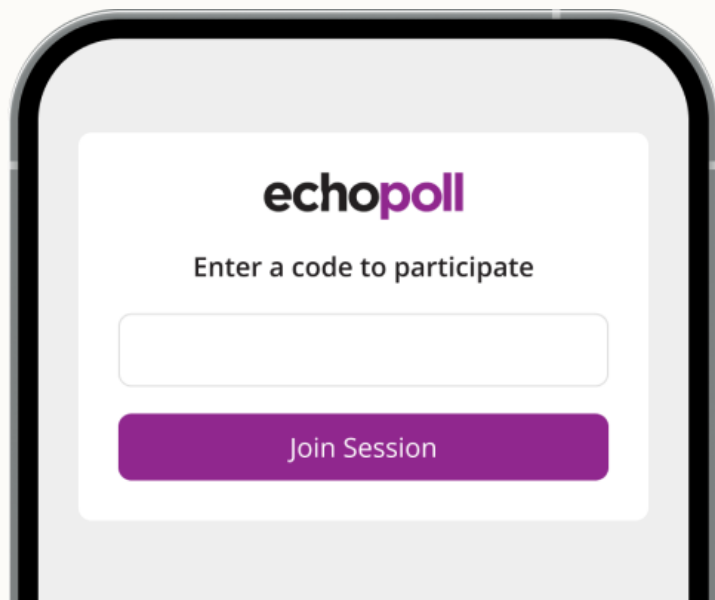




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BUSI4496 Supply Chain Planning and Management

Material Requirements Planning

Dr Ursula Davis



Attendance

608802





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

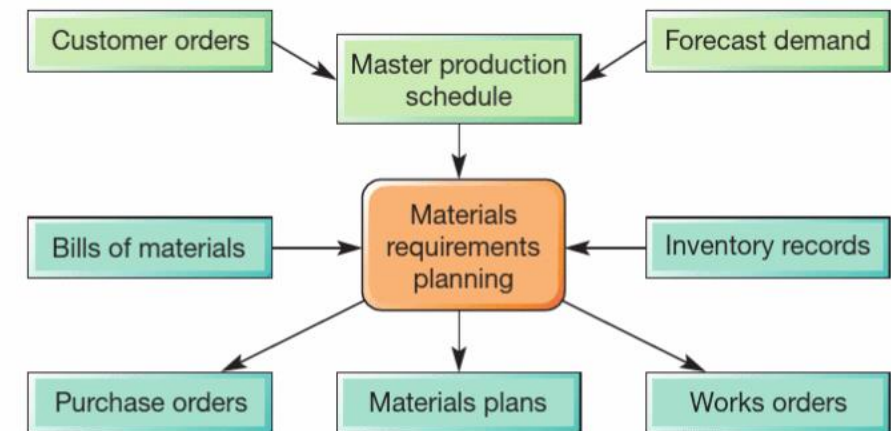


Figure 14.9 Materials requirements planning (MRP) schematic

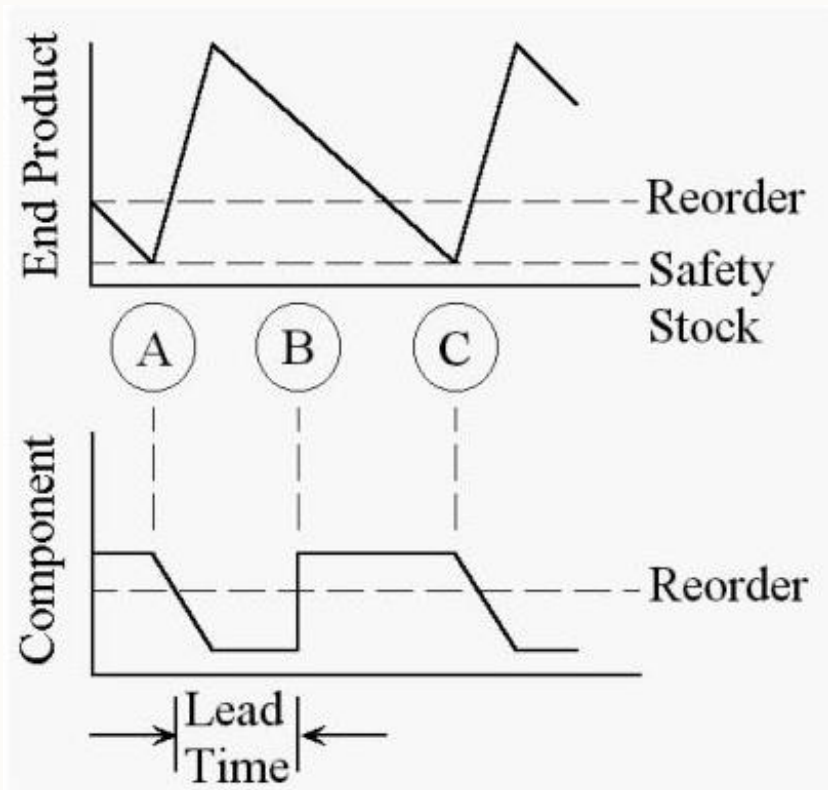
(Slack et al 2022)



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

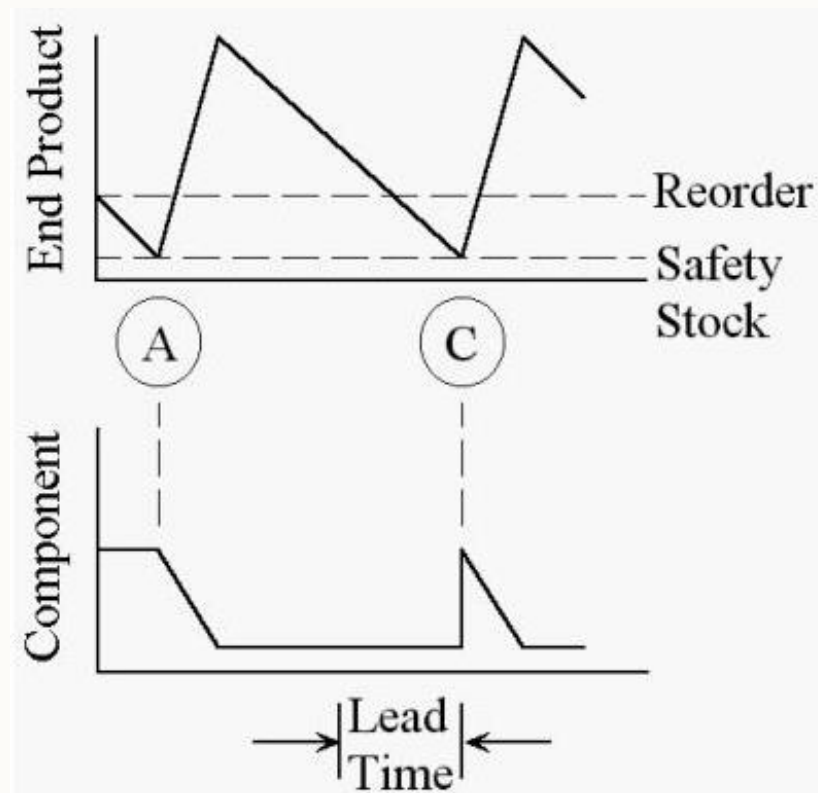


Intro to MRP

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)**



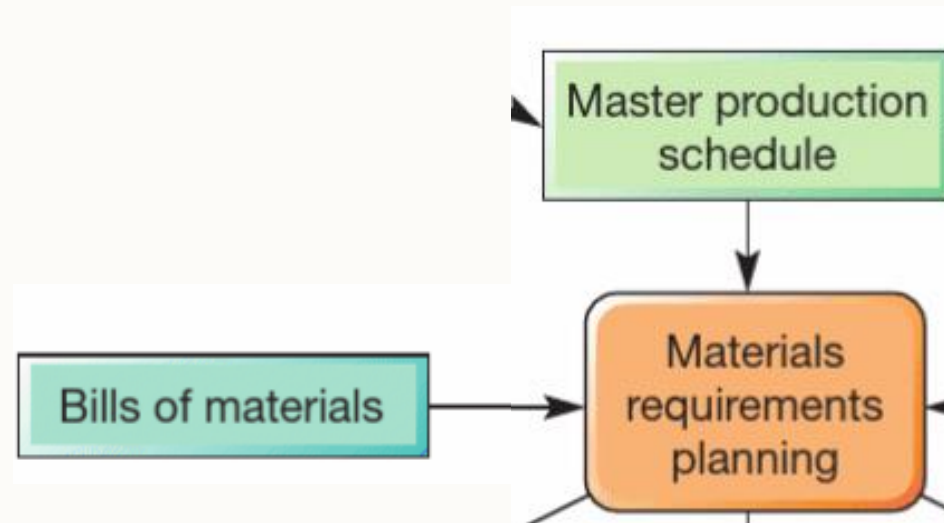
MPS contains a statement of the volume (how much) and timing (when) of the end products to be made

- 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?

ice fishing
swimming hiking
bungee jumping
weight lifting
video games
rock climbing
running kayaking jogging



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

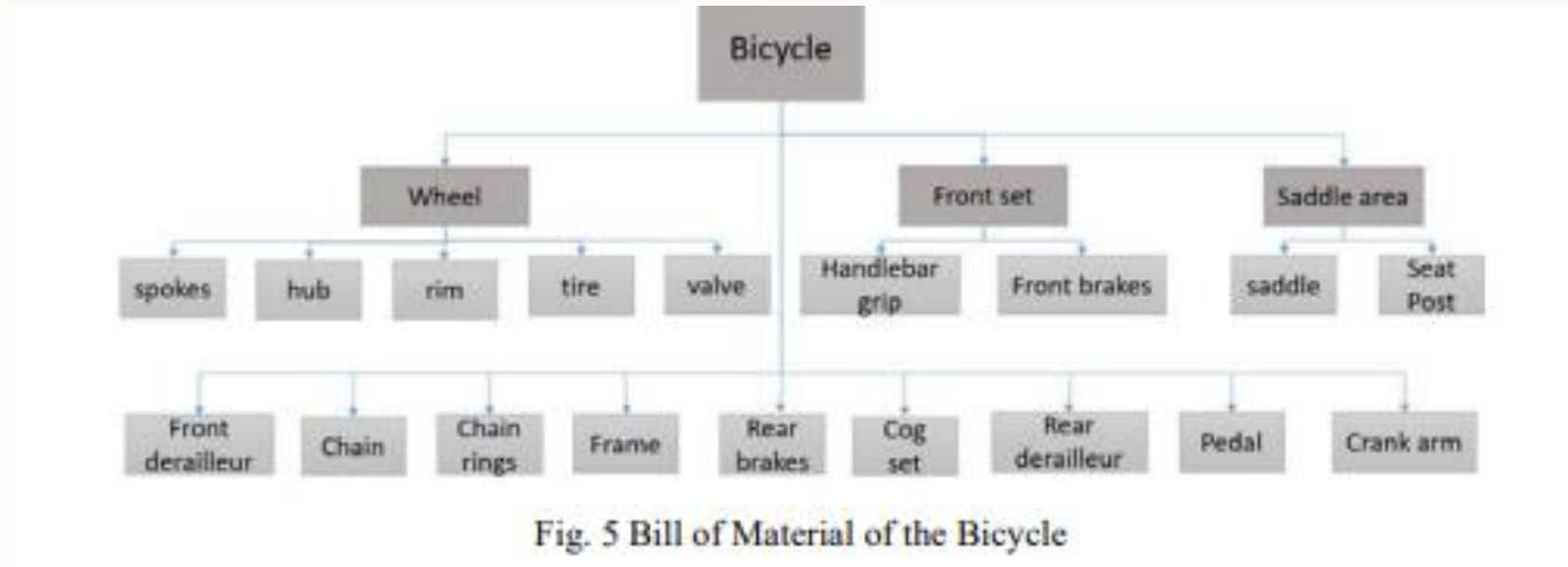
Rear derailleur
Cog set
Rear brakes

Front derailleur
Chain
Chain rings



Intro to MRP

Bill of materials



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 process

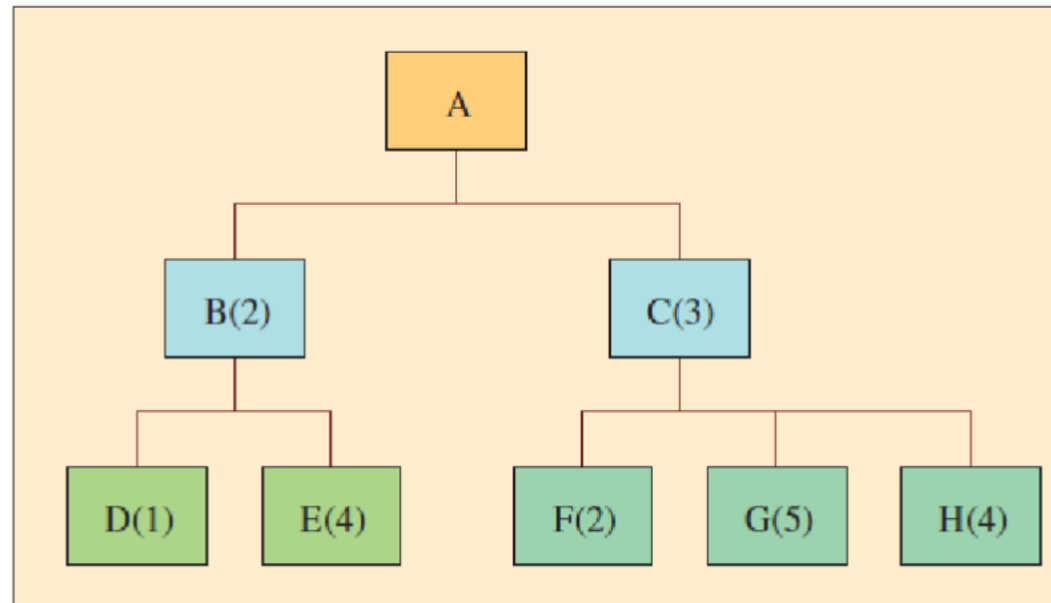
MRP Explosion Calculus

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%

A

0%

B

0%

C

0%

D



Enter question text here...

- A. Enter answer text here...
- B. Enter answer text here...
- C. Enter answer text here...
- D. Enter answer text here...





MRP Worked Example



MRP Worked Example

Explosion calculus example



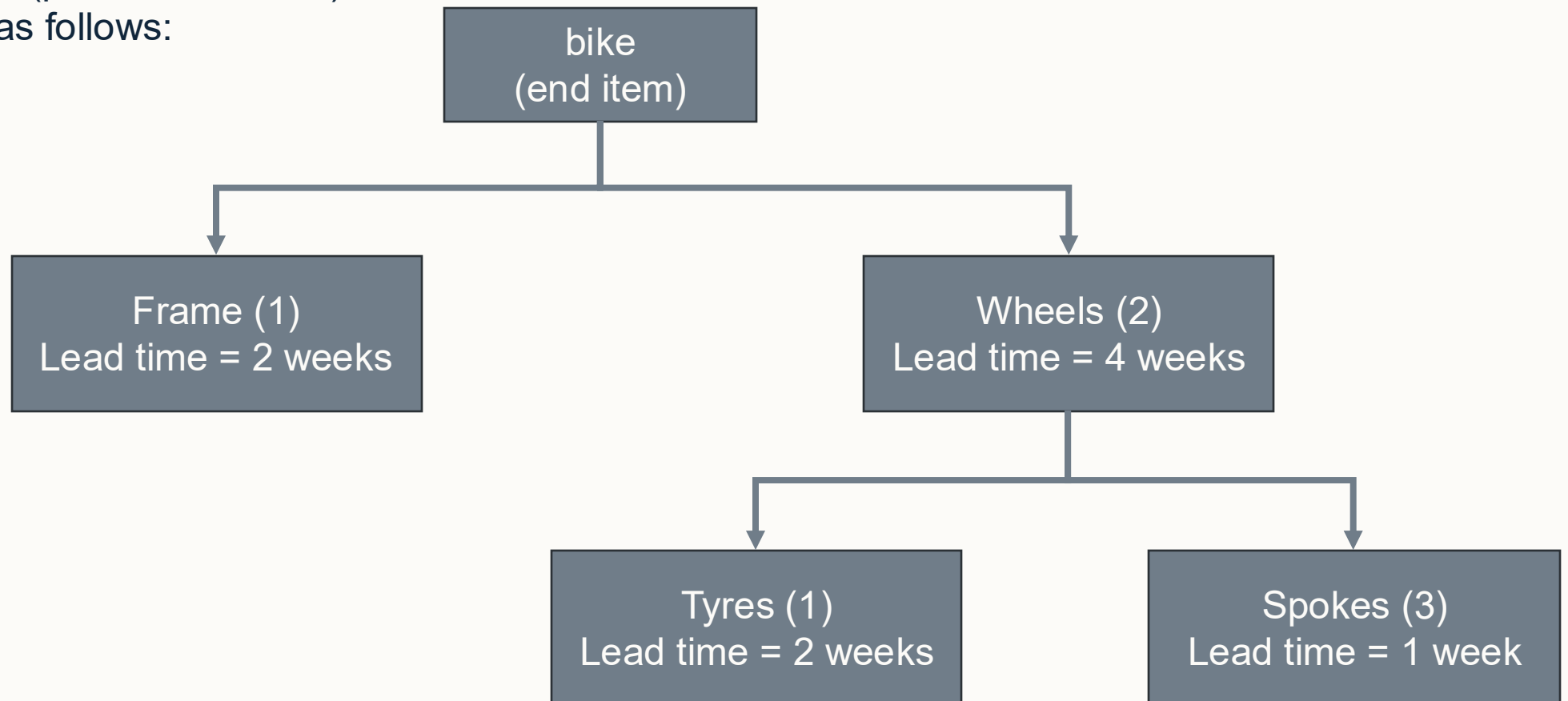
Our simplified bike is comprised of the frame, wheels, tyres, and spokes



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 7 weeks, scheduled receipts and existing inventory

Week	7	8	9	10	11	12	13	14	15	16	17
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 7 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	7	8	9	10	11	12	13	14	15	16	17
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	6	7	8	9	10	11	12	13	14	15	16	17
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)												
Planned order release (B)												



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	4	5	6	7	8	9	10	11	12	13	14	15	16	17
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)														
Planned order release (C)														

Handwritten annotations in red:

- Arrows pointing from week 8 to 5, week 9 to 6, week 10 to 7, week 11 to 8, week 12 to 9, week 13 to 10, week 14 to 11, week 15 to 12, week 16 to 13, week 17 to 14.
- Values written in red: 64, 24, 52, 24, 90, 28, 152, 76.



MRP Worked Example

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

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
Net requirement (C)		84	84	64	24	52	224	90	28	152	76
Gross requirement (D)		$84 \times 3 = 252$	$84 \times 3 = 252$	$64 \times 3 = 192$	$24 \times 3 = 72$	$52 \times 3 = 156$	$224 \times 3 = 672$	$90 \times 3 = 270$	$28 \times 3 = 84$	$152 \times 3 = 456$	$76 \times 3 = 228$
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

Fixed order cost

Number of orders placed



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)										
Inventory (B)										

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:

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

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

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





Capacity constraints

Lot shifting

- First let's check for a feasible plan

Recall,

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

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

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



Capacity constraints

Improvement procedure

- Based on a left-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?