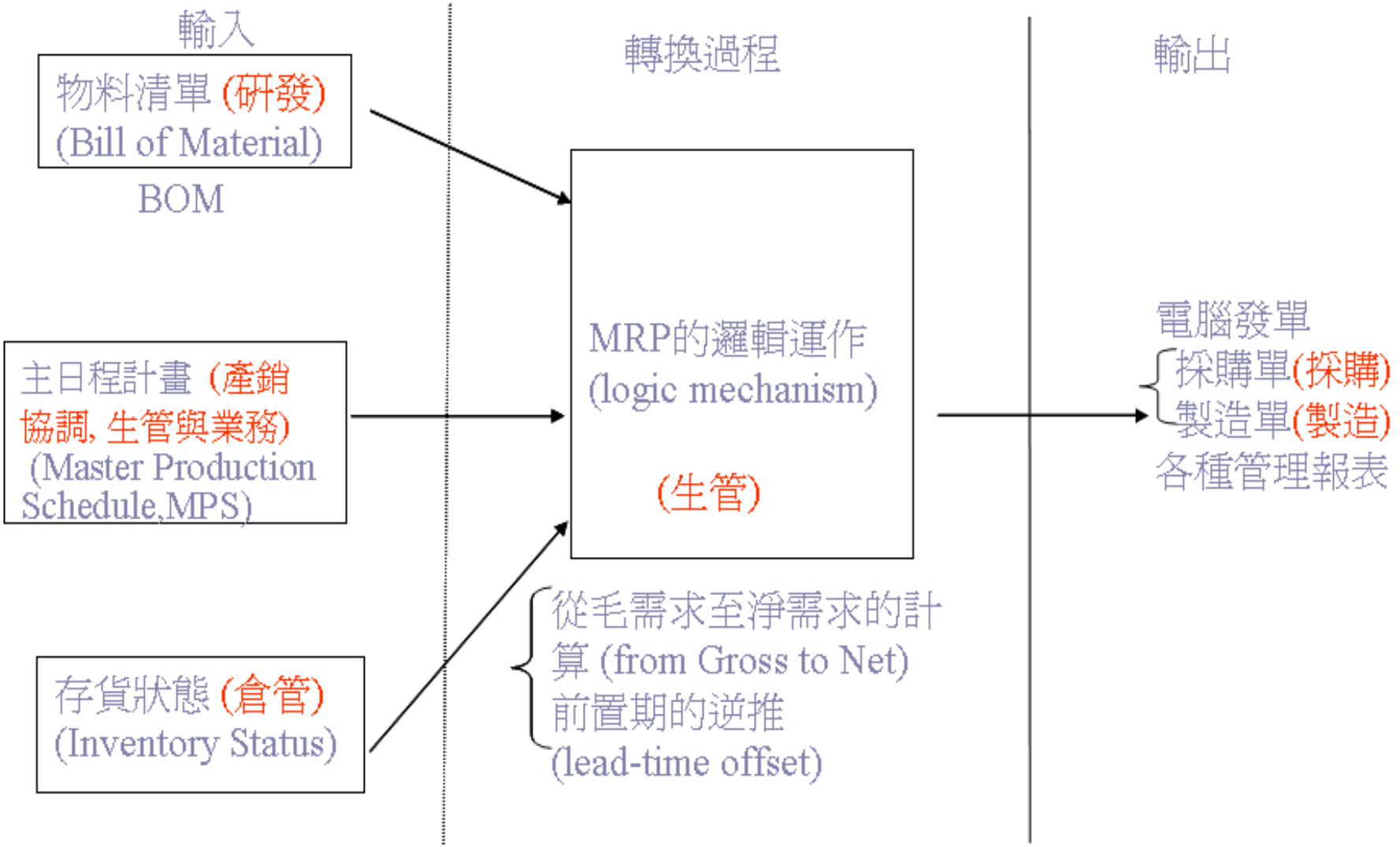
- 在1970年代企業大部份屬於製造產業。此時人工充沛、成本低廉、產品類型簡單、生產型態主要追求規模經濟的大量生產。製造業要能及時出貨，最大的關鍵在於正確、及時的用料規劃以及供料控制。

- 例如，業務接到訂單時，到底要採買哪些物料？要買多少？應該何時入庫？存貨要設定多少？這些都是當時企業最關心的議題，因此，資訊應用系統在產業界被拿來作為規劃及管理物料的工具，而整個物料規劃系統的發展主要源於MRP理論。

MRP（物料需求規劃）

- 顧客訂單與銷售預測 → 主日程計畫（Master Production Schedule, MPS，安排最終產品所需的數量與時間）→ 物料清單（Bill of Material, BOM）
  - 毛需求 (Gross Requirement，GR)
  - 在庫量（On Hand，OH：成品與半成品）
  - 在途量（On Order，或稱已訂未交量，Schedule Receipt，SR）
  - 淨需求 (Net Requirement，NR)計劃
  - 採購單 (Purchase Order，PO或稱採購令)
  - 製造單 (Work Order，WO或稱工單、工令、製令)

MRP展開架構圖


輸入
物料清單 (研發)
(Bill of Material)
BOM
主日程計畫 (產銷協調, 生管與業務)
(Master Production Schedule,MPS)
存貨狀態 (倉管)
(Inventory Status)
轉換過程
MRP的邏輯運作
(logic mechanism)
(生管)
從毛需求至淨需求的計算 (from Gross to Net)
前置期的逆推
(lead-time offset)
輸出
電腦發單
採購單(採購)
製造單(製造)
各種管理報表

MRP的邏輯運作

- 從毛需求至淨需求的計算
  - 根據MPS及BOM逐層計算
  - 由最終產品到相依零組件之淨需求，為相依性需求(dependent demand)之計算
  - 計算出所需之物料是什麼(what)？所需數量(how much)？
- 前置期(lead time)的逆推(offset)
  - 根據製造或生產前置時間，而決定發生PO或WO的時刻(time)？

Material Requirements Planning

Material Requirements Planning (MRP)

- The logic that ties production functions together from a material planning and control view.
- A logical, easily understood approach to the problem of managing the parts, components, and materials needed to produce end items
  - How much of each part to obtain?
  - When to order or produce the parts?
- Dependent demand drives the MPR system

MRP Applications and Benefits

Industry Type	Examples	Expected Benefits
Assemble-to-stock	Combines multiple component parts into a finished product, which is then stocked in inventory to satisfy customer demand. Examples: watches, tools, appliances.	High
Fabricate-to-stock	Items are manufactured by machine rather than assembled from parts. These are standard stock items carried in anticipation of customer demand. Examples: piston rings, electrical switches.	Low
Assemble-to-order	A final assembly is made from standard options that the customer chooses. Examples: trucks, generators, motors.	High
Fabricate-to-order	Items are manufactured by machine to customer order. These are generally industrial orders. Examples: bearings, gears, fasteners.	Low
Manufacture-to-order	Items are fabricated or assembled completely to customer specification. Examples: turbine generators, heavy machine tools.	High
Process	Includes industries such as foundries, rubber and plastics, specialty paper, chemicals, paint, drug, food processors.	Medium

Master Production Scheduling(主日程計畫)

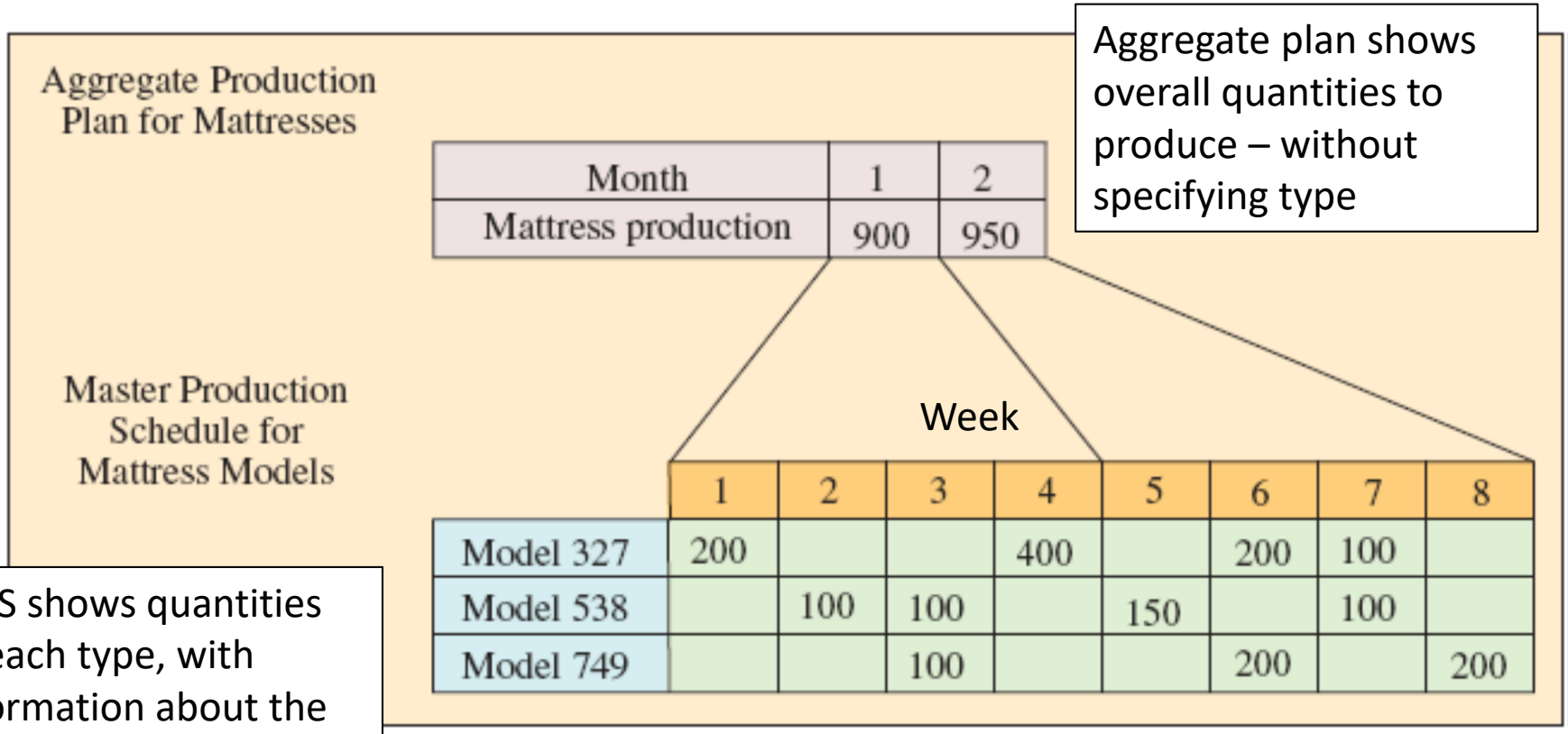
- The master schedule deals with end items and is a major input to the MRP process
- All production systems have limited capacity and limited resources
  - The aggregate plan provides the general range of operation, the master scheduler must specify exactly what is to be produced

- 主日程計劃(MPS，主排程計劃)：列有每週(或每日、每月等)所需生產之最終產品或服務零組件數量。

  ✓MPS 的資料來自顧客訂單的需求預測或實際的訂單

  ✓MPS內容為獨立性需求(independent demand)

Master Production Scheduling

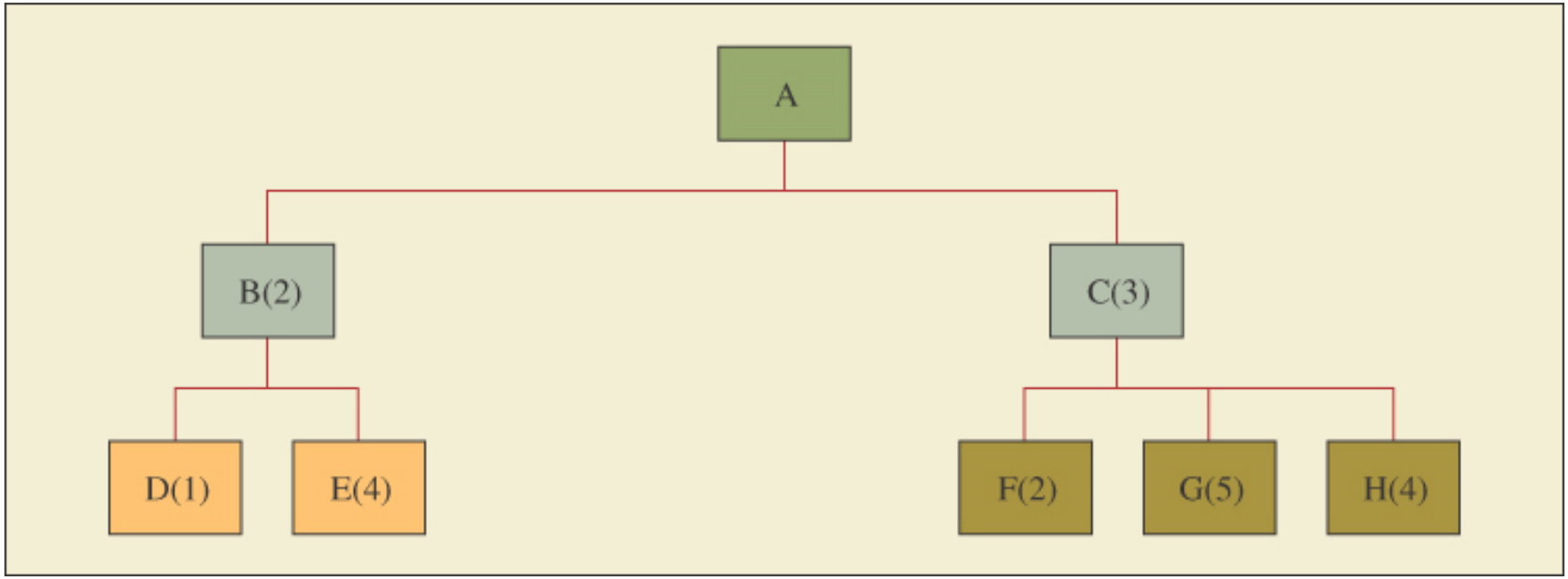


Bill of Material

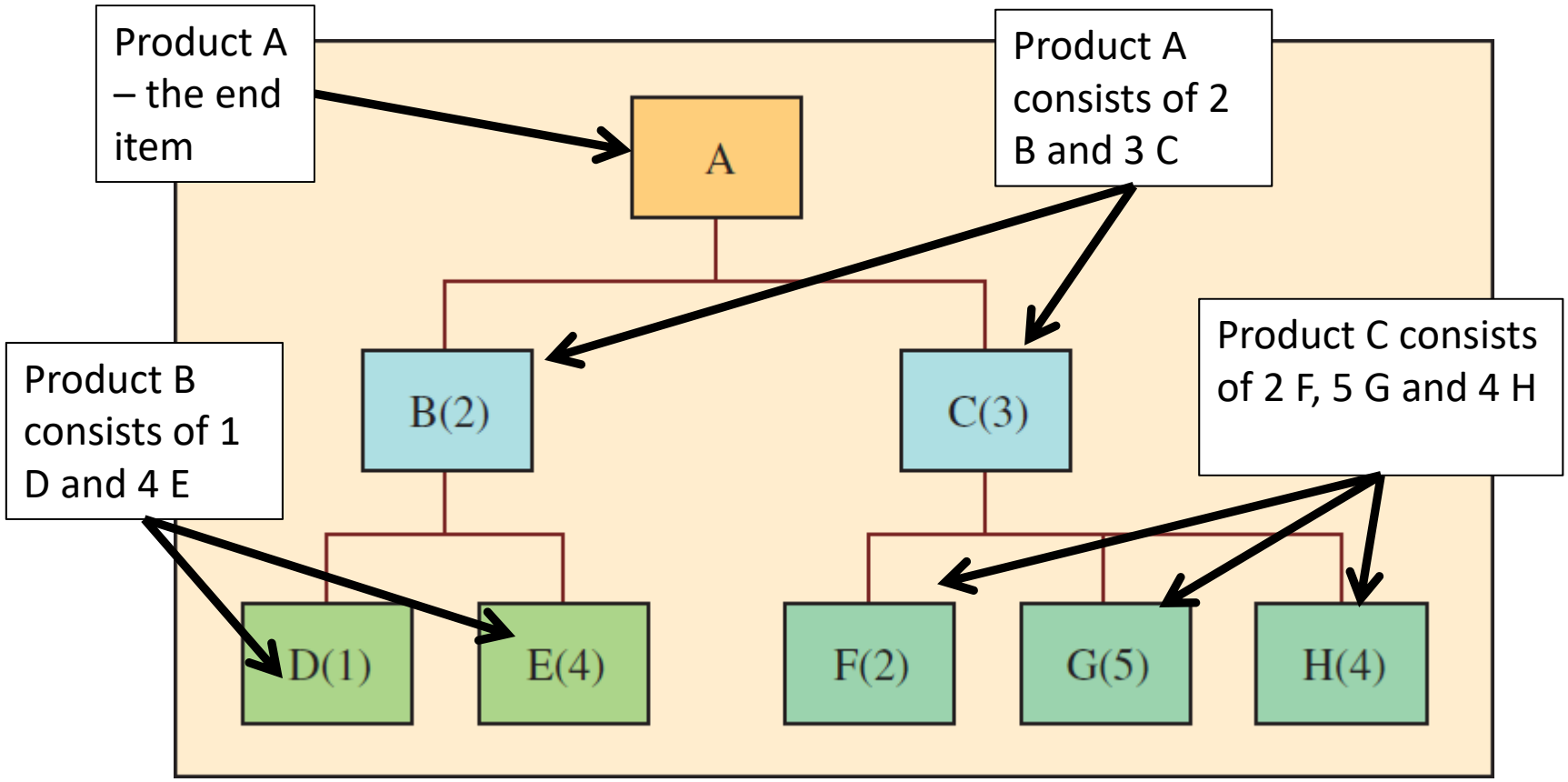
MRP的邏輯運作

- **產品結構檔或物料清單(BOM)**
  - ✓即生產所需零組件之清單
  - ✓用表列示或結構樹以顯示產品之裝配關係及所需零組件數量
  - ✓contains the complete product description, listing not only the materials, parts, and components but also the sequence in which the product is created

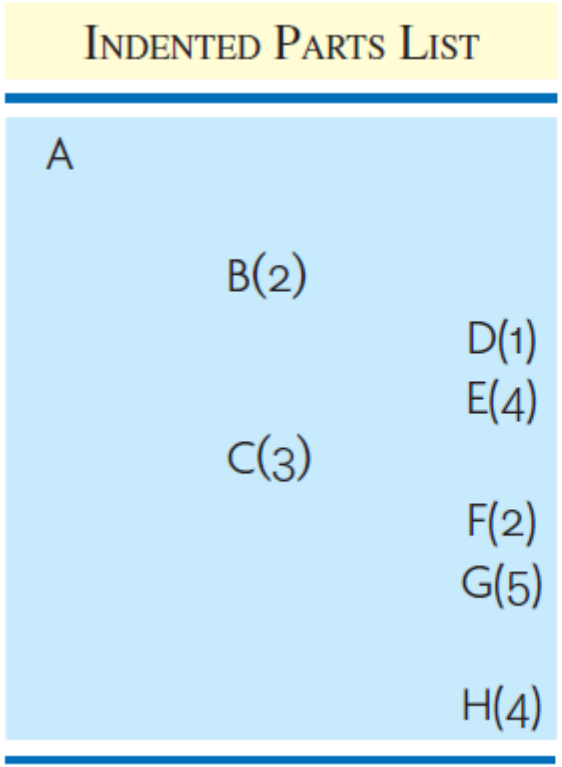
Example: BOM for product A

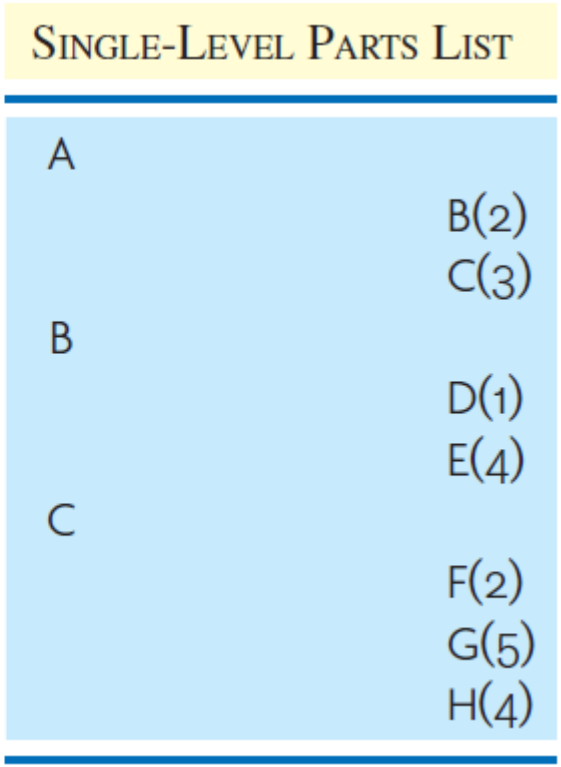


BOM Example


Product A – the end item
A
Product A consists of 2 B and 3 C
Product B consists of 1 D and 4 E
B(2)
C(3)
Product C consists of 2 F, 5 G and 4 H
D(1)
E(4)
F(2)
G(5)
H(4)

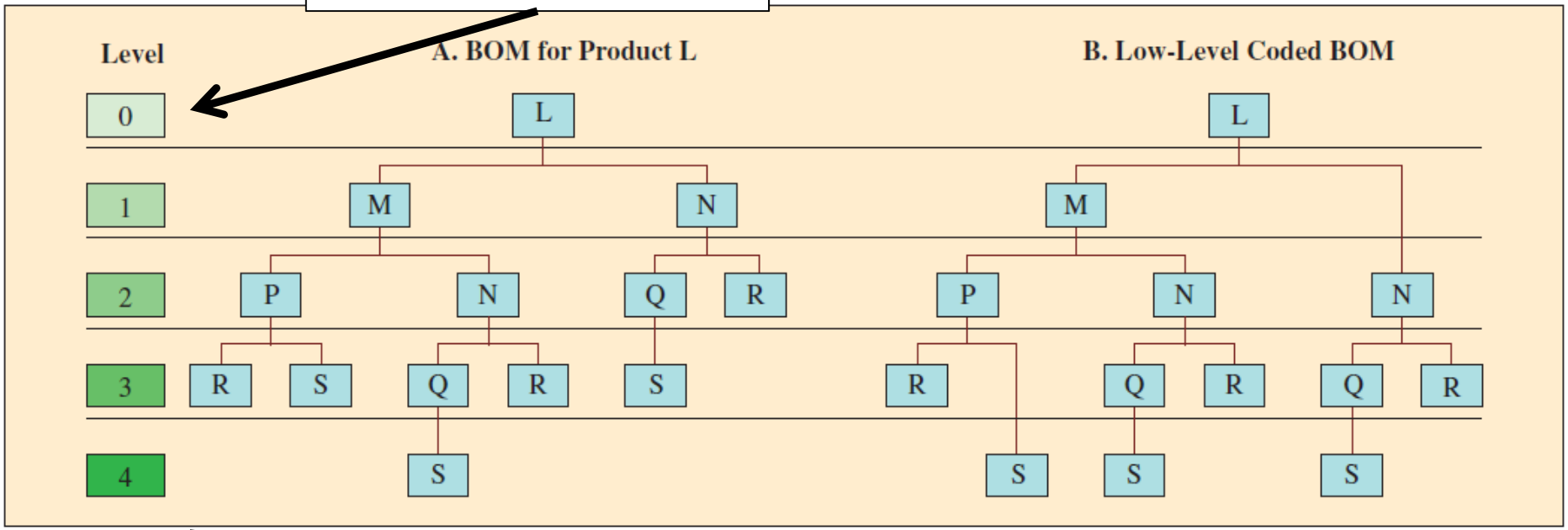
Alternate BOM Structures





BOM Hierarchy (Levels)

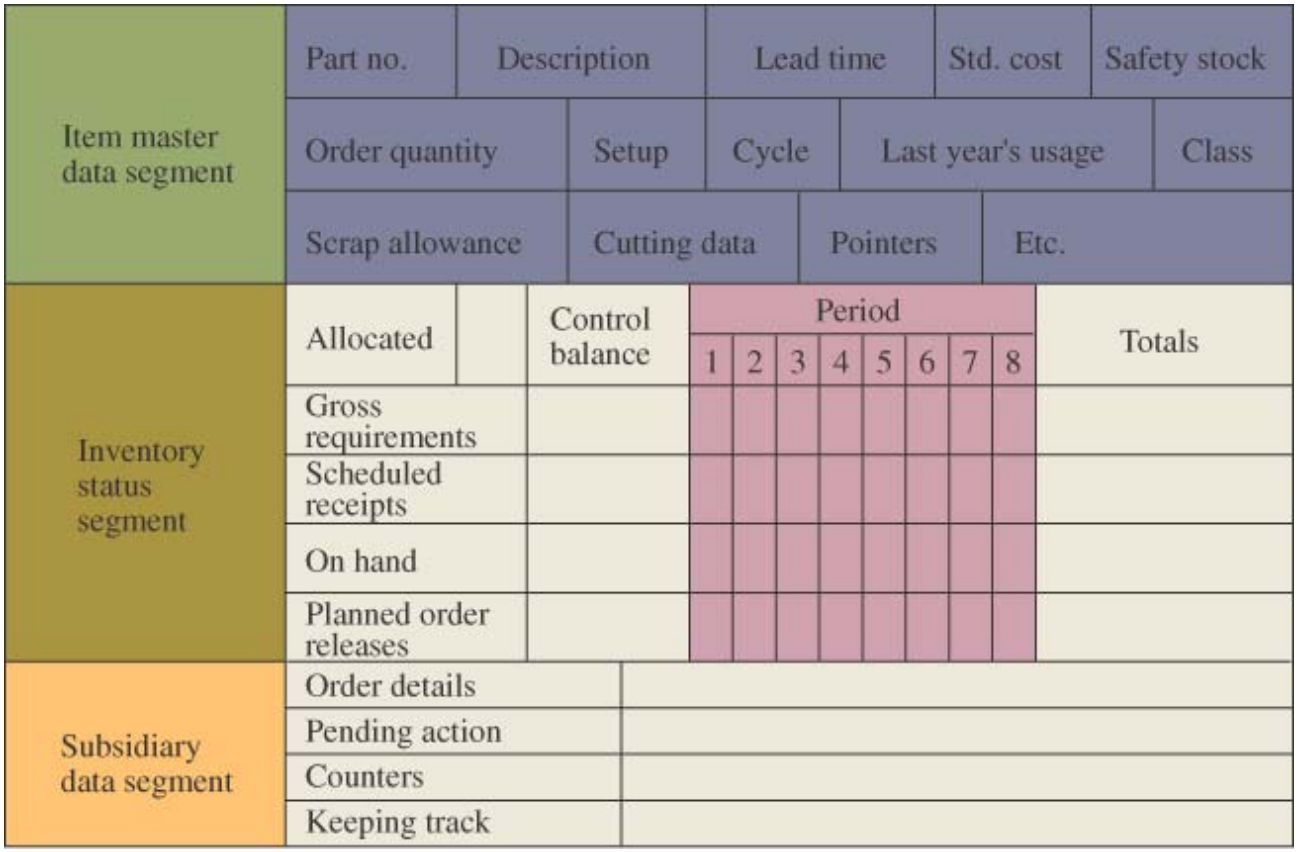
Higher levels (lower numbers) refer to end products



Lower levels (higher numbers) refer to components and raw materials

Inventory Records

- 存貨記錄檔
  - ✓包括零件編號、庫存量、在途量、成本資料及前置時間
  - ✓庫存量代表目前可供給的庫存，在途量代表未來的供給

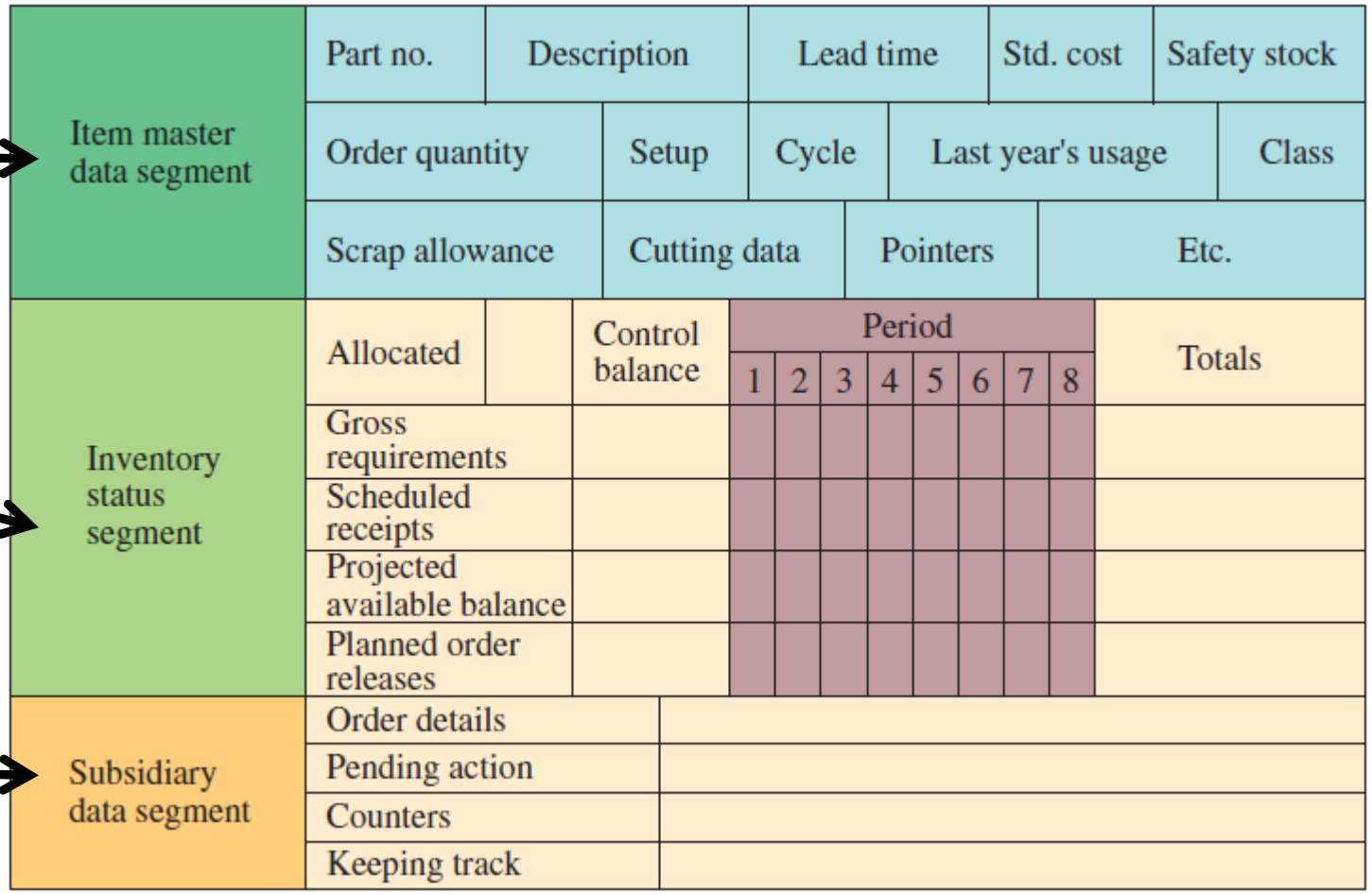


Inventory Status Records

Basic information describing the item

Information about part availability

Additional information that may be useful



MRP Explosion Process

The requirements for end items are retrieved from the master schedule

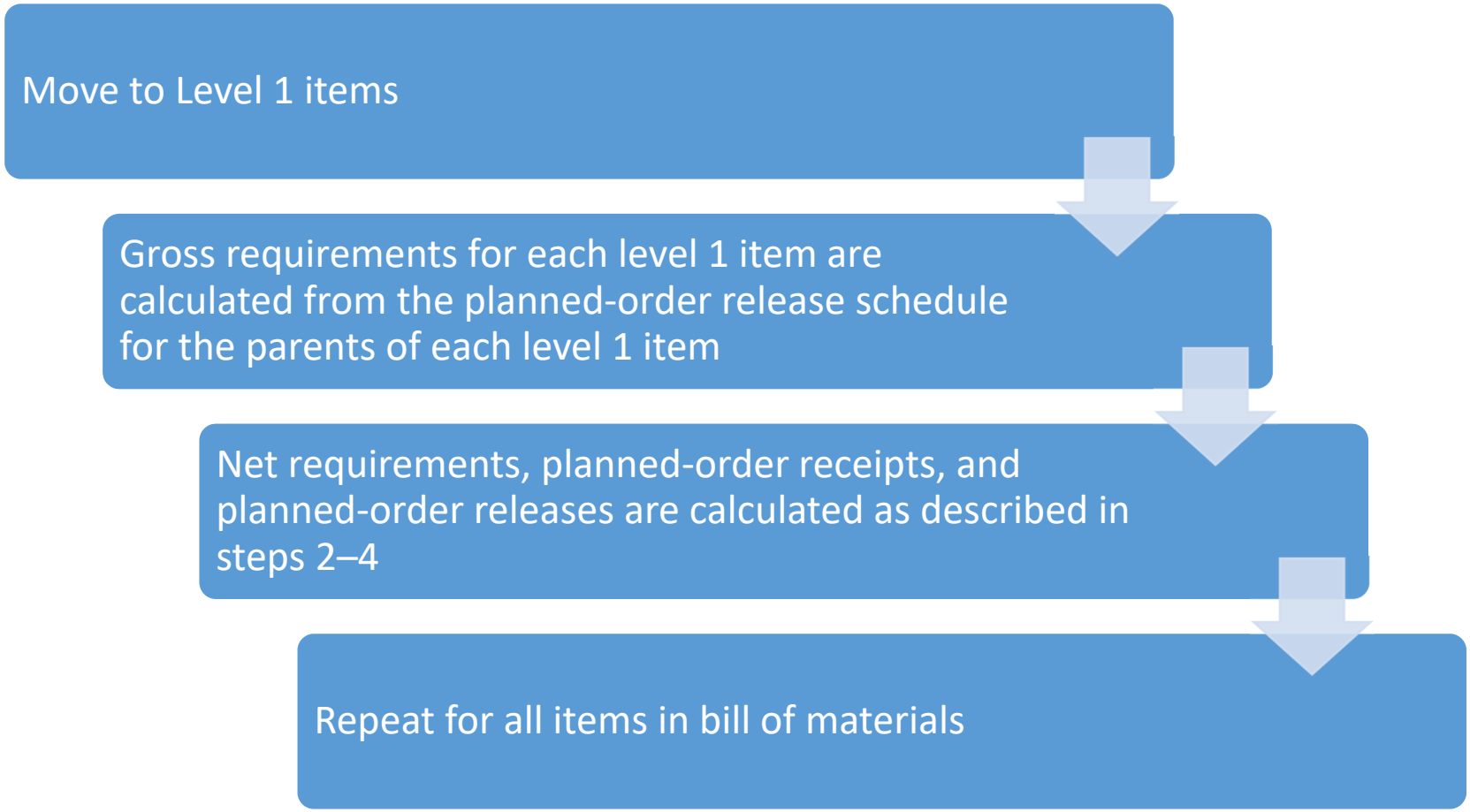
- These are referred to as “gross requirements” by the MRP program

On-hand balance and schedule of orders are used to calculate the “net requirements”

Net requirements data is used to calculate when orders should be received to meet these requirements

Planned order releases are generated by offsetting to allow for lead time

MRP Explosion Process (continued)



MRP Example – Ampere, Inc.

- Ampere, Inc., produces a line of electric meters installed in residential buildings
- Meters are of two basic types for different voltage and amperage ranges
  - Some subassemblies are sold separately for repair or for changeovers
- The problem is to determine a production schedule to identify each item, the period it is needed, and the appropriate quantities
- The schedule is then checked for feasibility, and the schedule is modified if necessary.

Future Requirements – Meters A and B and Subassembly D

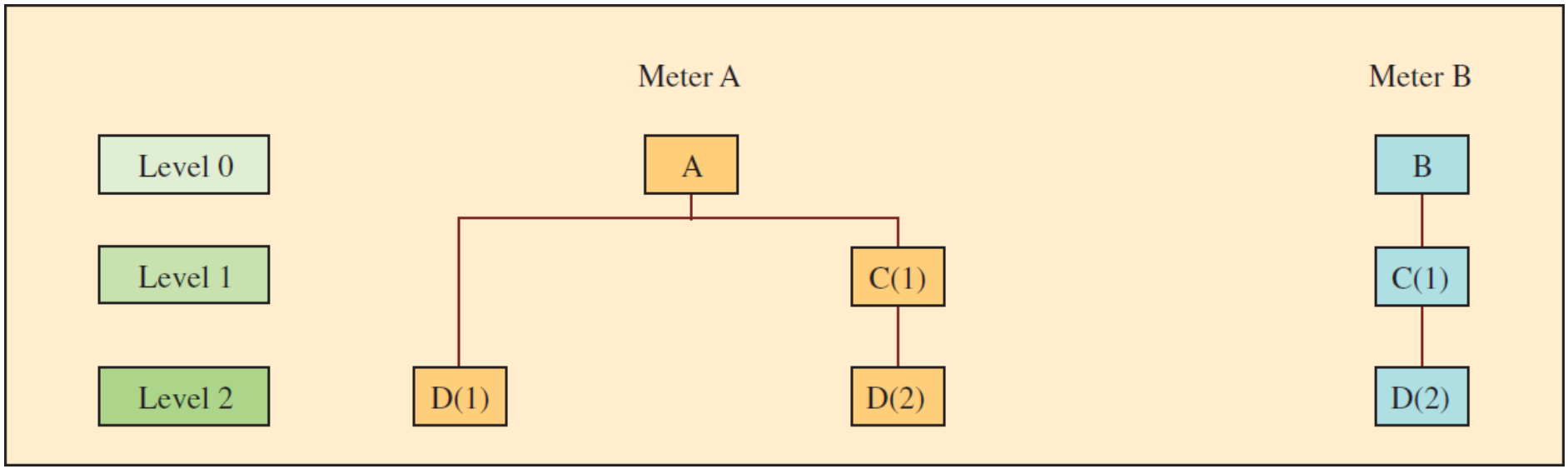
	Meter A		Meter B		Subassembly D	
Month	Known	Forecast	Known	Forecast	Known	Forecast
3	1,000	250	410	60	200	70
4	600	250	300	60	180	70
5	300	250	500	60	250	70

Assume that required quantity must be available during week 1 of each month

Trial Master Schedule

	Week								
	9	10	11	12	13	14	15	16	17
Meter A	1,250				850				550
Meter B	470				360				560
Subassembly D	270				250				320

Product Structure and Inventory Data



Item	On-Hand Inventory	Lead Time (Weeks)	Safety Stock	On Order
A	50	2	0	
B	60	2	0	10 (week 5)
C	40	1	5	
D	200	1	20	100 (week 4)

MRP Planning Schedule

		Week					
Item		4	5	6	7	8	9
A LT = 2 weeks On hand = 50 Safety stock = 0 Order qty = lot-for-lot	Gross requirements Scheduled receipts Projected available balance Net requirements Planned order receipts Planned order releases	50	50	50	50	50	1250 50 1200 1200
					1200		
B LT = 2 weeks On hand = 60 Safety stock = 0 Order qty = lot-for-lot	Gross requirements Scheduled receipts Projected available balance Net requirements Planned order receipts Planned order releases	60	10 70	70	70	70	470 0 400 400
					400		
C LT = 1 week On hand = 40 Safety stock = 5 Order qty = 2000	Gross requirements Scheduled receipts Projected available balance Net requirements Planned order receipts Planned order releases	35	35	35 2000	400+ 1200 435 1565 2000	435	435
D LT = 1 week On hand = 200 Safety stock = 20 Order qty = 5000	Gross requirements Scheduled receipts Projected available balance Net requirements Planned order receipts Planned order releases	100 280	280 5000	4000 1280 3720 5000	1200 80	80 5000	270 4810 190 5000

Example 9.1

	Week							
	1	2	3	4	5	6	7	8
VH1-234	34	37	41	45	48	48	48	48
VH2-100	104	134	144	155	134	140	141	145

	VH1-234	VH2-100	Light Socket
On hand	85	358	425
Q	200 (the production lot size)	400 (to production lot size)	500 (purchase quantity)
Lead time	1 week	1 week	3 weeks
Safety stock	0 units	0 units	20 units

Example 9.1

		Week							
Item		1	2	3	4	5	6	7	8
VH1-234	Gross requirement	34	37	41	45	48	48	48	48
$Q = 200$	Scheduled receipts								
LT = 1	Projected available balance	51	14	173	128	80	32	184	136
OH = 85	Net requirements			27				16	
SS = 0	Planned order receipts			200				200	
	Planned order releases		200				200		

To accommodate the lead time, orders must be released ahead of time

Without an order here, inventory will drop below the safety stock

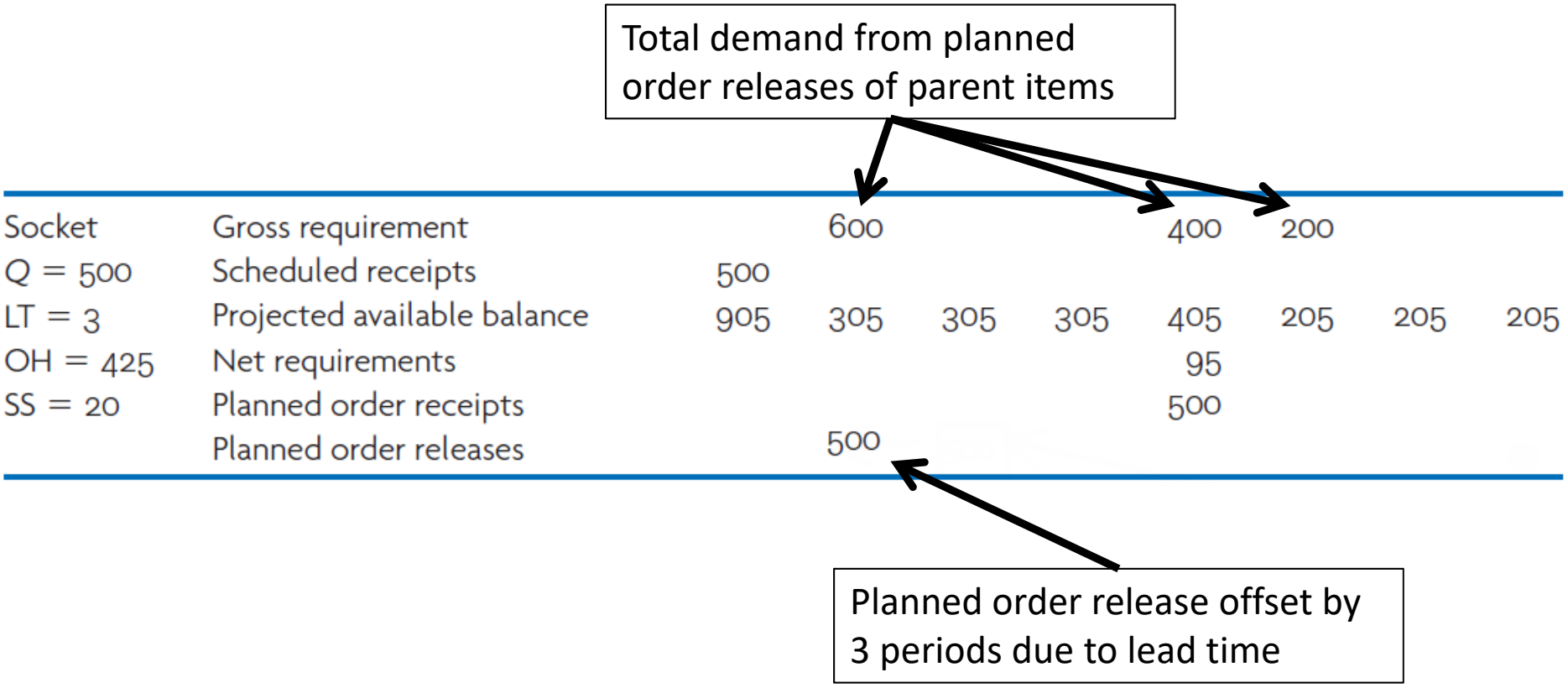
Example 9.1

VH2-100	Gross requirement	104	134	144	155	134	140	141	145
$Q = 400$	Scheduled receipts								
LT = 1	Projected available balance	254	120	376	221	87	347	206	61
OH = 358	Net requirements			24			53		
SS = 0	Planned order receipts			400			400		
	Planned order releases		400			400			

To accommodate the lead time, orders must be released ahead of time

Without an order here, inventory will drop below the safety stock

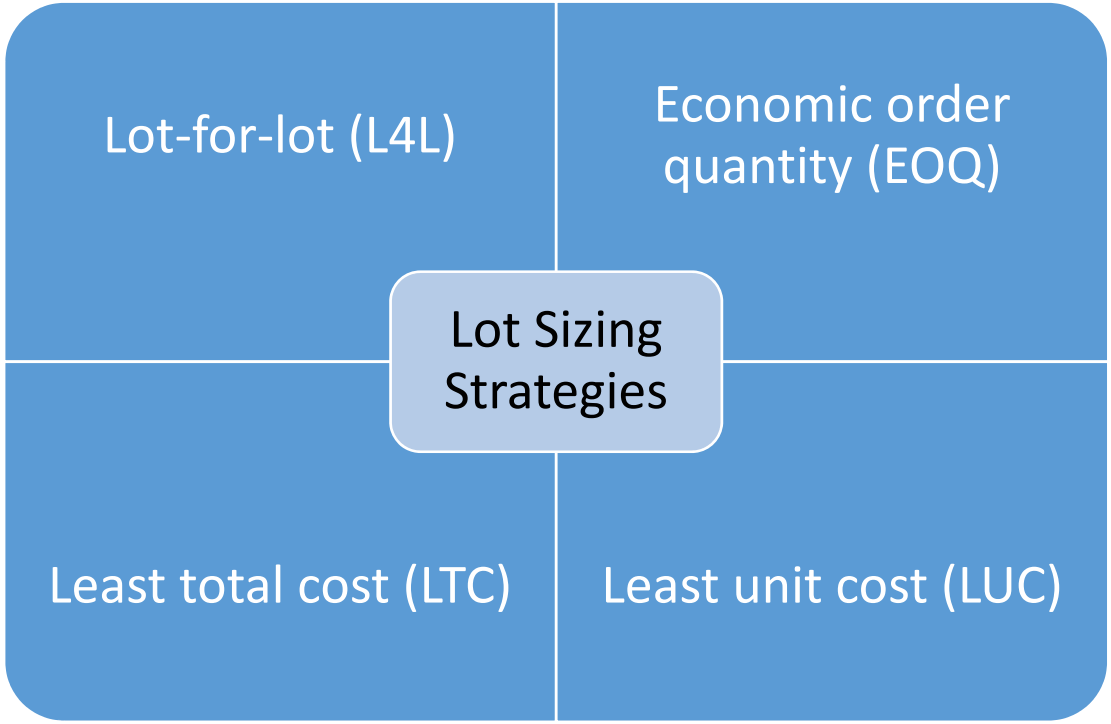
Example 9.1



Socket	Gross requirement		600			400	200		
$Q = 500$	Scheduled receipts	500							
$LT = 3$	Projected available balance	905	305	305	305	405	205	205	205
$OH = 425$	Net requirements					95			
$SS = 20$	Planned order receipts					500			
	Planned order releases		500						

Lot Sizing in MRP Systems

- Determination of lot sizes in an MRP system is a complicated and difficult problem
- Lot sizes - the part quantities issued in the planned order receipt and planned order release sections of an MRP schedule



Lot-for-Lot

Sets planned orders to exactly match the net requirements

Produces exactly what is needed each week with none carried over into future periods

Minimizes carrying cost

Does not take into account setup costs or capacity limitations.

Economic Order Quantity

Calculate reorder quantity based on EOQ

EOQ was not designed for a system with discrete time periods such as MRP

The lot sizes generated by EOQ do not always cover the entire number of periods

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Comparison – Lot-for-Lot and EOQ

Lot-for-Lot

(1) Week	(2) Net Requirements	(3) Production Quantity	(4) Ending Inventory	(5) Holding Cost	(6) Setup Cost	(7) Total Cost
1	50	50	0	$0.00	$47.00	$ 47.00
2	60	60	0	0.00	47.00	94.00
3	70	70	0	0.00	47.00	141.00
4	60	60	0	0.00	47.00	188.00
5	95	95	0	0.00	47.00	235.00
6	75	75	0	0.00	47.00	282.00
7	60	60	0	0.00	47.00	329.00
8	55	55	0	0.00	47.00	376.00

EOQ

Week	Net Requirements	Production Quantity	Ending Inventory	Holding Cost	Setup Cost	Total Cost
1	50	351	301	$15.05	$47.00	$ 62.05
2	60	0	241	12.05	0.00	74.10
3	70	0	171	8.55	0.00	82.65
4	60	0	111	5.55	0.00	88.20
5	95	0	16	0.80	0.00	89.00
6	75	351	292	14.60	47.00	150.60
7	60	0	232	11.60	0.00	162.20
8	55	0	177	8.85	0.00	171.05

Least Total Cost

- Least total cost method (LTC) - a dynamic lot-sizing technique that calculates the order quantity by comparing the carrying cost and the setup costs for various lot sizes and then selects the lot in which these are most nearly equal
  - Lot sizes evaluated are designed to cover an increasing amount of time (1 week, 2 weeks, etc.)
- Influenced by the length of the planning horizon

Least Total Cost

Weeks	Quantity Ordered	Carrying Cost	Order Cost	Total Cost	
1	50	$0.00	$47.00	$47.00	
1–2	110	3.00	47.00	50.00	
1–3	180	10.00	47.00	57.00	
1–4	240	19.00	47.00	66.00	1st order
1–5	335	38.00	47.00	85.00	← Least total cost
1–6	410	56.75	47.00	103.75	
1–7	470	74.75	47.00	121.75	
1–8	525	94.00	47.00	141.00	
6	75	0.00	47.00	47.00	
6–7	135	3.00	47.00	50.00	2nd order
6–8	190	8.50	47.00	55.50	← Least total cost

Week	Net Requirements	Production Quantity	Ending Inventory	Holding Cost	Setup Cost	Total Cost
1	50	335	285	$14.25	$47.00	$ 61.25
2	60	0	225	11.25	0.00	72.50
3	70	0	155	7.75	0.00	80.25
4	60	0	95	4.75	0.00	85.00
5	95	0	0	0.00	0.00	85.00
6	75	190	115	5.75	47.00	137.75
7	60	0	55	2.75	0.00	140.50
8	55	0	0	0.00	0.00	140.05

Least Unit Cost

- Least unit cost method - a dynamic lot-sizing technique that adds ordering and inventory carrying cost for each trial lot size and divides by the number of units in each lot size, picking the lot size with the lowest unit cost

Least Unit Cost

Weeks	Quantity Ordered	Carrying Cost	Order Cost	Total Cost	Unit Cost	
1	50	$ 0.00	$ 47.00	$ 47.00	$0.9400	
1–2	110	3.00	47.00	50.00	0.4545	
1–3	180	10.00	47.00	57.00	0.3167	
1–4	240	19.00	47.00	66.00	0.2750	
1–5	335	38.00	47.00	85.00	0.2537	1st order
1–6	410	56.75	47.00	103.75	0.2530	← Least unit cost
1–7	470	74.75	47.00	121.75	0.2590	
1–8	525	94.00	47.00	141.00	0.2686	
?	60	0.00	47.00	47.00	0.7833	2nd order
7–8	115	2.75	47.00	49.75	0.4326	← Least unit cost

Week	Net Requirements	Production Quantity	Ending Inventory	Holding Cost	Setup Cost	Total Cost
1	50	410	360	$18.00	$ 47.00	$ 65.00
2	60	0	300	15.00	0.00	80.00
3	70	0	230	11.50	0.00	91.50
4	60	0	170	8.50	0.00	100.00
5	95	0	75	3.75	0.00	103.75
6	75	0	0	0	0	103.75
7	60	115	55	2.75	47.00	153.50
8	55	0	0	0	0	$ 153.50

Exercises

- 15
- 20