Materials Requirement Planning (MRP) & Lean Manufacturing

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Objectives for Today

- Understand the difference between “push” and “pull” systems of production
- Describe the elements of a Materials Requirements Planning (MRP) system
- Understand some of the problems with MRP systems
- Describe the Toyota Production System (TPS)
- Understand the principles and tools of Just-in-Time (JIT) scheduling and lean production

Scheduling Problems

- General question now: how to calculate ***time-phased requirements***?
- This is different from ***consumption-based methods***, such as Reorder Point (ROP)

N=1 Project management

N= low volume, high variety – Job shop

- Single machine (Moore's algorithm)
- Sequential machines (Johnson's rule)
- Parallel machines

N= high volume / batch production, standard products with options

- MRP (Push)
- JIT (Pull)

N= very high volume, few or no variants

- Control theory

Some Key Questions

- How to organise the manufacturing of a complex product?
- How much raw material/parts should I order to keep production running?
- When should I be ordering raw material/parts in order to keep production running?
- What are pull vs. push planning systems?
- Under what conditions is pull vs. push most appropriate?

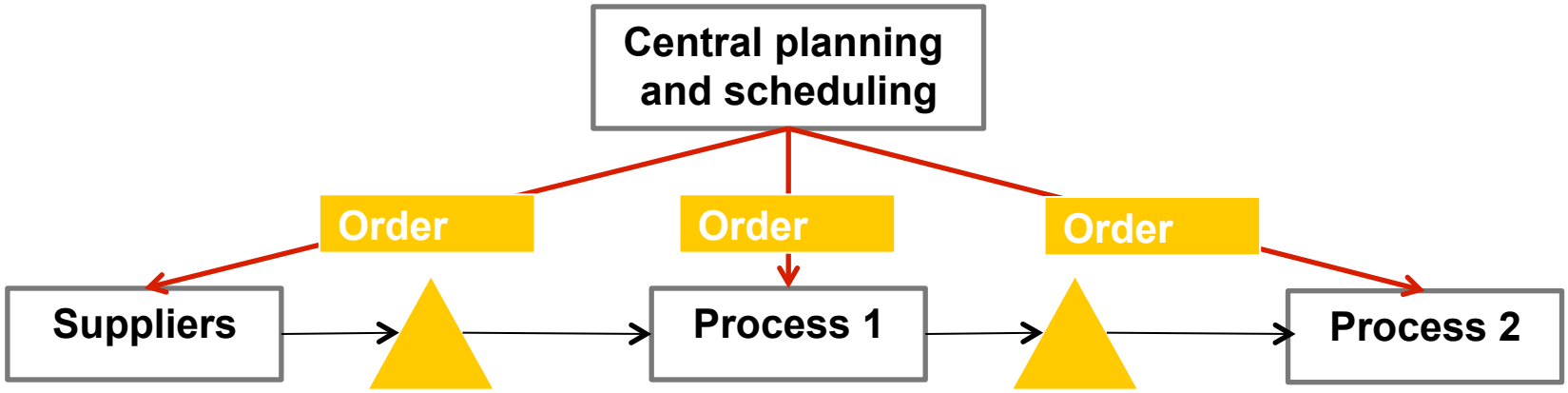
Materials Requirement Planning (MRP)

Requirements Planning?

You want to hold a party in two week's time and expect 100 people to attend. You are going to cook some of the food to be served and you only have two hot plates. How do you plan for this? What to do? When to do it? What do you need? How much to prepare?

- What is needed? Beer, Wine, Food, Snacks, Music, Movies,…
- How much is needed of each? Consider cooked food: ingredients....
- What do you already have at home?
- What is your current workload? Major project, Production game prep, Supervisions....
- Can some items be made early and frozen?
- Will some items have to be prepared fresh (salad?)
- When should you buy each of these?
- Do you have all the equipment? E.g. Need to borrow a powerful sound system? When?
- Need to rent DVDs?
- Need to increase credit limit on your card, when to call the bank?
- When do you invite your friends?!

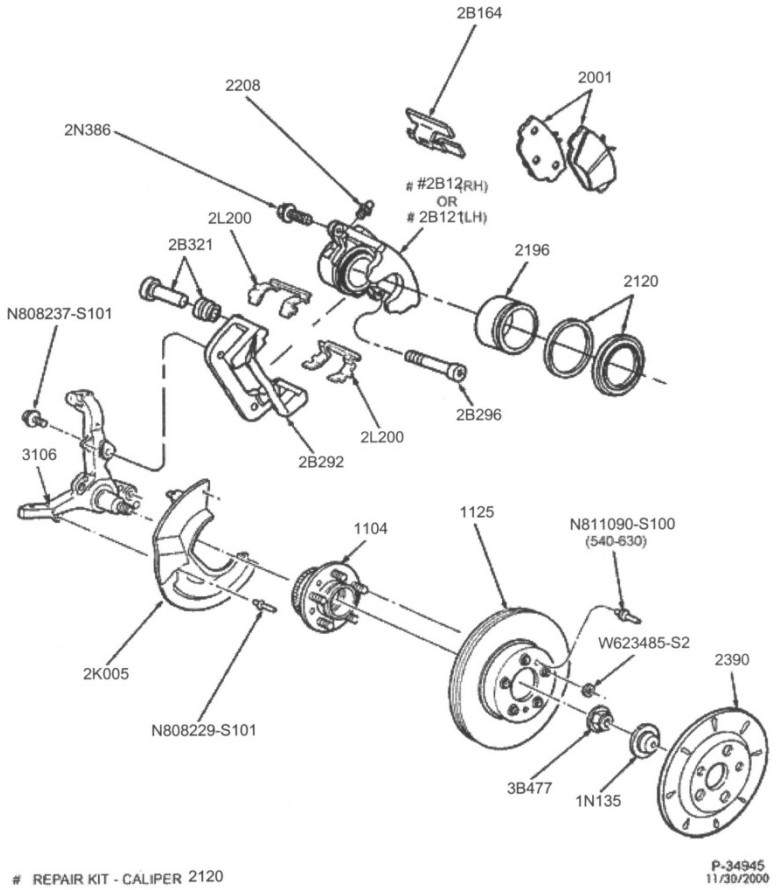
“Push” Scheduling



- In a **push** system, the orders are planned and issued centrally
- Upon completion, the order is moved forward, until the next process is issued with the order start processing it
- Hence, the **longest time** process sees the new order **first**
- This is called **backward** scheduling

MRP

- If you have a number of products, when should we make each component of each product, and when should we re-order raw materials or parts?
- EOQ calculation assumed constant rate of demand for products throughout the year. But:
  - Demand may be “seasonal” or “lumpy”
  - Even if demand for product is constant, if different products have common components, the demand for the components may be lumpy
- We need a systematic approach to plan production & ordering

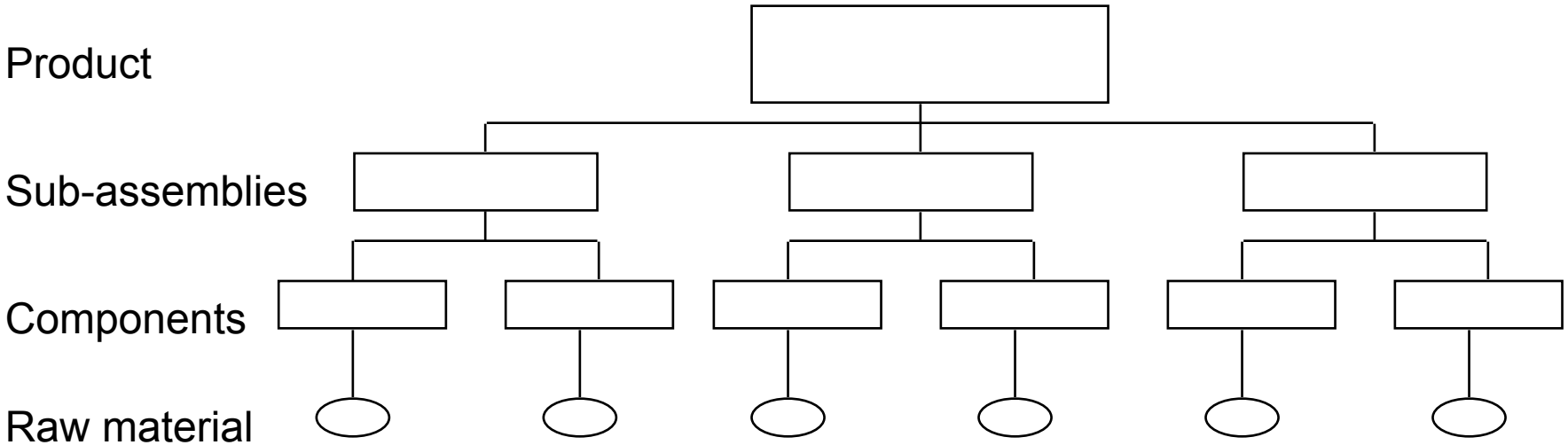


MRP

- MRP system were invented in 60s to cope with computational complexity of scheduling
  - Need to plan at top level item, for all items made in the plant
  - What happens if components are used in several final products?
- Computerised inventory control and production planning system
- Schedules component items and processes when needs – no earlier and no later

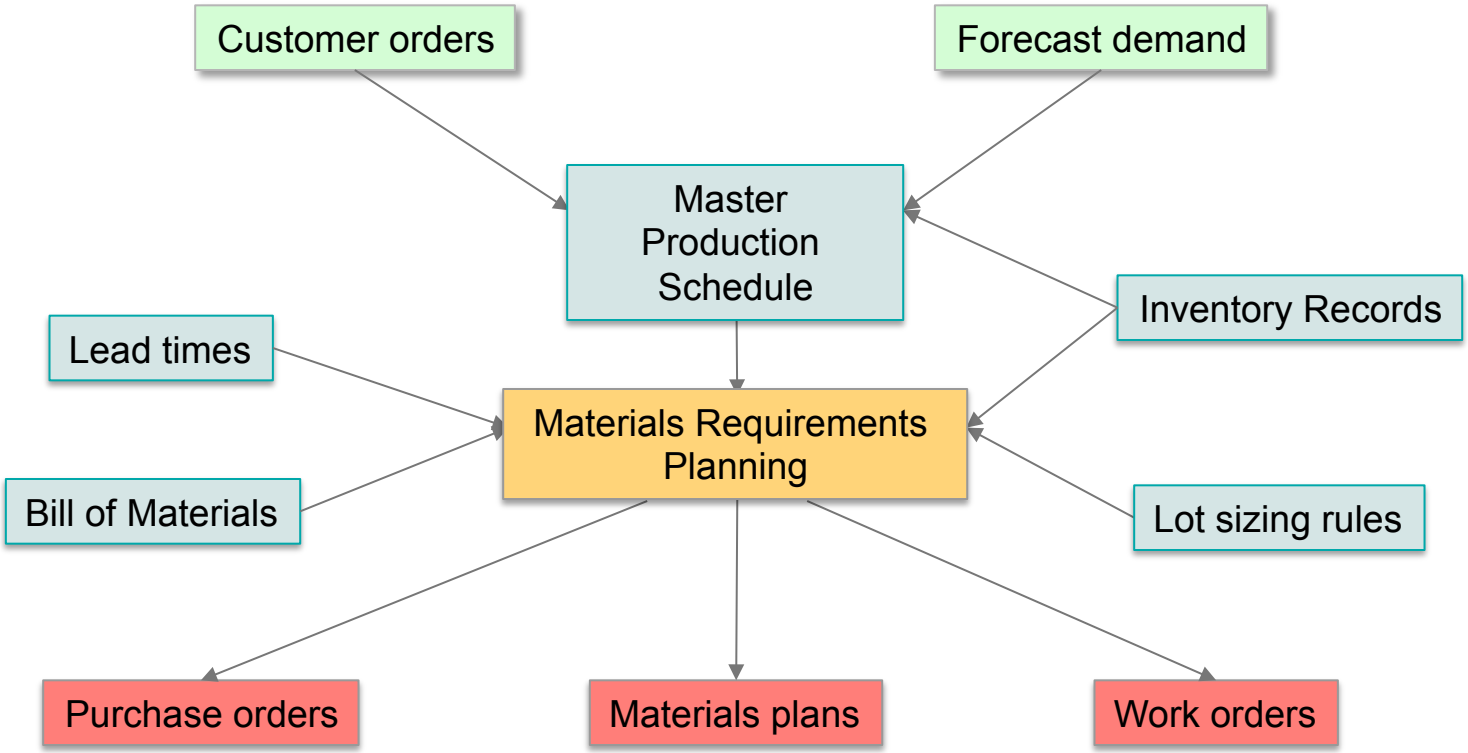
MRP: The Concept

From what you **expect** to sell …



Calculate what you need to get & do

MRP: Outline


Customer orders
Forecast demand
Master Production Schedule
Inventory Records
Lead times
Materials Requirements Planning
Bill of Materials
Lot sizing rules
Purchase orders
Materials plans
Work orders

Input: Master Production "Schedule"

"an attainable, overall build plan at the end item level that states

- what items are to be made,
- how many are to be made,
- and when they are to be made

over the planning horizon by period."

Future product requirements are calculated from existing orders and sales forecasts.

NB This is a **gross** schedule different to the **daily/hourly** scheduling of jobs onto machines covered in Lecture 4.

Example of MPS

Chase demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)										
MPS										
On hand inventory	30									

Example of MPS

Chase demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)										
MPS										
On hand inventory	**30**									

Example of MPS

Chase demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)		20	10	0	0	0	0	0	0	0
MPS										
On hand inventory	**30**									

Example of MPS

Chase demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)		20	10	0	0	0	0	0	0	0
MPS		0	0	0	10	15	15	15	20	20
On hand inventory	30									

Example of MPS

Level demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)										
MPS										
On hand inventory	30									

Example of MPS

Level demand production plan?

Total demand = 125

Total requirement = 125-30 = 95

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)										
MPS										
On hand inventory	30									

Example of MPS

Level demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)										
MPS		11	11	11	11	11	11	11	11	11
On hand inventory	30									

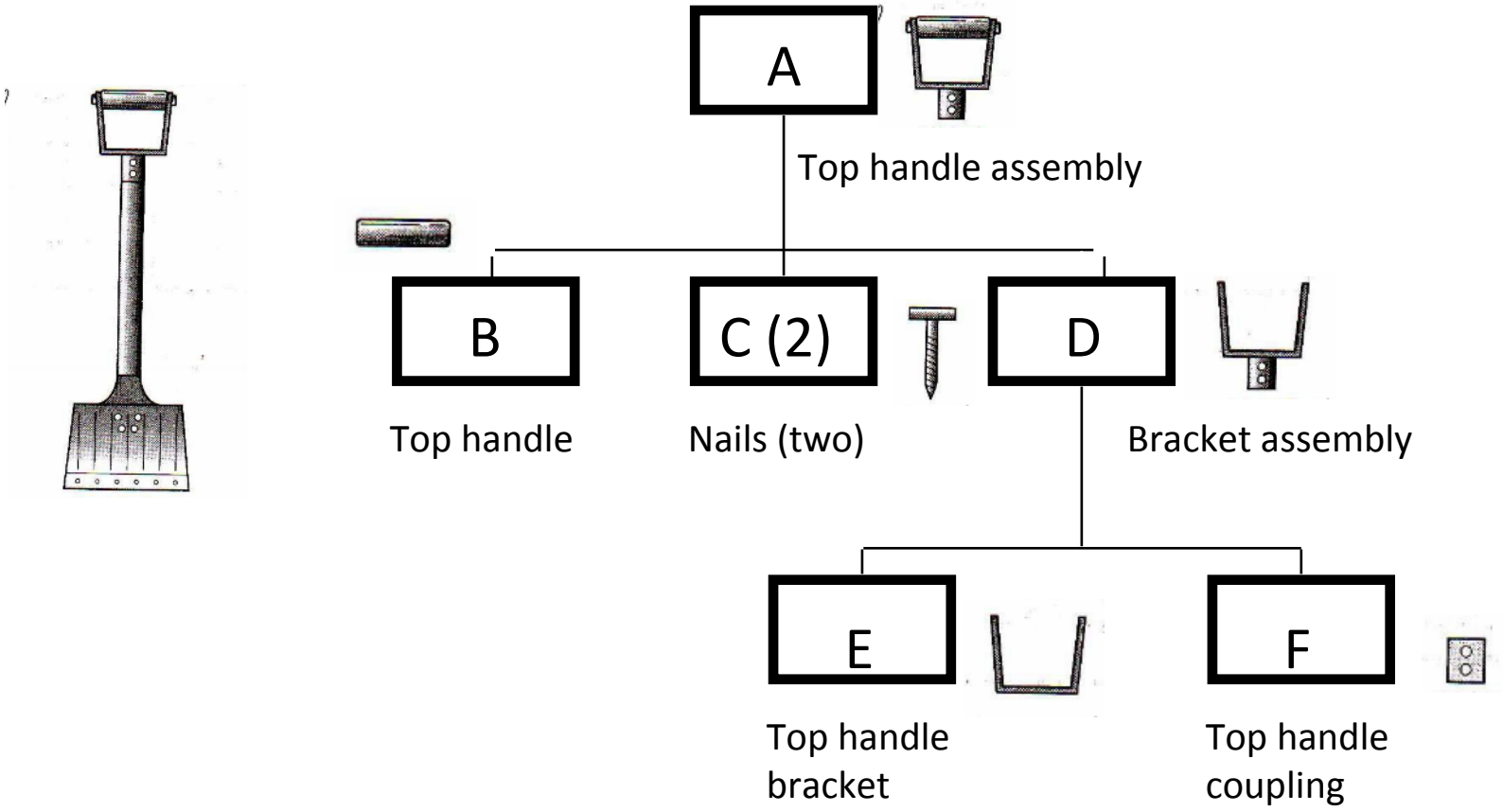
Example of MPS

Level demand production plan?

		Week number								
		1	2	3	4	5	6	7	8	9
Demand		10	10	10	10	15	15	15	20	20
Available (at end of week)		31	32	33	34	30	26	22	13	4
MPS		11	11	11	11	11	11	11	11	11
On hand inventory	30									

MRP Input: Bill of Materials

The bill of materials simply gives a component breakdown of the product e.g., Top handle assembly of a snow shovel



Thus knowledge of the MPS and the BOM allows “explosion of requirements” for each component and each raw material item

MRP Calculations

Outline

- INPUTS: MRP requires five types of information:
  - Master Production Schedule – a complete list of the volume and due dates of all expected product sales
  - Bill of Material File – design information relating products to components – usually expressed in hierarchical form
  - Inventory Record File – a record of current stocks
  - Lead times – prediction of how long it will take to complete each task
  - Lot sizing rules – to determine the size of batch to be ordered

- OUTPUTS: From these, MRP packages calculate
  - Material requirements plans –
    - Gross: the total requirements for each component and raw material item
    - Net: the shortfall between current inventory and gross requirements
  - Also Purchase Orders, Work Orders are generated

Components of an MRP Record

- **Gross Requirements** – Total independent and dependent demand, before netting on-hand inventory and scheduled receipts
- **Scheduled Receipts** – Production orders and purchase orders that have already been released
  - On their due date, they will be added to the projected available balance
  - Scheduled receipts are not altered automatically by the MRP system, and are not exploded into requirements for components.
- **Projected Available Balance** – on-hand inventory, projected into the future
- **Planned Order Release** – a suggested order quantity, release date and due date created by the MRP system
  - Planned orders at one level of the bill of material will be exploded into gross requirements for components at the next lower level
- [Net Requirements - Gross requirements less available inventory]

The Basic MRP Record

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance	15	*15*	*5*	*40*	*40*	*45*	*45*	*5*	*0*
Net Requirements		*0*	*0*	*10*	*0*	*0*	*0*	*35*	*5*
Planned Order Release			*?*				*?*	*?*	

Need to calculate this

Gross Requirements

- Found from the MPS phased into time “buckets”

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		10	20		10		40	5

Net Requirements

- Calculated from gross requirements, accounting for existing stock and existing scheduled receipts

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance (15 at start)	15	15	5			5	5		
Net Requirements				10				35	5

$$NR_i = \max \{0, GR_i - PAB_{i-1} - SR_i \}$$
$$PAB_i = \max \{0, PAB_{i-1} - GR_i + SR_i \}$$

Planned Order Releases

- Lead time and lot sizing rule dictate Planned Order Release

Lead Time = 1 period / Lot-sizing rule: Lot-for-lot

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance (15 at start)	15	15	5			5	5		
Net Requirements				10				35	5
Planned Order Release									

Planned Order Releases

- Lead time and lot sizing rule dictate Planned Order Release

Lead Time = 1 period / Lot-sizing rule: Lot-for-lot

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance (15 at start)	15	15	5			5	5		
Net Requirements				10				35	5
Planned Order Release			10				35	5	

Planned Order Releases

- Lead time and lot sizing rule dictate Planned Order Release

Lead Time = 1 period / Lot-sizing rule: EOQ = 50

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance (15 at start)	15	15	5			5	5		
Net Requirements				10				35	5
Planned Order Release									

Planned Order Releases

- Lead time and lot sizing rule dictate Planned Order Release

Lead Time = 1 period / Lot-sizing rule: EOQ = 50

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance (15 at start)	15	15	5						
Net Requirements				10					
Planned Order Release			50						

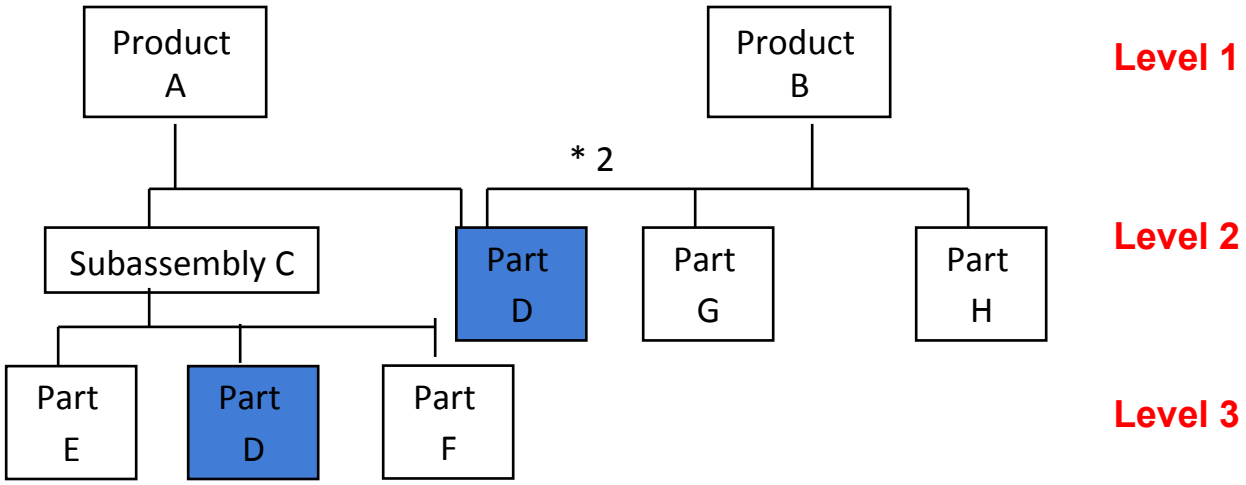
Planned Order Releases

- Lead time and lot sizing rule dictate Planned Order Release

Lead Time = 1 period / Lot-sizing rule: EOQ = 50

Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
Projected Available Balance (15 at start)	15	15	5	40	40	45	45	5	0
Net Requirements				10					
Planned Order Release			50						

Exploding the BOM

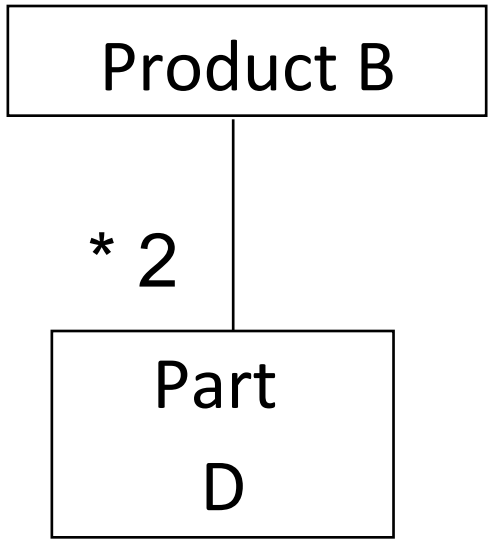


Total Demand for Part D = Demand for Product A

+ 2 Demand for Product B*

+ Demand for Subassembly C

Consider a Simpler BOM



Level 1

Level 2

Planned Order Release Across Levels

The effect of lead times is to shift forwards the planned order release. Assuming a lead time of one period, we have:

Comp B @ Level 1

Period		1	2	3	4	5	6	7	8
Gross Requirements			10	20		10		40	5
Scheduled Receipts				5		15			
PAB (15 at start)	15								
Net Requirements									
Planned order releases			10				35	5	

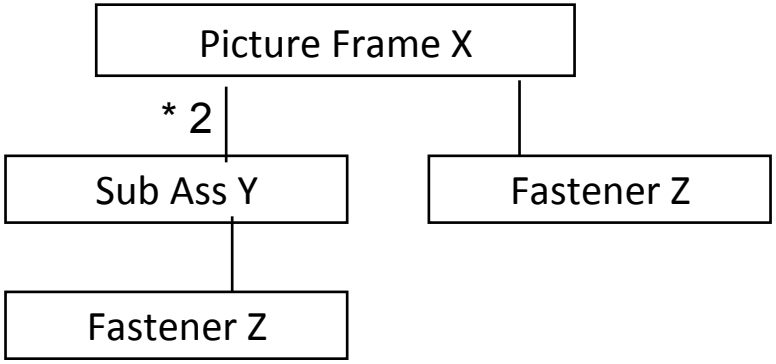
Assume that each component B at level 1 requires two components D at level 2 of the BOM,

Comp D @ Level 2

Period		1	2	3	4	5	6	7	8
Gross Requirements		0	20	0	0	0	70	10	0
Scheduled Receipts				10					
PAB (4 at start)	4	4	0	10	10	10			
Net Requirements			16				60	10	

Another Example

- The Acme Picture Frame Co. wants to make 30 picture frames per week with the following product structure (indented bill of materials):



- The company currently has 30 Picture Frames, 120 Subassemblies, and 70 Fasteners on hand
- There are two scheduled receipts: an order for 100 Subassemblies to arrive at the beginning of week 2, and an order of 70 Fasteners to arrive at the beginning of week 3.
- The lead time for Picture Frames is 1 week, with an EOQ of 45
- The lead time for Subassemblies is 2 weeks, with an EOQ of 70
- The lead time for Fasteners is 1 week, and are ordered on a lot-for-lot basis

Construct the MRP records for parts X, Y, and Z for the next six weeks

Completing the MRP Record

Part X; Lead Time = 1 week
Lot-sizing rule: EOQ (45)

Period	**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements	30	30	30	30	30	30
Scheduled Receipts						
Projected Available Balance 30						
Planned Order Release						

Completing the MRP Record

Part X; Lead Time = 1 week
Lot-sizing rule: EOQ (45)

Period		**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements		30	30	30	30	30	30
Scheduled Receipts							
Projected Available Balance	30	0	15	30	0	15	30
Planned Order Release		45	45	0	45	45	0

Part Y; Lead Time = 2 weeks
Lot-sizing rule: EOQ = 70

Period		**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements							
Scheduled Receipts							
Projected available balance	120						
Planned order release							

Completing the MRP Record

Part X; Lead Time = 1 week
Lot-sizing rule: EOQ (45)

Period		**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements		30	30	30	30	30	30
Scheduled Receipts							
Projected Available Balance	30	0	15	30	0	15	30
Planned Order Release		45	45	0	45	45	0

Part Y; Lead Time = 2 weeks
Lot-sizing rule: EOQ = 70

Period		**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements		90	90	0	90	90	0
Scheduled Receipts			100				
Projected available balance	120	30	40	40	20	0	0
Planned order release		0	70	70	0	0	0

Completing the MRP Record

Part Z; Lead Time = 1 week
Lot-sizing rule: Lot-for-Lot

Period		**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements							
Scheduled Receipts				70			
Projected Available Balance	70						
Planned Order Release							

Completing the MRP Record

Part Z; Lead Time = 1 week
Lot-sizing rule: Lot-for-Lot

Period		**1**	**2**	**3**	**4**	**5**	**6**
Gross Requirements		45	115	70	45	45	0
Scheduled Receipts				70			
Projected Available Balance	70	25	0	0	0	0	0
Planned Order Release		90	0	45	45	0	0

MRP Output

- MRP systems can be used to generate a wide range of outputs, as (within limits) they describe the future operation of the factory. These include
  - **Inventory order action** – details of when orders for raw materials must be placed
  - **Factory schedule** – broad timing information on what should be occurring throughout the factory over the planning time horizon
  - **Machine loading information** – data on the quantity of work to be undertaken by each machine
  - **Rescheduling data** – given some discrepancy between reality and the prescribed schedule, the MRP system can indicate precisely what will be affected by late completion of some component

MRP Exam Question

1 A company manufactures two products, A and B, with the following Bill of Materials:

A	
	C
	D (2 off)
B	
	D
	E

Demand for Products A and B over the next 13 weeks is:

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Product A	30	40	50	50	30	30	40	50	40	30	30	40	40
Product B	60	20	40	10	50	50	10	10	0	20	40	60	30

(a) Given the following data on lot sizing rules, lead times and inventory, calculate the Material Requirements Plan for all products and parts over the planning horizon. [40%]

	Order quantity	**Lead Time**	**On-Hand Inventory**	**Scheduled receipts (period 1)**
Product A:	Economic Order Quantity = 67	2	53	67
Product B:	Fixed Order Quantity =100	1	100	
Part C:	Lot-for-Lot	3	72	67
Part D:	Minimum Order Quantity =100	1	100	
Part E:	Lot-for-Lot	1	0	

Limitations and Extensions of MRP

MRP Limitations

- MRP is by far the most widely used production planning / scheduling system available today, but:
  - It takes no account of available machine/production capacity
  - It has no feedback – having issued the plan, it assumes that this will work
  - Unaccounted errors
    - The accuracy of the data provided, including sales forecasting data, cannot be guaranteed
    - Keeping accurate records of inventory – both stock and in-process is notoriously difficult
  - Fragile
    - Any delay in any component prior to an assembly operation will prevent completion of assembly – so shortages always deny the master production schedule
  - … MRP pushes production – production is not triggered or pulled by specific orders [rather by aggregate forecasts]

In a Nutshell MRP

IS …

- A good database
- A good transition processor
- Essential source of information and almost impossible to replace in many companies!

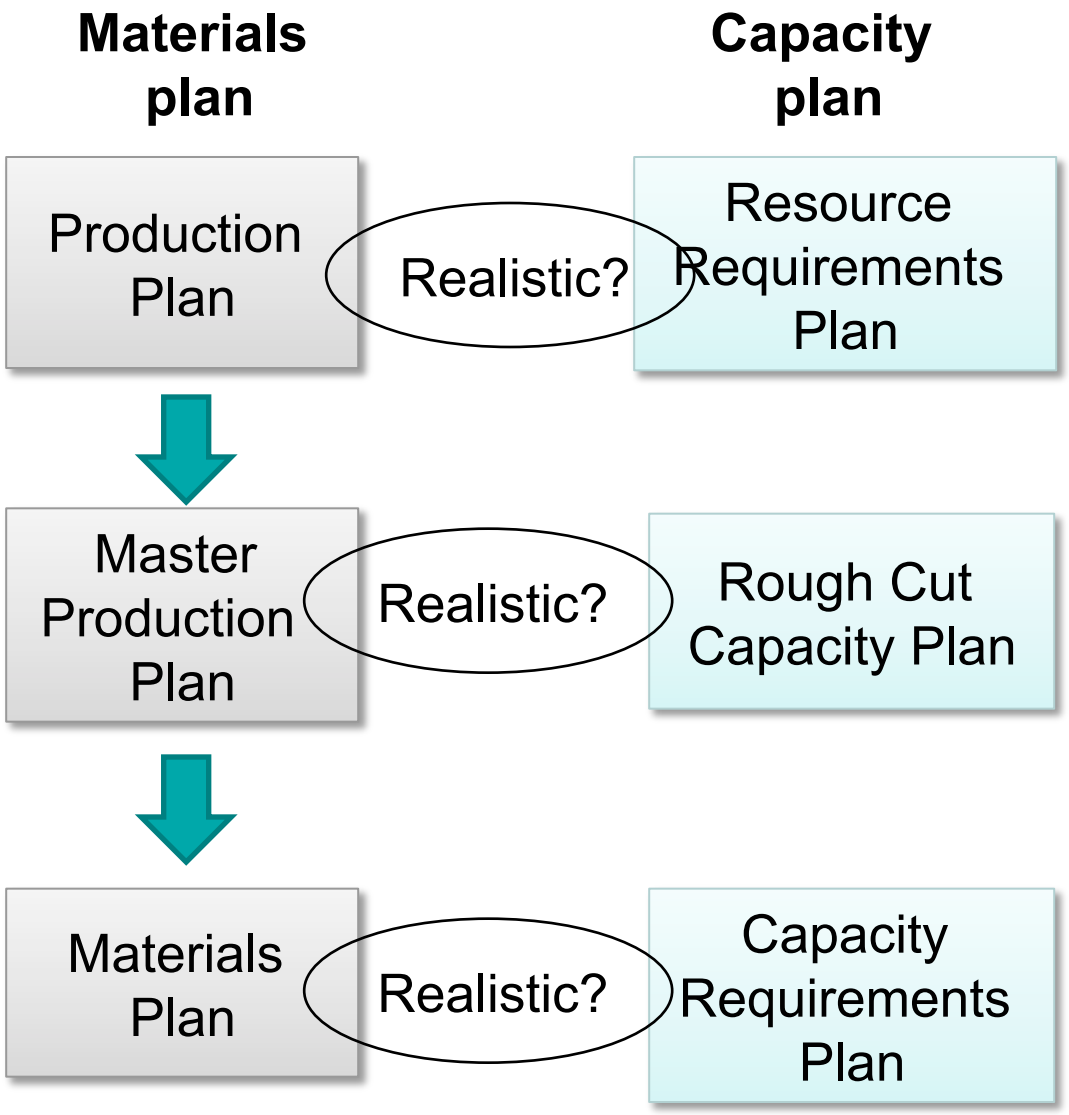
IS NOT …

- A good scheduler
  - Assumes infinite capacity
  - Works on fixed batches
  - Works in fixed lead times
  - Schedules backwards, therefore cannot synchronise

MRP Extensions

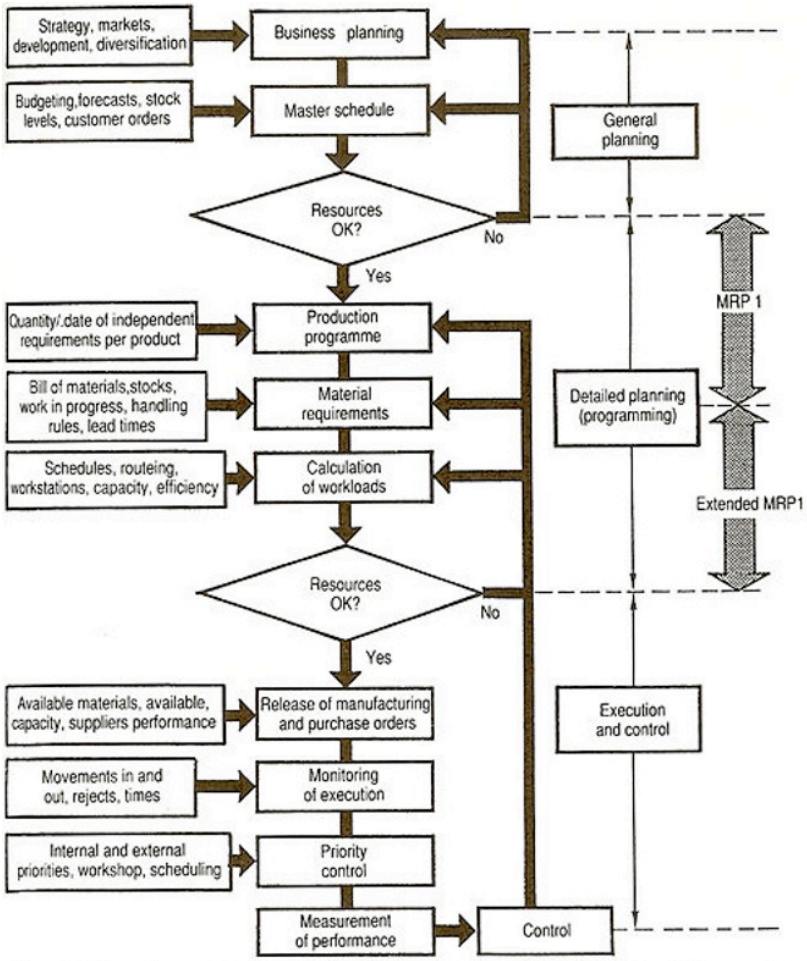
- Address limitations of MRP
  - Capacity
  - Feedback
  - Push
- Extend functionality of MRP
  - Non production functions
  - Multi site operations

Closed Loop MRP



Manufacturing Resource Planning (MRP II)

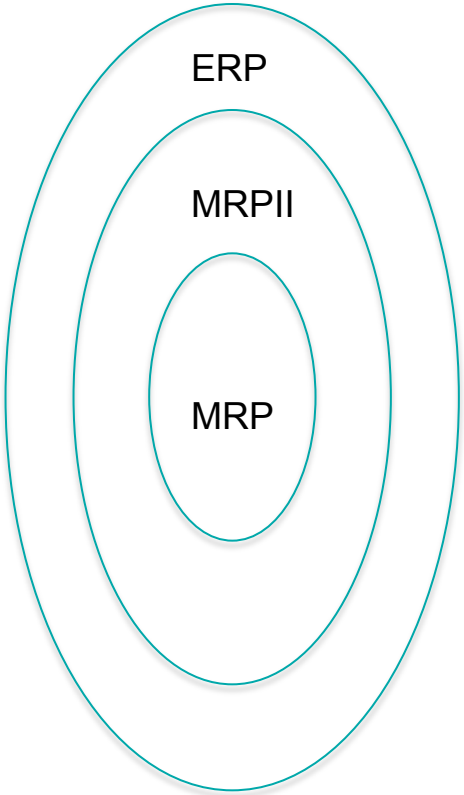
- MRP II is a method for the effective planning of all resources of a manufacturing company
  - Manufacturing, marketing, finance, and engineering
- Key distinctions from MRP :
  - Integrated closed loop system
  - Used by all functional areas to "run the business"
  - Efficient data management
  - Financial planning/cost information
  - Sophisticated "what if" simulation capabilities



Around 1980, over-frequent changes in sales forecasts, entailing continual reajustments in production, as well as the unsuitability of the parameters fixed buy the system, led MRP (Material Requirement Planning) to evolve into a new concept : Manufacturating Resource Planning or MRP2

Enterprise Resource Planning (ERP)

- Enhancement of MRP II
- Takes an whole-enterprise view: manufacturing, marketing, sales, service, design, inventory, procurement, distribution, facilities management, quality, HR, finance, etc.
- Aimed at complete integration of enterprise-level information
- Considers linkage to the “extended enterprise” – suppliers and customers
- More in Lecture 8



Microsoft Dynamics

ORACLE
e-businesssuite

SAP®

MRP Extensions

- Address limitations of MRP
  - Capacity [closed loop MRP/MRPII]
  - Feedback [MRP update procedures]
  - Push [integrate pull capabilities / JIT]

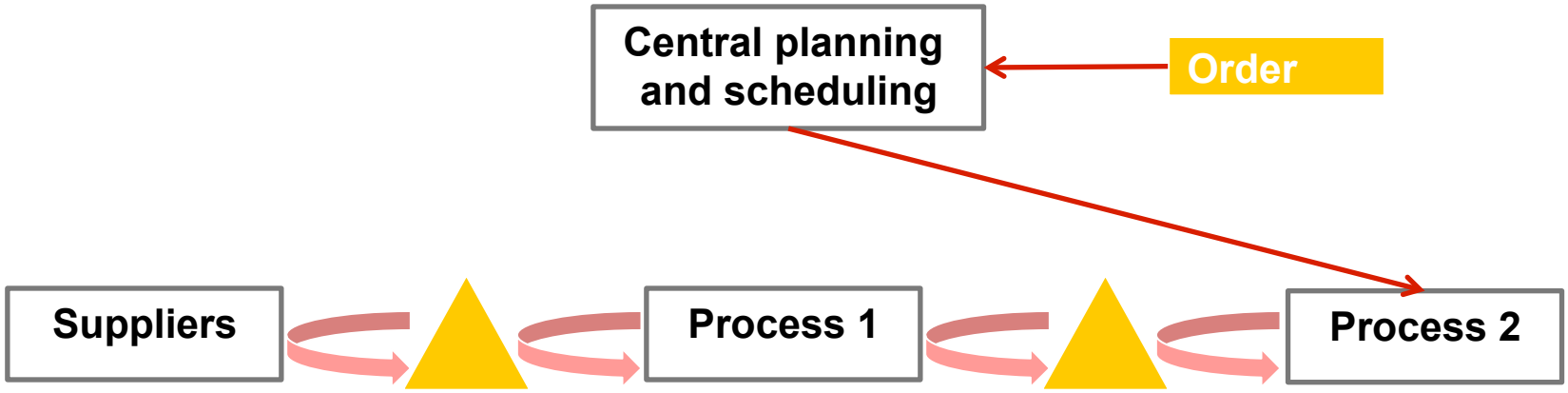
- Extend functionality of MRP
  - Non production functions [MRPII/ERP]
  - Multi site operations [ERP]

Costs of MRP/ERP Systems

- Training
  - training trainers and users
  - exposure of top and middle management
  - connecting activities eg purchasing
  - customers and vendors
- Data accuracy
  - auditing the current status
  - developing the correct data
  - designing new systems to keep it right
  - creating new forms, procedures & incentives
- Personnel
  - full-time project team members
  - part-time project team members
  - systems and staff people who work on the project
  - outside consultants, trainers, programmers
- Support for people
  - new tools
  - redefined jobs
  - revised pay schemes
  - changed incentives
- Re-layout of facilities
  - factory floor changes
  - new inventory locations and containers
  - changes or elimination of office space
  - installation of support tools
- Software
  - package purchase + installation support
  - customisation of output documents and screens
  - enhancement and implementation of upgrades
  - maintenance and evaluation of new alternatives
- Hardware
  - basic expansion or acquisition of computers
  - networking equipment
  - special devices
  - provision for growth and staged implementation

Just-In-Time (JIT) Systems

“Pull” Scheduling



- In a **pull** system, processes are triggered by a replenishment signal
- Upon withdrawal of material from inventory, the preceding process is authorised to start processing, and **only then**!
- Hence, the **final** process sees the new order **first**
- This is called **forward** scheduling
- Simplest form: two-bin approach

Toyota Production System (TPS)

Toyota Production System (TPS)

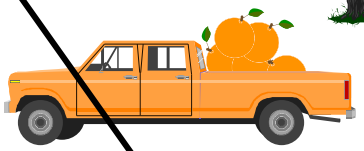
- Taiichi Ohno starts developing TPS in engine shop in 1948
  - Pillars of TPS are “Jidoka”, and Just-in-Time.
- Principles of TPS:
  - Only make what is required, when it is required, just in time
  - Use small batches
  - Reduce seven wastes (overproduction, inventory, transportation, motion, inappropriate processing, defects, waiting/delay)
- Toyota overcame obstacles of economically producing a high variety of products in small batches
- Supported by tightly synchronised supplier network at close proximity

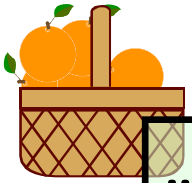
Just-in-Time Scheduling

- The idea of JIT merges:
  - The supermarket concept of “on-the-shelf inventory”
  - The two-bin replenishment system
- Production orders are based on replenishment
- The demand signal is conveyed via **kanban** cards
- The system is tightly controlled, as it is “fragile”, i.e., unable to cope with large swings in volume or product mix Need to keep schedule variability within 5-10%
- Just-in-Time is central part of the Toyota Production System (TPS), also referred to as “Lean Production”

MRP Systems: “Push” Production

… triggers purchase …



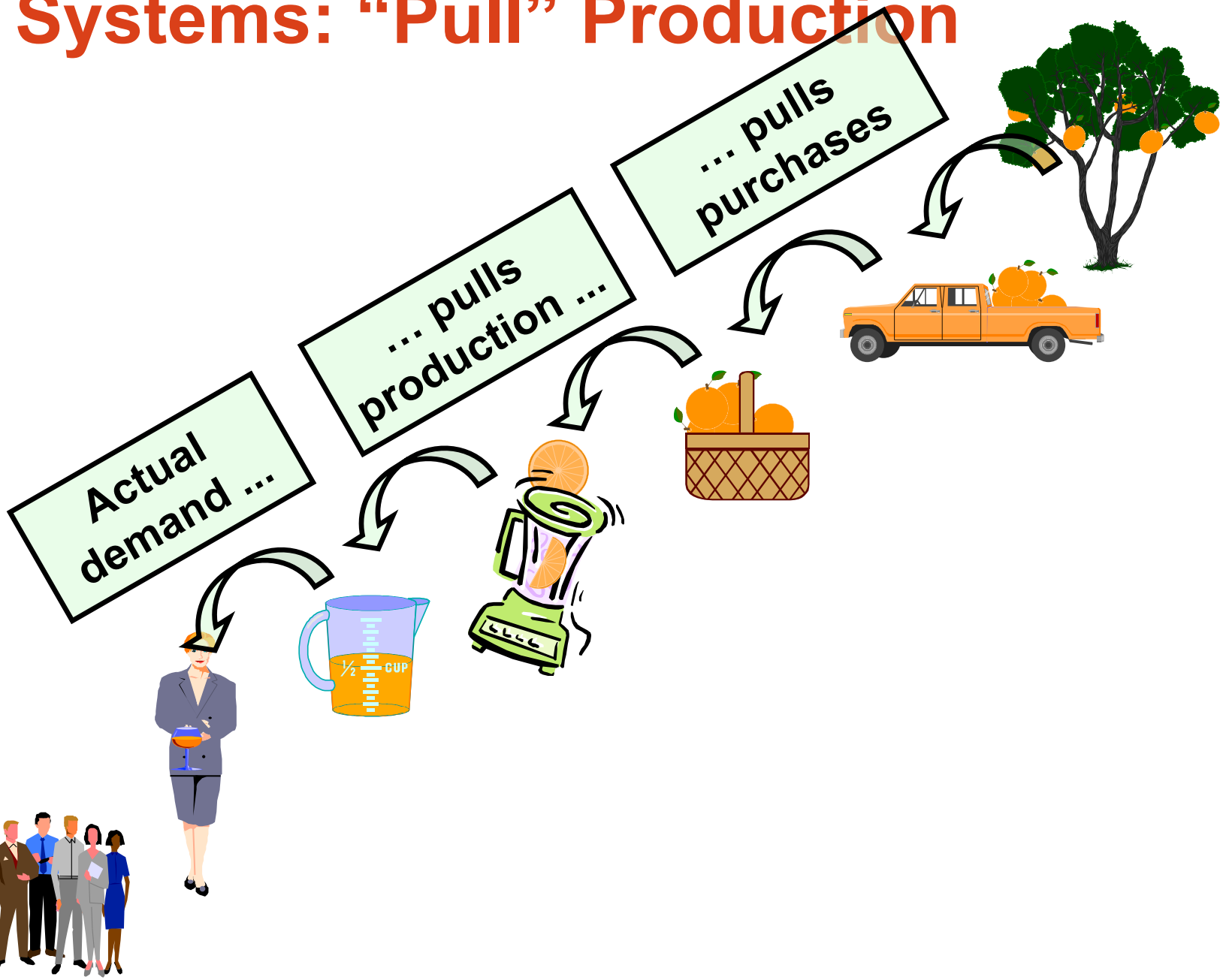


… raw materials push production …

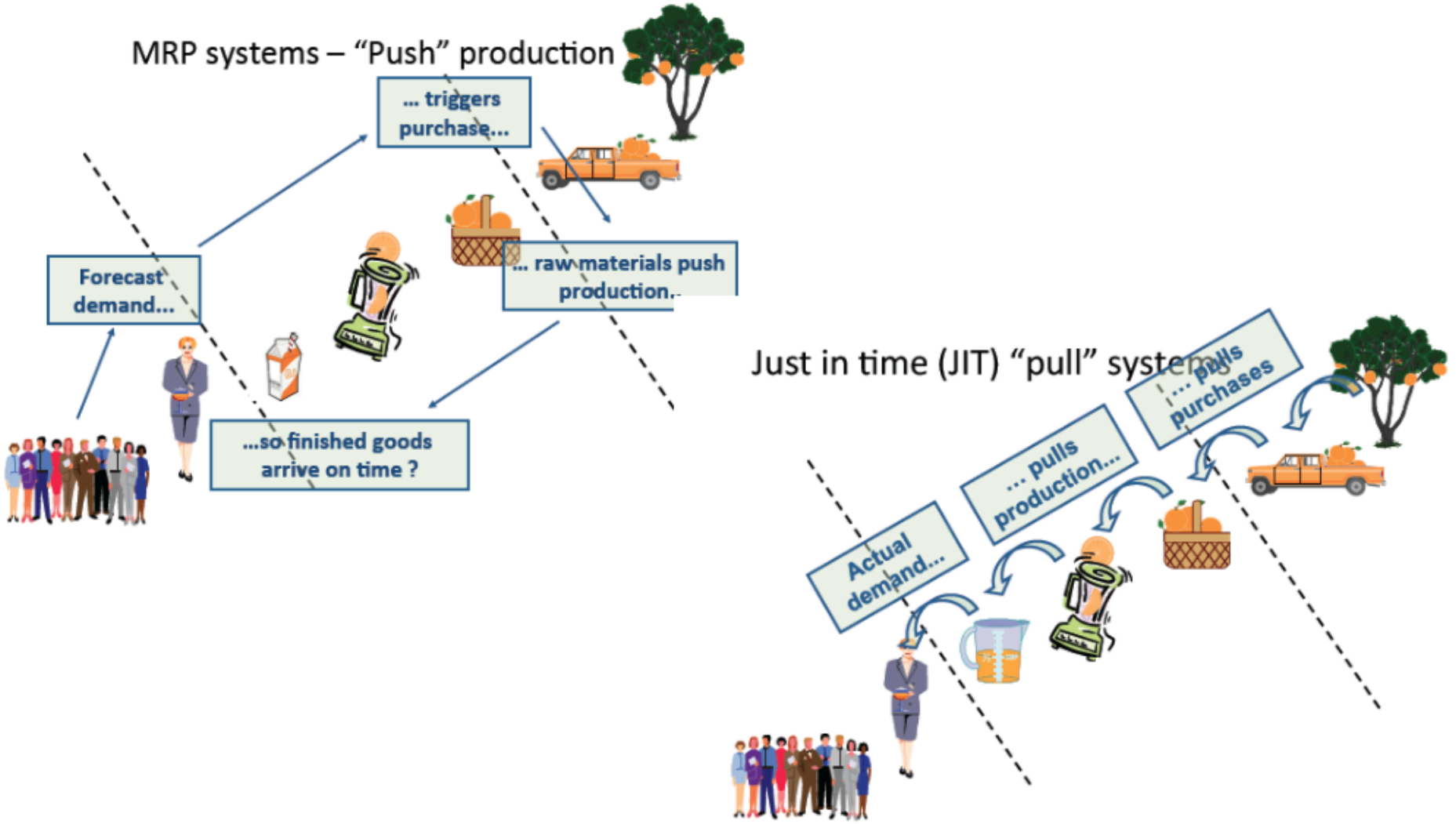
Forecast demand…

… so finished goods arrive on schedule ?

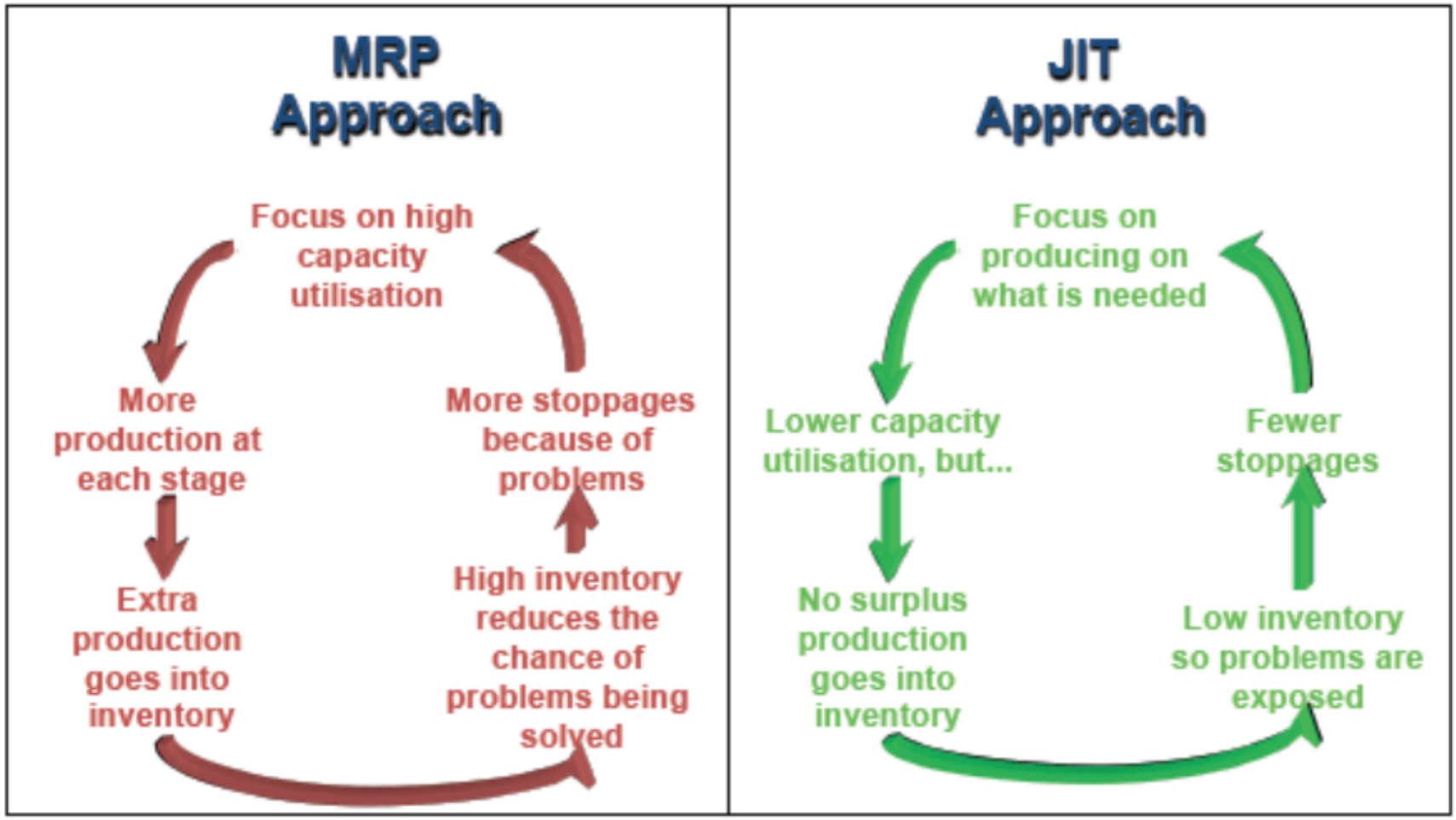
JIT Systems: “Pull” Production



MRP vs. JIT


MRP systems – "Push" production
... triggers purchase...
Forecast demand...
... raw materials push production...
...so finished goods arrive on time ?
Just in time (JIT) "pull" systems
... pulls purchases
... pulls production...
Actual demand...

MRP vs. JIT


MRP Approach
Focus on high capacity utilisation
More production at each stage
Extra production goes into inventory
High inventory reduces the chance of problems being solved
More stoppages because of problems
JIT Approach
Focus on producing on what is needed
Lower capacity utilisation, but...
No surplus production goes into inventory
Low inventory so problems are exposed
Fewer stoppages

TPS Elements – Taiichi Ohno

- All processes driven to be in control and capable
  - Standardised work practices
  - “Simplify, highlight deviations, mistake-proof”
- Problems are natural and opportunities to learn, not blame!
  - Most problems arise from not following standards
  - Every problem has root cause and counter-measures
- Every activity must add value
  - Eliminate waste through continuous improvement
- Make what customers want when they want it,just-in-time
  - Smooth production “pulse”
- Select and invest in people
  - Managers chosen as best teachers/problem-solvers
  - Empowerment & multi-skilling

Lean Thinking

Where Does The Term “Lean” Come From?

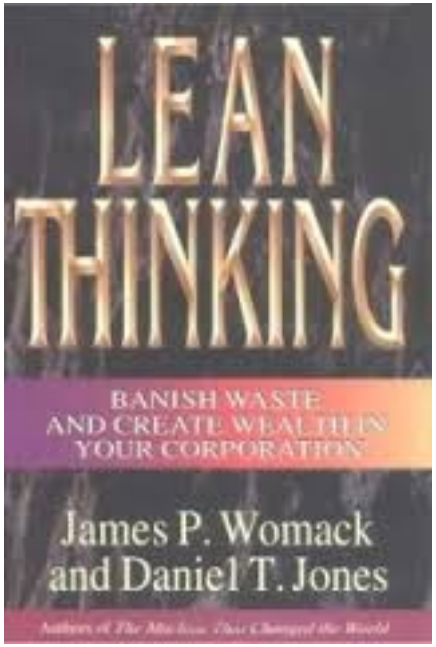
- MIT International Motor Vehicle Program
- Started in 1979, ongoing to date!
- 5 Year – 5 Million Dollar Program
- Coordinated by MIT – Researchers from around the World
- Research into all aspects of the Toyota Production System
- Policy forums for senior industry, government and union officials
- “Lean Production” coined by John Krafcik (1989)

The NUMMI Experience

- **Joint Venture GM/Toyota plant, closed 1982, reopened in 1984, closed 2010**
- **Dramatic improvements compared to previous GM plant**
  - Assembly hours/car 36 to 19
  - Assembly defects/car 1.5 to 0.5
  - Worker absenteeism 15% to 1.5%
- **Changes:**
  - Toyota management – Lean Production principles
  - Work organization – teams, few job classifications, focus on quality,
  - Still unionized workforce
- **Transfer to other GM plants took many years**
  - GM management lacked commitment
  - NUMMI plant visits for management were for brief time periods only
  - Visiting teams below critical size

→... but: NUMMI showed that lean was not culturally bound!

Five Lean Principles



1. Specify what creates ***value*** from the customers perspective

2. Identify all steps across the whole ***value stream***

3. Make those actions that create value ***flow***

4. Only make what is ***pulled*** by the customer just-in-time

5. Strive for ***perfection*** by continually removing successive layers of waste

Waste – the Central Focus of Lean!

- Waste is anything which does not add value to a product or service in any office or manufacturing activity!

  … essentially everything the customer is not prepared to pay for!

- Frequently used term: “muda” (=waste)
  - Muda (waste)
  - Muri (excessive strain)
  - Mura (unevenness or irregularity)

What Do You See?

Lean Thinking - Seven Deadly Wastes

After years of trying to eliminate waste, Ohno identified 7 types of waste:

1. Overproduction
2. Waiting
3. Transportation
4. Processing
5. Inventory
6. Motion
7. Defects

"The root of all unprofitable activity within the organization."

T-Shirts

Jidoka

While **JIT** forms the pillar of **Flow** (or “Go”), **Jidoka** is the pillar of **Quality** (or “Stop”)

Jidoka is described as “autonomation” or “humanising the interface between operator and machine”

Jidoka is operationalised by:

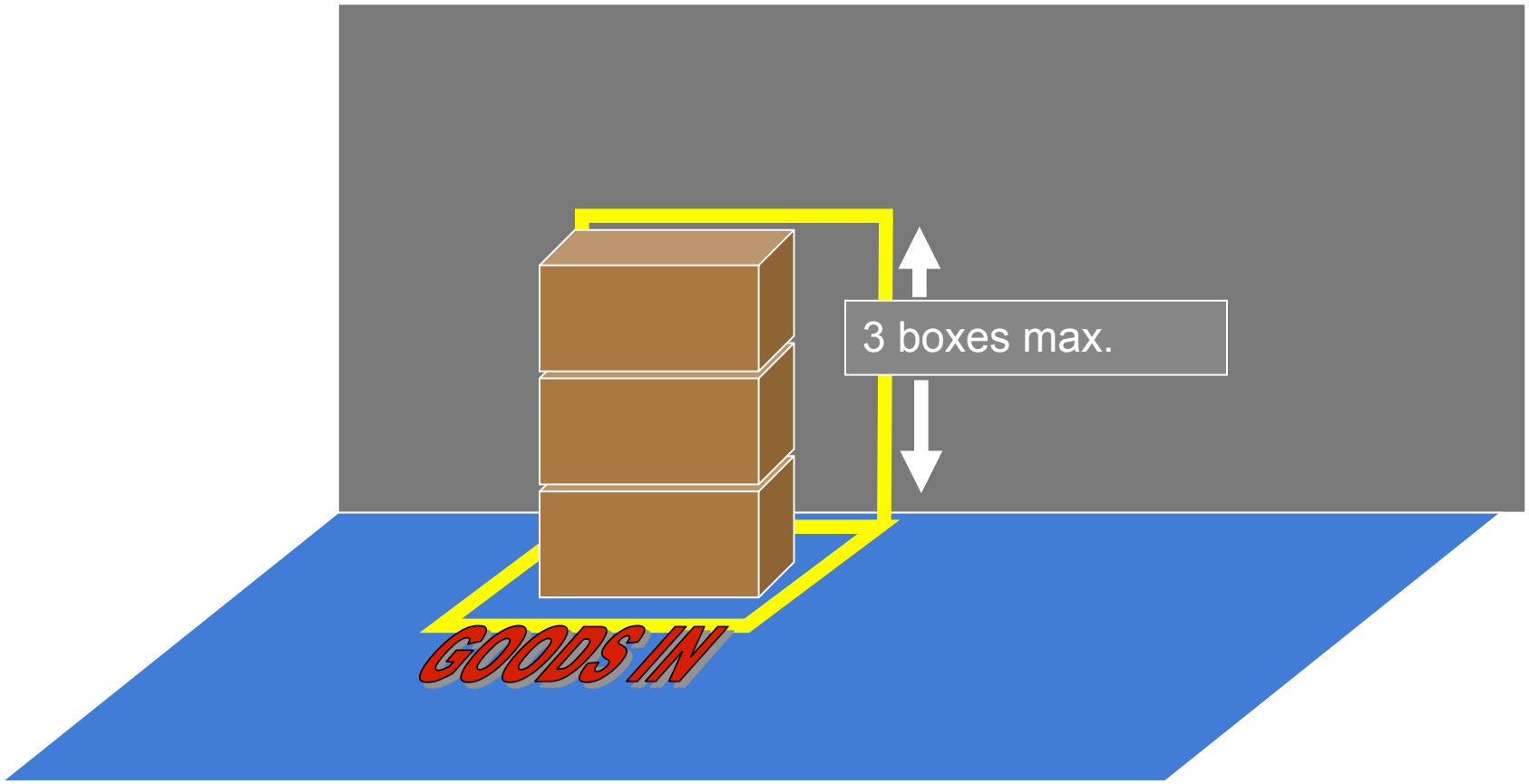
- **Fail-safeing/ poka-yoke** (or machine jidoka) e.g.
  - Limit switches which only allow machine operation if the part is positioned correctly
  - Digital counters on machines to ensure that the correct number of cuts, passes or holes have been machined
- **Line-stop authority** (or human jidoka)
- **Visual control** (at-a-glance status of production processes and visibility of process standards)
  - Andon display above each workstation indicating its state: working, waiting for work, broken down, stopped etc.

5S

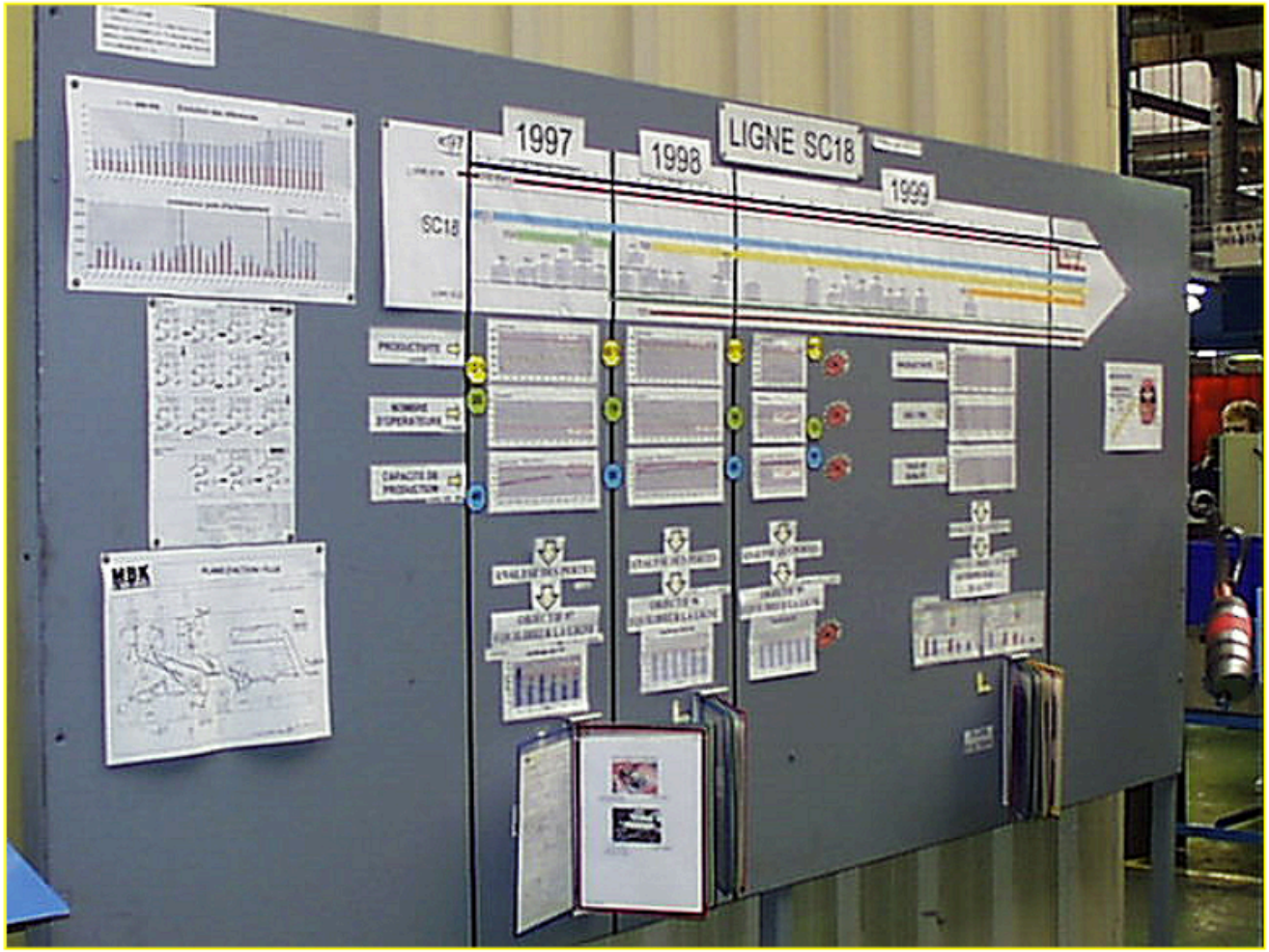
- System to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results.
- **As much to do with the mind as with the physical situation!**
- Known also as CANDO

▪ Seiri	Sort	Clear
▪ Seiton	Stabilize	Arrange
▪ Seiso	Shine	Neatness
▪ Seiketsu	Standardise	Discipline
▪ Shitsuke	Sustain	On-going improvement

Visual Operational Control



Visibility



Continuous Improvement

"Kaikaku"

- Step change
- Short-term execution
- 2-3 day workshops – implement changes on the spot!
- Limited / narrow scope (e.g., one machine or area on shop-floor)

"Kaizen"

- Literally "Changing something for the better" by eliminating waste
- Long-term activities
- Gradual / incremental improvements
- No limit in focus, often extends to suppliers and distribution

The DNA of TPS

How much should Toyota be afraid of copycats?

- It is possible to copy the shop-floor techniques by themselves
- Some improvement in productivity and quality will result
- Lack of flexibility in adjusting to change will persist
- System will not able to learn autonomously
- Continuous improvement needs to be driven by workforce, cannot be dictated by management

Dynamic learning capability is Toyota's key advantage:
Lean is a mindset, a system – not a "toolbox"!

Features of a Lean Organisation

- So what does it look like if lean principles are put into practice?
- Features to look for:
  - The learning organisation: mistakes are opportunities!
  - Visual management: targets and achievements
  - Continuous improvement activities
  - Standard operating procedures (SOPs)
  - Empowerment
  - Multi-skilling
  - Teamwork

JIT Summary

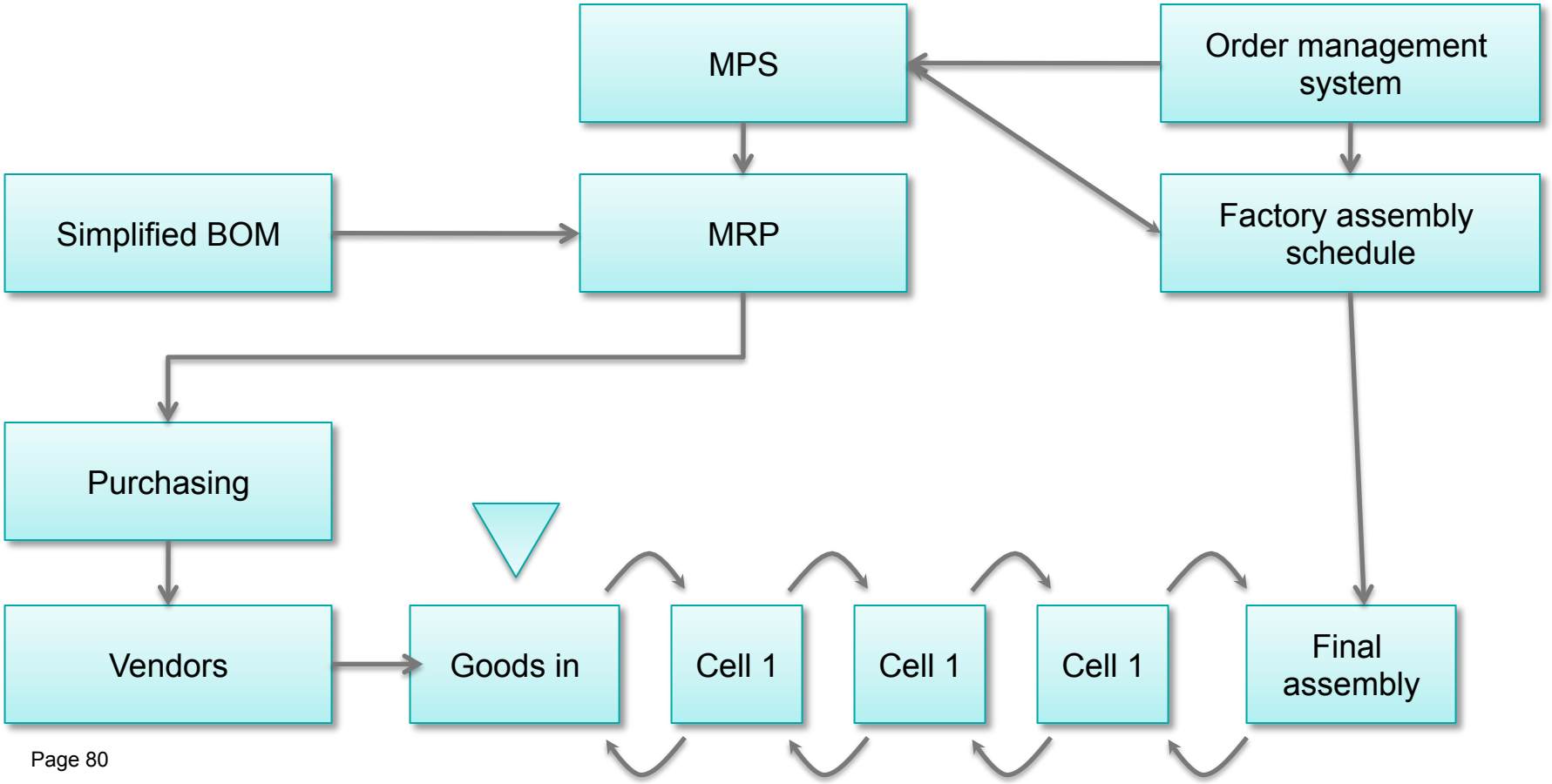
- Batch sizes are as small as possible (ideal would be single-piece flow)
- Relies on the use of physical inventory control cues (or kanban) to signal the need to move or produce new raw materials or components from the previous process.
- Often requires suppliers to deliver components using JIT. The company signals its suppliers, using computers or delivery of empty containers, to supply more of a particular component when they are needed.
  - Supply chain infrastructure needs to be set up to do this. Delivery windows may be measured in minutes.
  - NB Frequent, small deliveries are not particularly “green”
- Results in significant reduction in waste associated with unnecessary inventory, WIP, and overproduction

Meals Per Hour

Integrating MRP and JIT

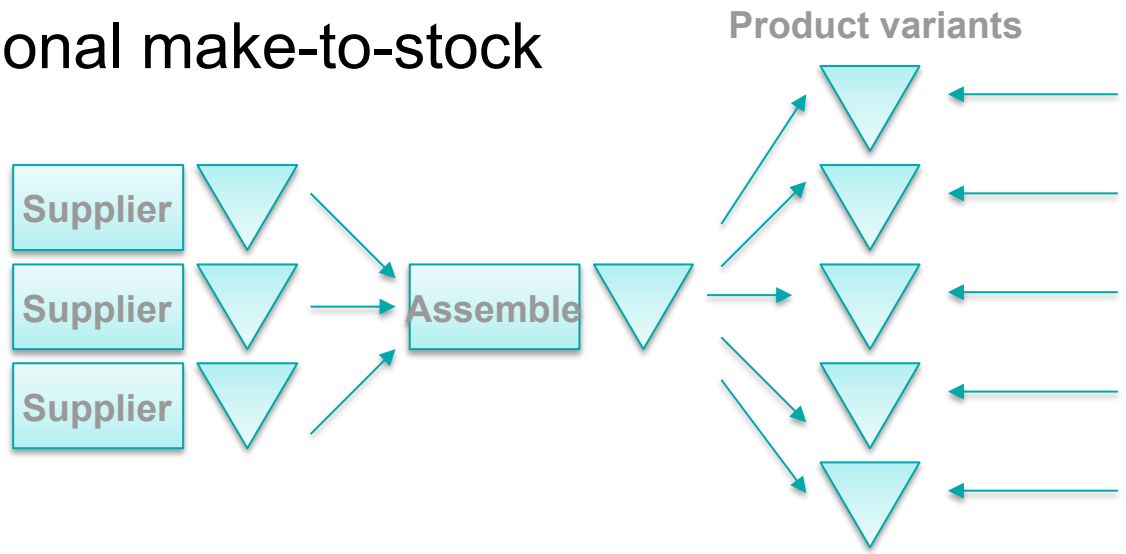
Combining JIT & MRP

- MRP for overall control, JIT for internal control
- MRP creates supplier schedules, shop-floor production controlled by kanban

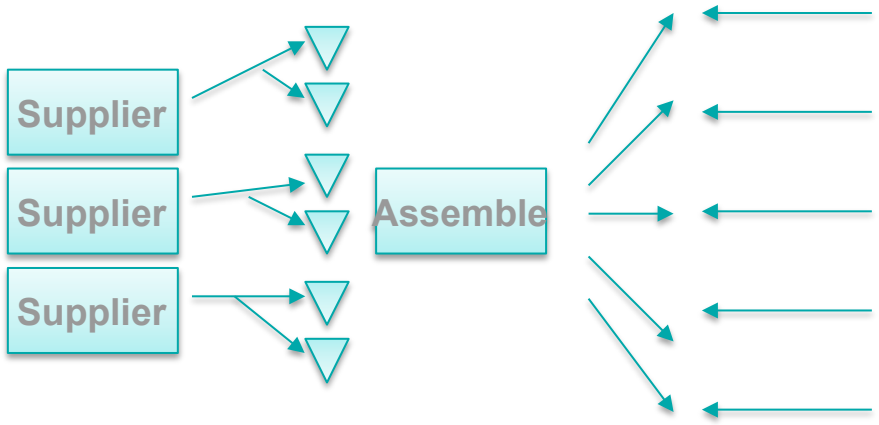


Push-Pull Systems

- Conventional make-to-stock



- Improved assemble-to-order

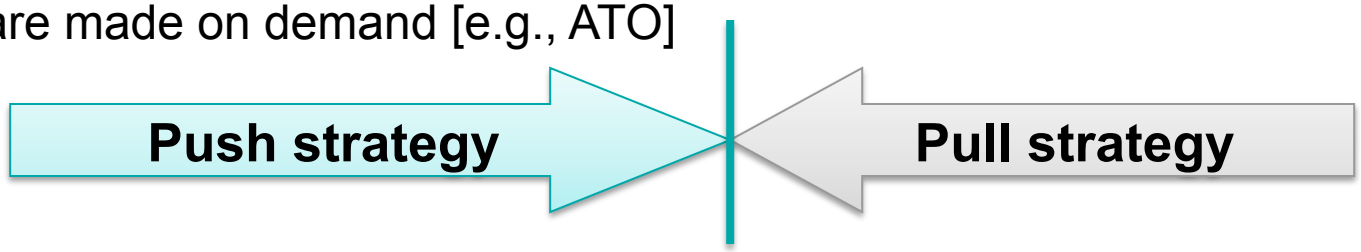


Push-Pull Systems

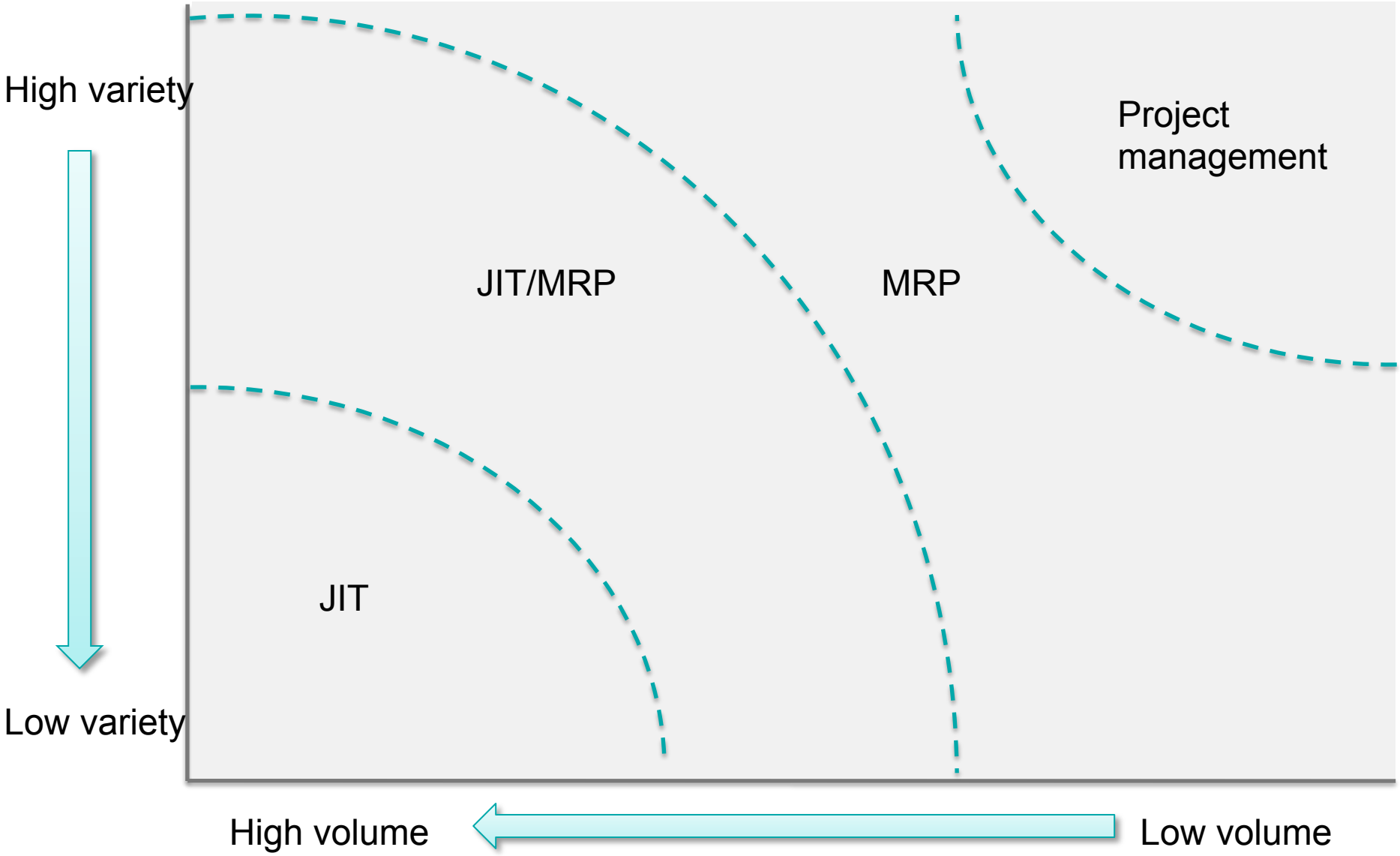
Push systems depend on forecast demand

Pull systems require long lead time compared to production

Push-pull: parts inventory replenished on forecasts, but products are made on demand [e.g., ATO]



When to Use JIT, MRP, and Combined Systems?



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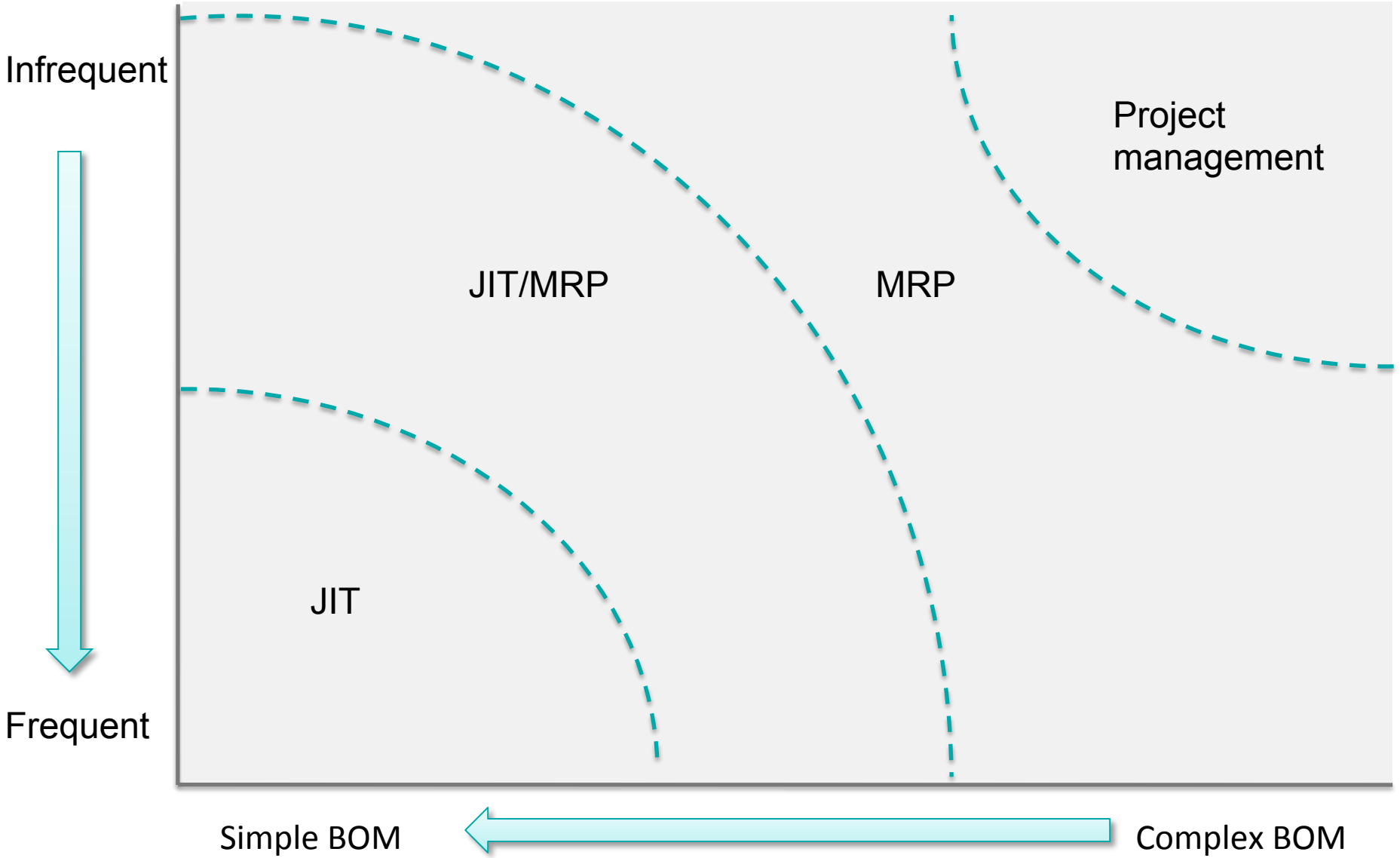
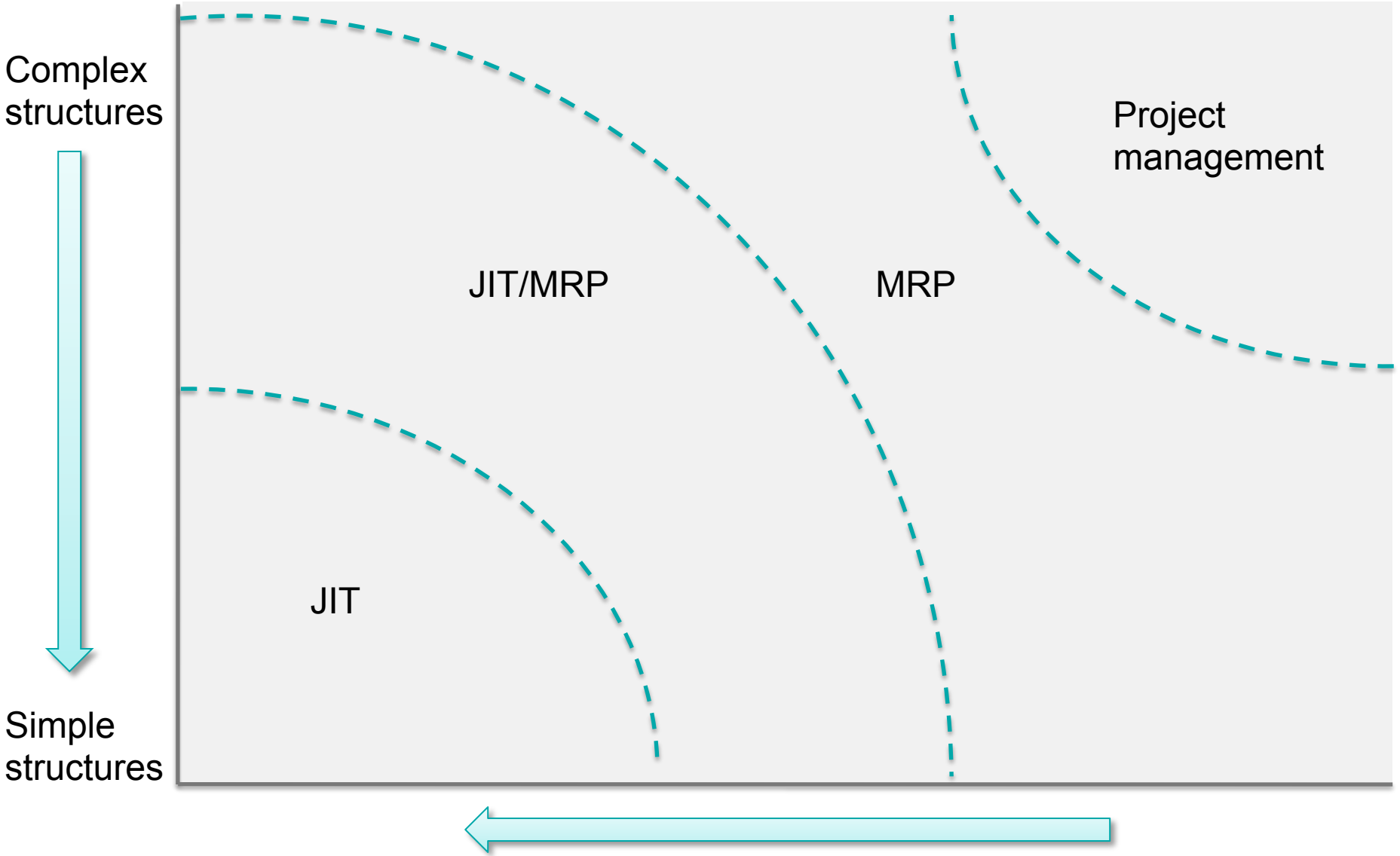


When to Use JIT, MRP, and Combined Systems?



When to Use JIT, MRP, and Combined Systems?

- Ford Fiesta production
- Customised Land Rover production
- Restaurant kitchen
- Crossrail construction
- Boeing 737 assembly line
- Mobile phone assembly line
- Baked bean production

NB: Orders may come from wholesalers, retailers or consumers

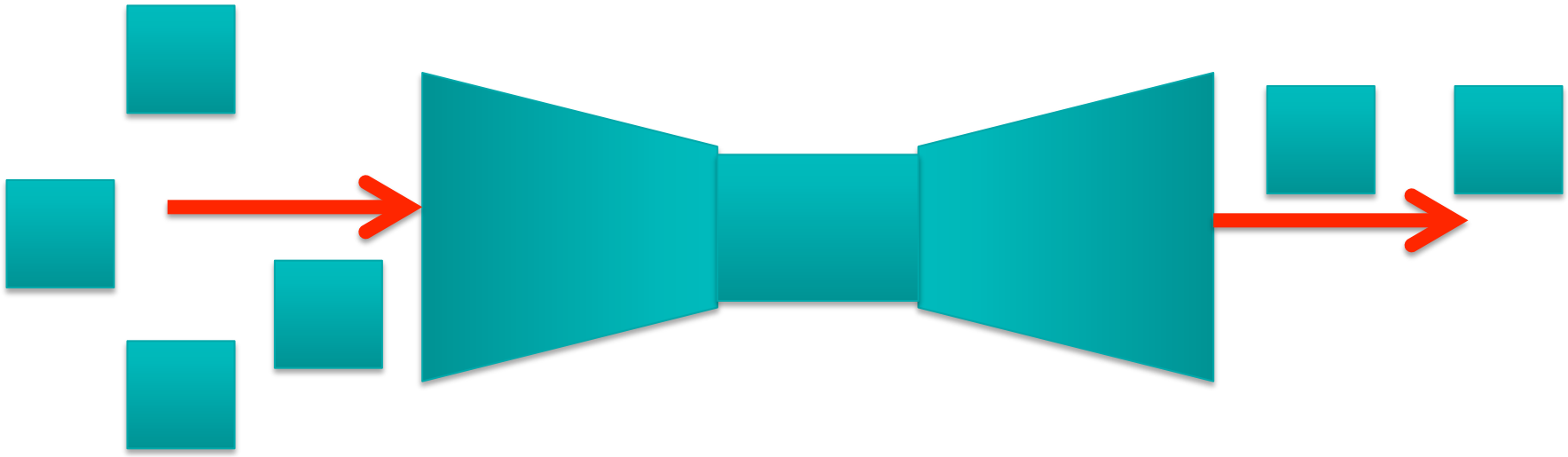
Optimised Production Technology (OPT)

Optimised Production Technology (OPT)

Aka TOC - Theory of Constraints:

- A further production planning/control/scheduling approach:
  - based on ten rules, the key one of which is the first: “Balance flow not capacity”
- The essence:
  - There is always a bottleneck
  - All factory operations are constrained by the bottlenecks
  - Run factory around the bottleneck [in JIT is last workstation]
    - schedule the bottleneck
    - schedule all other workstations relative to bottleneck

OPT: Bottleneck Management



Ensure WIP available
upstream

Ensure WIP flowing
Readily downstream

Comparing Three Approaches?

Production Managers Options	MRP & Dispatching Rules	JIT	OPT
When to order	Early - according to forecast demand	According to demand	Use actual/forecast demand to keep bottleneck busy
What to do next	Dispatching rules	No choice – track demand	Keep the bottleneck busy
Batch size	EBQ etc. chosen from setup times	One	EBQ for the bottleneck
When to start	According to standard times + forecast demand	When demand occurs	Relate forecast demand to the bottleneck
Predicted due date	According to standard times	Now	According to bottleneck
Managing defects	Hidden by inventory – keep going	Stop immediately and solve as part of operations	Not a problem unless at the bottleneck

Some Key Questions

- How to organise the manufacturing of a complex product?
- How much raw material/parts should I order to keep production running?
- When should I be ordering raw material/parts in order to keep production running?
- What are pull vs. push planning systems?
- Under what conditions is pull vs. push most appropriate?

Take-away Points: MRP

- For inventory systems with dependent demand
- Basic idea: (Assumes deterministic demand)
  - Look forward to production requirements
  - Don't order until you need to
  - Order only what you need
- Cascade of demands through production hierarchy.
  - Projected Requirements
  - Scheduled Receipts
  - On-Hand Inventory
  - Planned Order Releases
- Difficulties with MRP:
  - Complex to install
  - System "nervousness"
- "When": Demand requirements $\Rightarrow$ on-hand inventory $\Rightarrow$ planned order releases
- "How much": Lot sizing

Take-away Points

- **Push** systems schedule and issue orders centrally. **MRP** systems are computerised systems to support push scheduling.
- In a **pull** system, processes are triggered by a replenishment signal, such as the **kanban** cards in **JIT** scheduling.
- The best known pull system is the **Toyota Production System (TPS).** Study of the TPS led to the concepts of **lean production** and **lean thinking,** which are now extremely influential in operations management practice.
- Lean is more than the tools, it is a **mindset**
- MRP and JIT are not exclusive and can be combined

Operations Management

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