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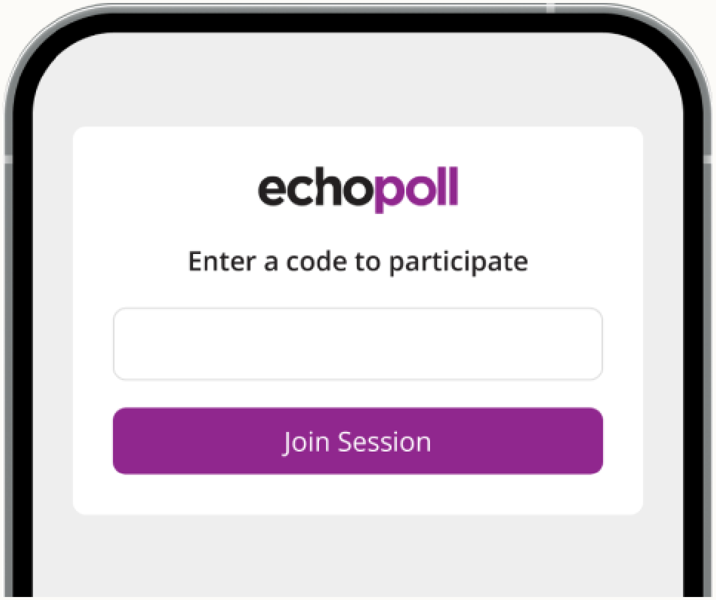

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BUSI4496 Supply Chain Planning and Management

Material Requirements Planning

Dr Ursula Davis

Attendance

Today's Content

1. Learning Objectives
2. Introduction to MRP
3. The MRP process
4. MRP worked example
5. Capacity constraints

1. Learning Objectives

01

Define key concepts (Material requirements planning, Master production schedule, Bill of Materials)

02

Understand how MRP supports planning and control

03

Apply methods and techniques to support MRP

Introduction to MRP

Introduction to MRP

The planning process

Hierarchy of production planning decisions:

Forecasted demand for the finished goods inform our production schedule:

Forecast of aggregate demand for t period horizon

↓

Aggregate Production Plan

Determination of aggregate production and workforce levels for t period planning horizon

↓

Master Production Schedule (MPS)

Production levels by item by time period

↓

Materials Requirements Planning System (MRP)

Detailed timetable for production and assembly of components and subassemblies

Intro to MRP

What is MRP?

MRP, materials requirement planning, is an approach to calculating **how many** parts, or materials of particular types are required and **what times** they are required

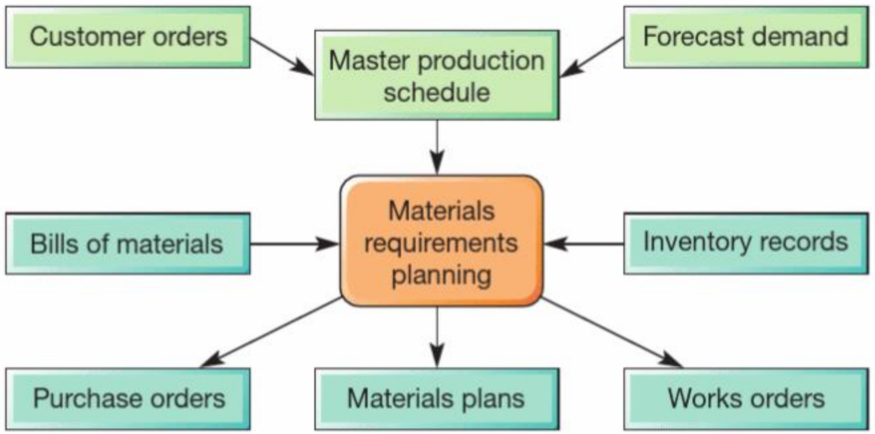


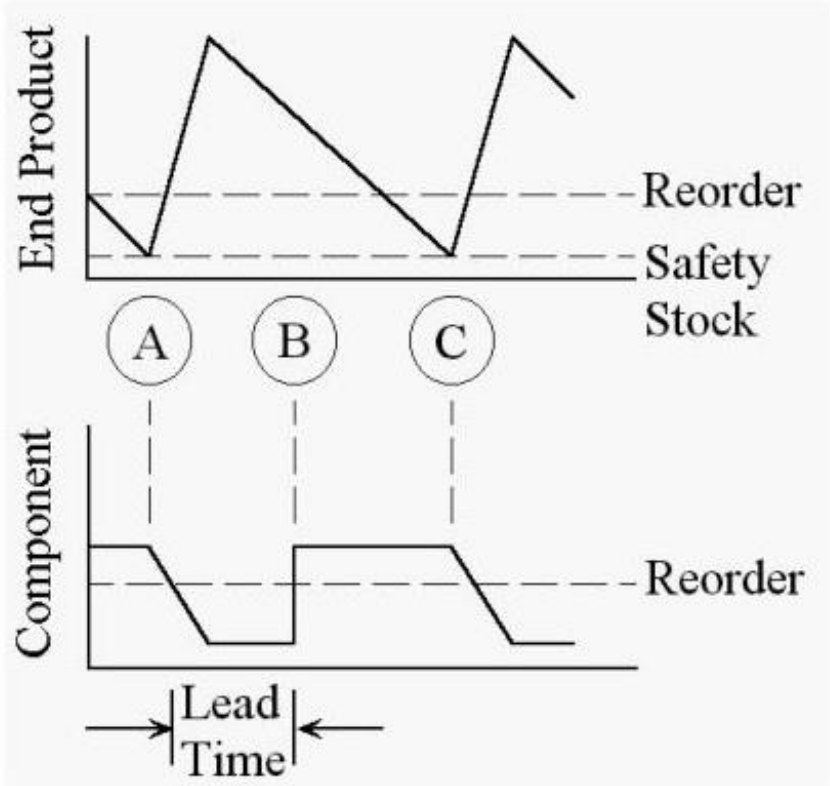
Figure 14.9 Materials requirements planning (MRP) schematic

(Slack et al 2022)

Intro to MRP

Why MRP?

Inventory without an MRP system:



When production stops (at t=0), finished product inventory decreases, because we are still selling…but our component inventory remains unchanged.
When production restarts, finished product inventory increases but component inventory decreases

- Component is ordered at time **A,** when inventory level hits the reorder points **R**
- Component is received at point **B,** but isn't required until time **C**

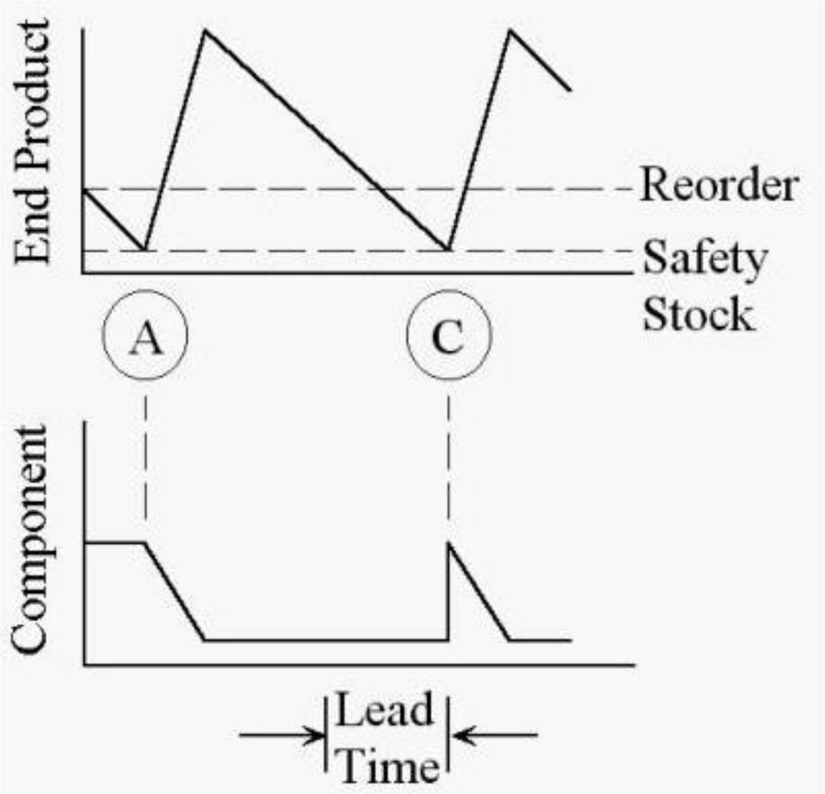
Meaning unnecessary inventory holding cost incurred between time B and C

Intro to MRP

Why MRP?

- With an MRP system, given the production schedule of the finished goods (plus other information) it is possible to predict the exact time, **C**, when the component is required.
- We can make the order at such that it is received at time **C**

Avoiding unnecessary inventory cost



Inventory with MRP system

Intro to MRP

MRP assumptions

- Demand is known (we can use forecasted demand)
- No back-ordering
- No capacity constraints
- Static over the planning horizon
- Lead times are known, constant & independent of lot-size

Intro to MRP

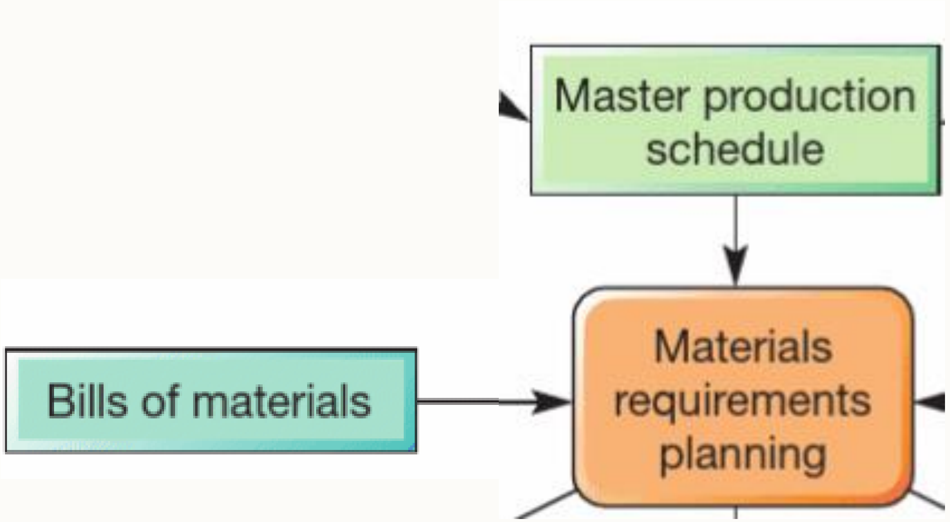
The main input to MRP is the **Master Production Schedule (MPS)**

MPS contains a statement of the volume (how much) and timing (when) of the end products to be made

- Considers independent demand of un-aggregated items
- Considers all sources of demand: customer demand, spare parts, internal orders, safety stock requirement…

Intro to MRP

To find the required volume of parts and materials (MRP), we need to know the individual part requirements for each product…



This is known as the Bill of Materials

Or a product structure, or product tree

Intro to MRP

Bill of materials

What are some of the component items that make up our final item, the bike?

Intro to MRP

Bill of materials

Saddle area:
Saddle
Seat post

Front set:
Handlebars
Front brakes

Wheel:
Spokes
Hub
Rim
Tire
Valve

Pedal
Crank arm

Frame

Rear derailleur
Cog set
Rear brakes

Front derailleur
Chain
Chain rings

Intro to MRP

Bill of materials

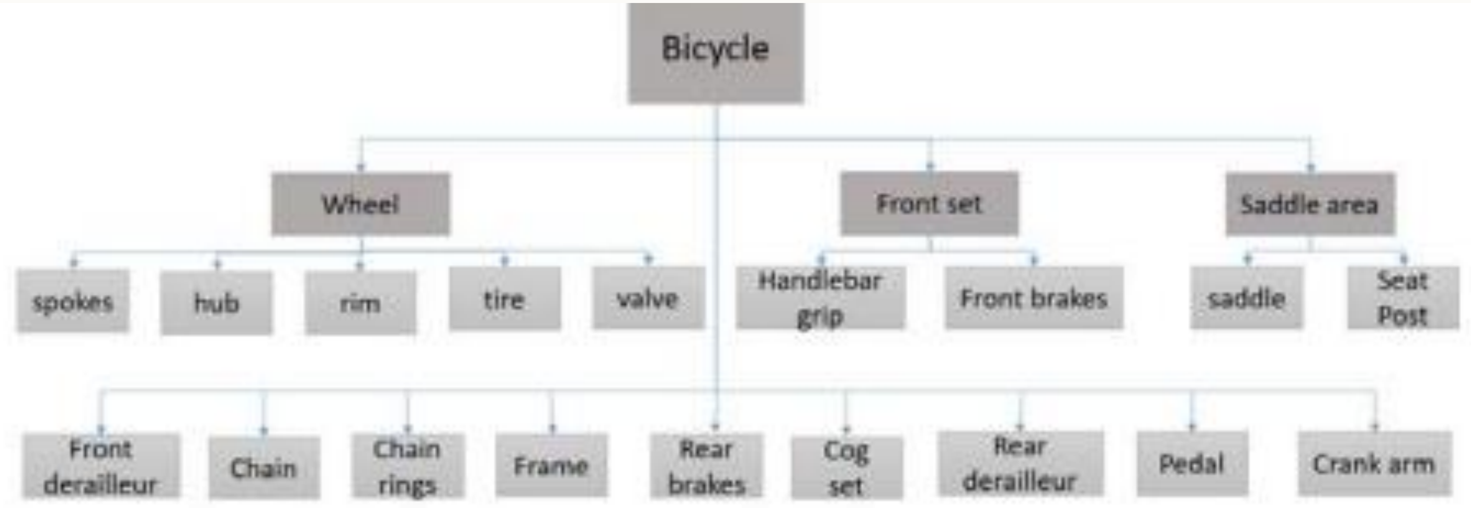


Fig. 5 Bill of Material of the Bicycle

Here, we need to know the **lead time** of **each** component, and the **number** of components that are required for end item.

MRP Process

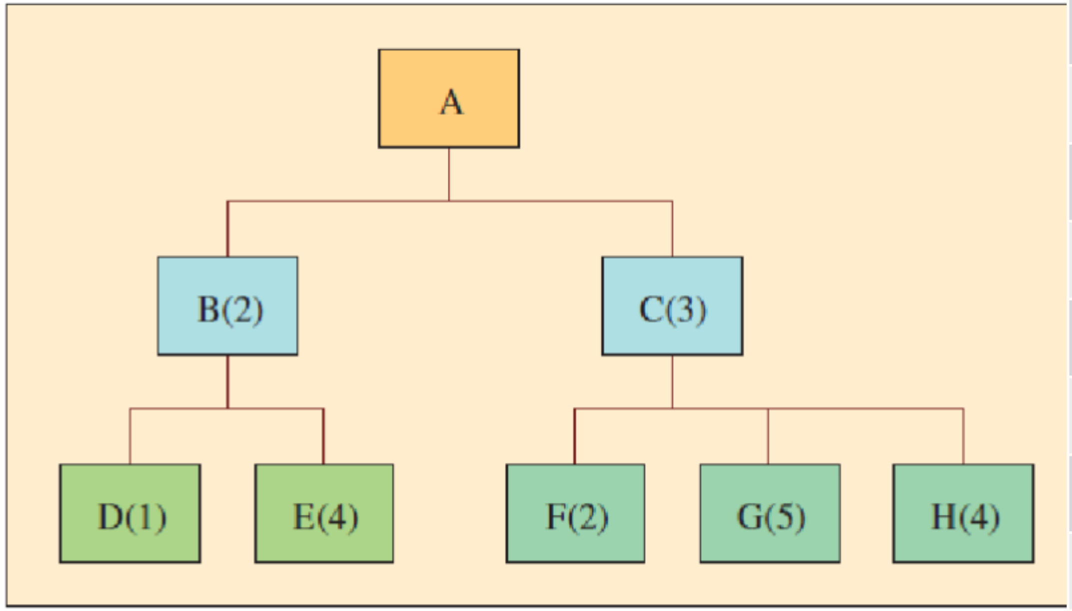
MRP Explosion Calculus

AKA the MRP netting process

Provides rules for translating the gross requirements at one level to produce schedule at that level and the requirements at lower levels

If we wanted to produce X units of A: we would need to work out how many units of B, and C are needed, & subsequently how many units of D, E, F, G, and H…

But not forgetting: Inventory records



Indented Parts List		
A		
	B(2)	
		D(1)
		E(4)
	C(3)	
		F(2)
		G(5)
		H(4)

MRP process

MRP Explosion Calculus

1. Convert Gross requirements into Net requirements

- Deduct any on-hand inventory
- Deduct scheduled receipts

2. Convert Net requirements into Time-phased net requirements

- Take lead time into account

3. Convert Time-phased Net requirements into Planned Order Release

- Calculate ending inventory

Proceed to the next level

- Planned order release at one level defines the gross requirements for the next level down

MRP Process

Lot sizing: Lot-for-lot

A Lot for Lot policy aims to minimise inventory & thus requires an order to be placed **each** period…

meaning that the number of orders is maximised across the period, and we incur the maximum order cost

…and every time we make an order, there is an associated fixed

If ordering cost is significant, we may want to combine multiple lots into one order, but this increases inventory holding cost

If we only order as much as is needed there will be no ending inventory… issues? Demand fluctuations? Supply fluctuations?

MRP Process

Lot sizing: Other policies

Sometimes it is not possible to use a Lot-for-lot (L4L) policy, minimum order quantity or quantities may be required in multiples of 50, 100…

So what can we do instead?

We can use EOQ

- Every time we are required to place an order, the lot size = EOQ

Choose the correct option that completes the sentence: MRP tells us…

A. How much to order and when to order it

B. How much to order and when to make it

C. How much inventory we should have at any point in the planning horizon

D. How much inventory we do have at any point in the planning horizon

0%	0%	0%	0%
A	B	C	D

MRP Worked Example

MRP Worked Example

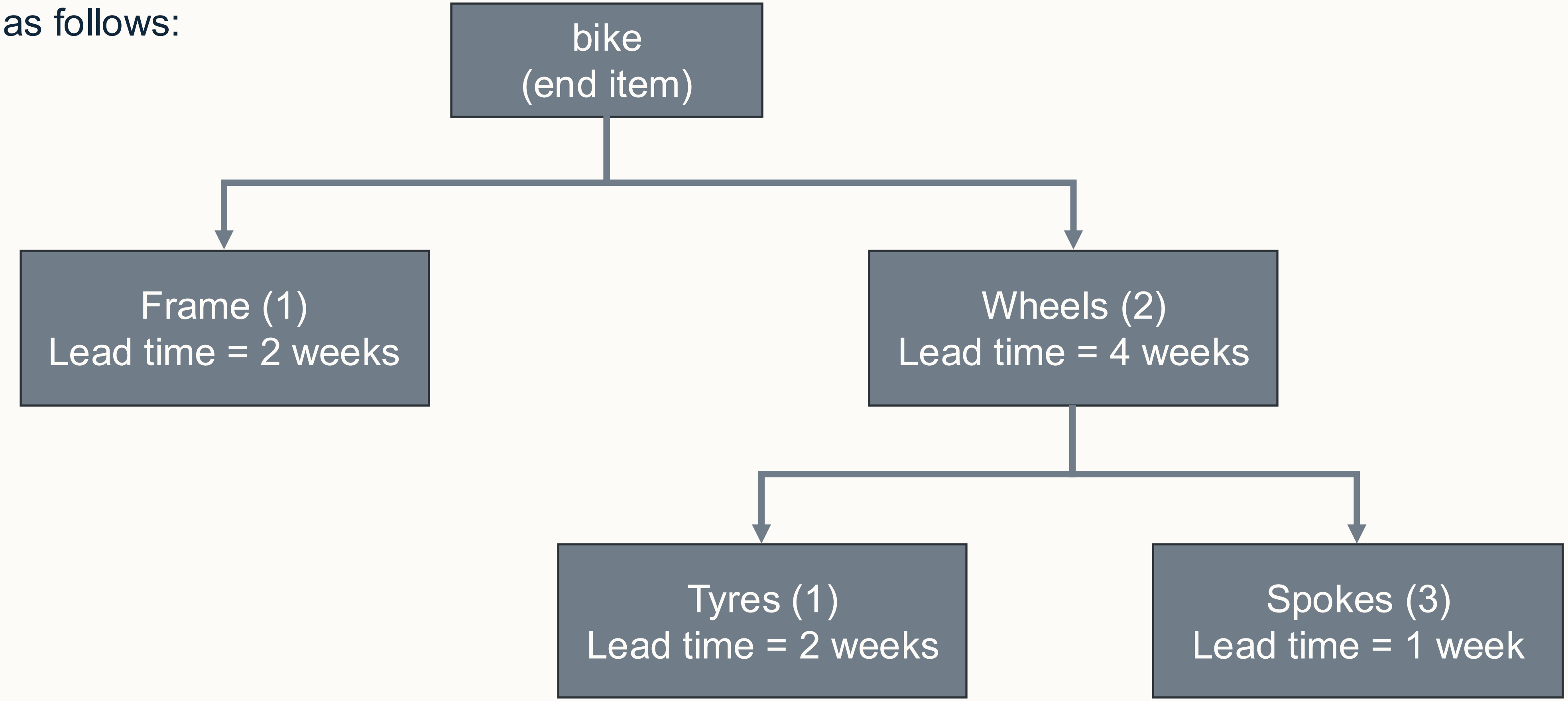
Explosion calculus example

Our simplified bike is comprised of the frame, wheels, tyres, and spokes

MRP Worked Example

Explosion calculus example

Our bill of materials (product structure) can be visualised as follows:



What is the lead time for our final item?

A. 11 weeks
B. 9 weeks
C. 7 weeks
D. 6 weeks

MRP Worked Example

Explosion calculus example

Suppose we have the following information for the bike, including gross requirements, lead time of 6 weeks, scheduled receipts and existing inventory

Week	6	7	8	9	10	11	12	13	14	15	16
Gross requirements		77	42	38	21	26	112	45	14	76	38
Scheduled receipts		12		6	9						
Inventory	23										

We have no additional information for the frame and wheels

We have inventory of 186 spokes at end of week 3 and scheduled receipts for 96 spokes at start of week 5.

Calculate planned order release for frame and spokes (assume lot for lot lotsizing).

MRP Worked Example

Explosion calculus example

Starting with our end item, Bike (A)

23 items in inventory
lead time of 6 weeks

1. Convert Gross requirements into Net requirements
- Deduct any on-hand inventory
- Deduct scheduled receipts

2. Convert Net requirements into Time-phased net requirements
- Take lead time into account

3. Convert Time-phased Net requirements into Planned Order Release
- Calculate ending inventory

Proceed to the next level
- Planned order release at one level defines the gross requirements for the next level down

Week	6	7	8	9	10	11	12	13	14	15	16
Gross requirements		77	42	38	21	26	112	45	14	76	38
Scheduled receipts		12		6	9						
Inventory	23										
Net requirement											

MRP Worked Example

Explosion calculus example

Next item: Frame (B)	
1 bike requires 1 frame	
no inventory	no scheduled receipts
lead time of 2 weeks	

1. Convert Gross requirements into Net requirements
- Deduct any on-hand inventory
- Deduct scheduled receipts

2. Convert Net requirements into Time-phased net requirements
- Take lead time into account

3. Convert Time-phased Net requirements into Planned Order Release
- Calculate ending inventory

Proceed to the next level
- Planned order release at one level defines the gross requirements for the next level down

Week	5	6	7	8	9	10	11	12	13	14	15	16
Net requirement (A)			42	42	32	12	26	112	45	14	76	38
Gross requirement (B)			42	42	32	12	26	112	45	14	76	38
Net requirement (B)			42	42	32	12	26	112	45	14	76	38
Time Phased Net requirement (B)	**42**	**42**	**32**	**12**	**26**	**112**	**45**	**14**	**76**	**38**		
Planned order release (B)	**42**	**42**	**32**	**12**	**26**	**112**	**45**	**14**	**76**	**38**		

MRP Worked Example

Explosion calculus example

Next item: Wheels (C)

1 bike requires 2 wheels

no inventory | no scheduled receipts

lead time of 4 weeks

1. Convert Gross requirements into Net requirements
- Deduct any on-hand inventory
- Deduct scheduled receipts

2. Convert Net requirements into Time-phased net requirements
- Take lead time into account

3. Convert Time-phased Net requirements into Planned Order Release
- Calculate ending inventory

Proceed to the next level
- Planned order release at one level defines the gross requirements for the next level down

Week	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Net requirement (A)					42	42	32	12	26	112	45	14	76	38
Gross requirement (C)					42	42	32	12	26	112	45	14	76	38
Net requirement (C)					84	84	64	24	52	224	90	28	152	76
Time Phased Net requirement (C)	**84**	**84**	**64**	**24**	**52**	**224**	**28**	**28**	**152**	**76**				
Planned order release (C)	**84**	**84**	**64**	**24**	**52**	**224**	**28**	**28**	**152**	**76**				

MRP Worked Example

1. Convert Gross requirements into Net requirements
- Deduct any on-hand inventory
- Deduct scheduled receipts

2. Convert Net requirements into Time-phased net requirements
- Take lead time into account

3. Convert Time-phased Net requirements into Planned Order Release
- Calculate ending inventory

Proceed to the next level
- Planned order release at one level defines the gross requirements for the next level down

Explosion calculus example

Next item: Spokes (D) | 1 wheel requires 3 spokes

Inventory: 186 units week3 | Receipt of 96 units in week 5

lead time of 1 week

Week	2	3	4	5	7	8	9	10	11	12	13
Net requirement (C)		**84**	**84**	**64**	**24**	**52**	**224**	**90**	**28**	**152**	**76**
Gross requirement (D)		84*3 = 252	84*3 = 252	64*3 = 192	24*3 = 72	52*3 = 156	224*3= 672	90*3 = 270	28*3 = 84	152*3 = 456	76*3 = 228
Scheduled Receipts (D)			96								
Inventory	186	0	96	0							
Net requirement (D)	0	252-186= 66	252-96 = 156	192	72	156	672	270	84	456	228
Time Phased Net requirement (D)	**66**	**156**	**192**	**72**	**156**	**672**	**270**	**84**	**456**	**228**	
Planned order release (D)	**66**	**156**	**192**	**72**	**156**	**672**	**270**	**84**	**456**	**228**	

MRP Worked Example

Lot-for-lot

Let's look at planned order release for component B, the frame

For which fixed order cost = £132 and holding cost is £0.60 per unit per week

Week	6	7	8	9	10	11	12	13	14	15
Planned order release (B)	42	42	32	12	26	112	45	14	76	38

Under the Lot-for-lot policy: *lot size = planned order release for the period*

We are keeping no inventory

Thus, our cost = £132 *10 = £1320

Number of orders placed

Fixed order cost

MRP Worked Example

EOQ

Our fixed order cost = £132 and holding cost is £0.60 per unit per week

Average demand per week: $\lambda = \frac{439}{10} = 43.9$

Week	6	7	8	9	10	11	12	13	14	15
Time phased net requirement (B)	42	42	32	12	26	112	45	14	76	38
EOQ (B)	139	0			139	0	139	0	0	139
Inventory (B)	139-42 = **97**	97-42= **55**	55-32=**23**	23-12 = **11**	139 +11-26 =**124**	124 - 112 = **12**	139+12 - 45 = **106**	**92**	**16**	**117**

Thus, cost = £132 *4 + £0.6*653 = **£919.8**

Inventory holding cost

Number of units in inventory

Lot sizing

EOQ

EOQ is not the best approach for determining lot size, in this example and more generally…

…because EOQ assumes demand is constant, but in this example, demand appears to fluctuate

For time-varying, known demand other approaches include:
Silver-Meal heuristic, Least Unit Cost heuristic, Part Period Balancing heuristic, Wagner-Whitin (Optimal procedure)

General idea: balance / trade-off setup costs and holding costs

Capacity Constraints

Capacity constraints

We might also have constraints on…

Production quantities

Capacity

The ending inventory of order period typically not zero!

Capacity fluctuates, if capacity is low, we need to ensure that we can meet demand across all periods

Capacity constraints

Feasibility check

We can check for **feasibility**: using checking the cumulative demand and cumulative capacity

- If for every period, the cumulative capacity is larger or equal to the cumulative demand then there is a feasible solution

- Else, if there is a period in which cumulative capacity is smaller than the cumulative demand, there will be a shortage and therefore no feasible solution

- Mathematically we can write this as:

$$\sum_{i=1}^{j} c_i \geq \sum_{i=1}^{i} d_i \quad \text{for } 1 \leq j \leq n$$

c_i is the capacity for period i and d_i is the demand for period i

Capacity constraints

Lot shifting

A technique that constructs a feasible production plan IF one exists, otherwise demonstrates that there is no feasible solution

Loft shifting is a heuristic: the production plan obtained through this technique is not necessarily optimal

Steps of loft shifting method:

- Find the first period with capacity less than demand
- If possible, backshift the excess capacity to previous periods
- If not possible to backshift the excess, then stop, there is no feasible solution

Capacity constraints

Lot shifting

- Example: Find a feasible production plan for the following demand and capacity information

Week	1	2	3	4	5	6	7	8	9
d_i	100	79	230	105	3	10	99	126	40
c_i	120	200	200	400	300	50	120	50	30

Capacity constraints

Lot shifting

- First let's check for a feasible plan

Recall,

$\sum_{i=1}^{j} c_i \geq \sum_{i=1}^{i} d_i \quad$ for $1 \leq j \leq n$

Here,

$$\sum_{i=1}^{j} c_i = 1470 \geq \sum_{i=1}^{i} d_i = 792$$

Therefore, a feasible plan exists

Week	1	2	3	4	5	6	7	8	9
d_i	100	79	230	105	3	10	99	126	40
c_i	120	200	200	400	300	50	120	50	30
d'_i	100	79	230	105	3	10	99	136	30
d'_i	100	79	230	105	3	10	185	50	30
d'_i	100	79	230	105	3	75	120	50	30
d'_i	100	79	230	105	28	50	120	50	30
d'_i	100	109	200	105	28	50	120	50	30
Inv	0	30	0	0	25	65	86	10	0

The lot shifting procedure will always identify a feasible plan, but it may not always be optimal!

Capacity constraints

Improvement procedure

- Based on a loft-shifted plan, we can find an improved plan:
  - ➢Start with the last period and work backwards
  - ➢Back-shift entire demand to period with enough capacity **IF** additional holding cost is less than setup/ordering cost

Capacity constraints

Improved procedure

- Lot shifting gives the following plan:

Month	Demand	Capacity	Excess
June	13	30	30-13=17
July	13	13	0
August	13	13	0
September	16	17	1

- If fixed cost K = £50

  and holding cost h = £2 per unit per month,

  can we improve this plan?

- Start at the end (Sept) should we back-shift Sept to June (enough capacity)?
  - Additional holding cost would be: 16*2*3 = £96 > £50 No!
- August? Additional holding cost = 13*2*2 = £50 > £50, no
- July? Additional holding cost = 13*2*1 = £26 < £50 – yes back-shift July production to June

Capacity constraints

Final remarks

- Other approaches include:
- Silver-Meal heuristic, Least Unit Cost heuristic, Part Period Balancing heuristic, Wagner-Whitin (Optimal procedure)
- Useful when demand is known, but varies with time

Complete the sentence: I am…

A. Very confident that I could calculate planned order release for MRP
B. Confident that I could calculate planned order release for MRP
C. Somewhat confident that I could calculate planned order release for MRP
D. Not confident that I could calculate planned order release for MRP

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Thank you

Any questions?

Silver Meal Heuristic

Additional Online Content

Silver Meal Heuristic

- **Aim**: to determine the production quantities necessary to meet the requirements at minimal cost
- Forward method works by determining the average cost per period as a function of the number of periods the current order spans
- Formula is given by:

$$C(j) = (K + hd_2 + 2hd_3 + \cdots + (j-1)hd_j)/j$$

Where C(j) = average holding and set up cost **per period**

K = order or set up cost

h = holding cost

d = demand

Silver Meal Heuristic

- Step One: Start calculation at period 1
  - C(1) = K
  - C(2) = $(K + hd_2)/2$
  - C(3) = $(K + hd_2 + 2hd_3)/3$

- Step Two: Stop the calculation when C(j) > C(j-1)

- Step 3: Set $y_1 = d_1 + d_2 + \ ... + d_{j-1}$