Material Requirement Planning (MRP)

MG2029 Production planning and control

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This lecture material is based on:

- ”Production and operation analysis” by Nahmias S. (7th ed) Chapter 8.1 – 8.4
- Hakan Akillioglu, researcher KTH

The basic idea of MRP

- When the final due date for a product is known, and the time required for each production step is known

Then

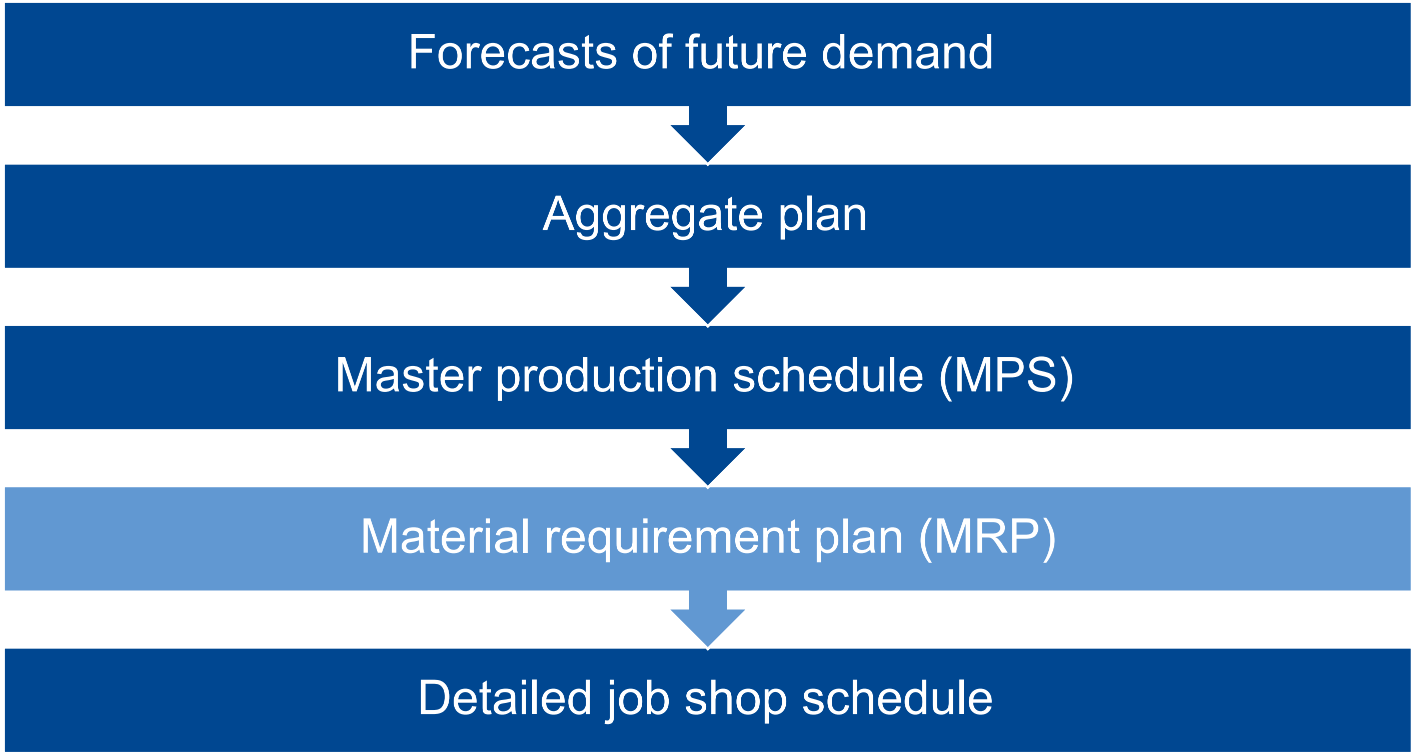
- Intermediate due dates and material requirement times can be determined
  - With the help of components' list of the product

Demand characteristics

- Independent demand is the demand coming from outside the system, i.e. Demand for end items
- Dependent demand is the demand for components and raw materials given the independent demands for end items
- MRP relates the independent demand to dependent demand and to the production/procurement schedules for components
- MRP; outputs a schedule of job and purchase orders (timing and quantity) to satisfy material requirements generated by external demand

Planning hierarchy

- MRP starts with MPS
- MPS gives gross requirements to MRP for the independent demand items

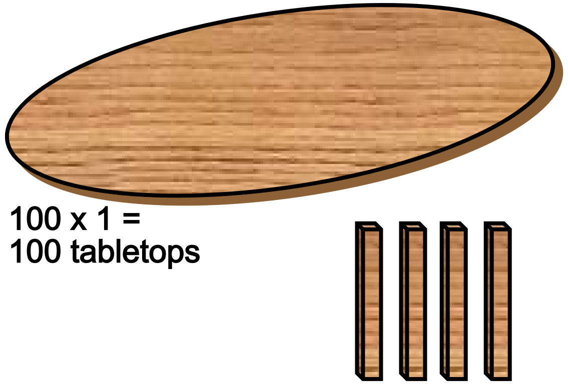


Demand characteristics

Independent demand

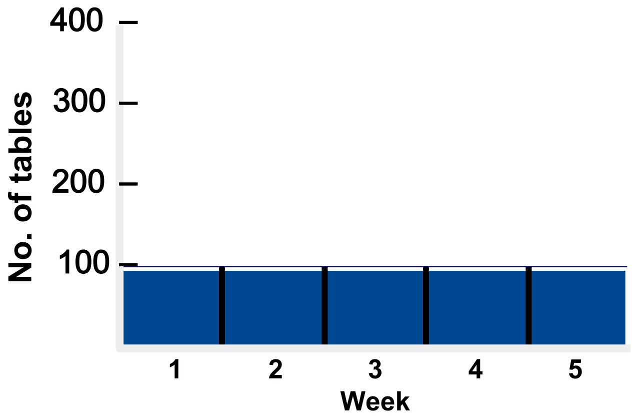
100 tables

Dependent demand

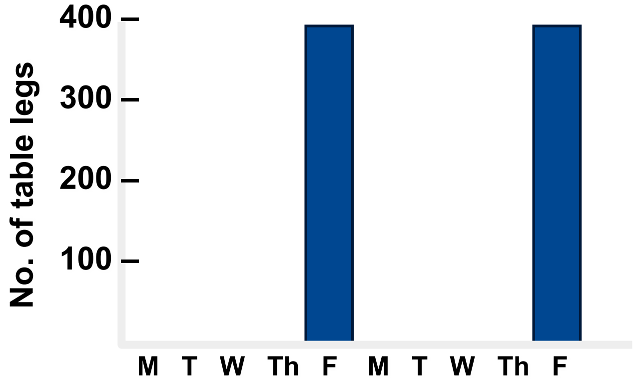


100 x 4 = 400 table legs

Continuous demand

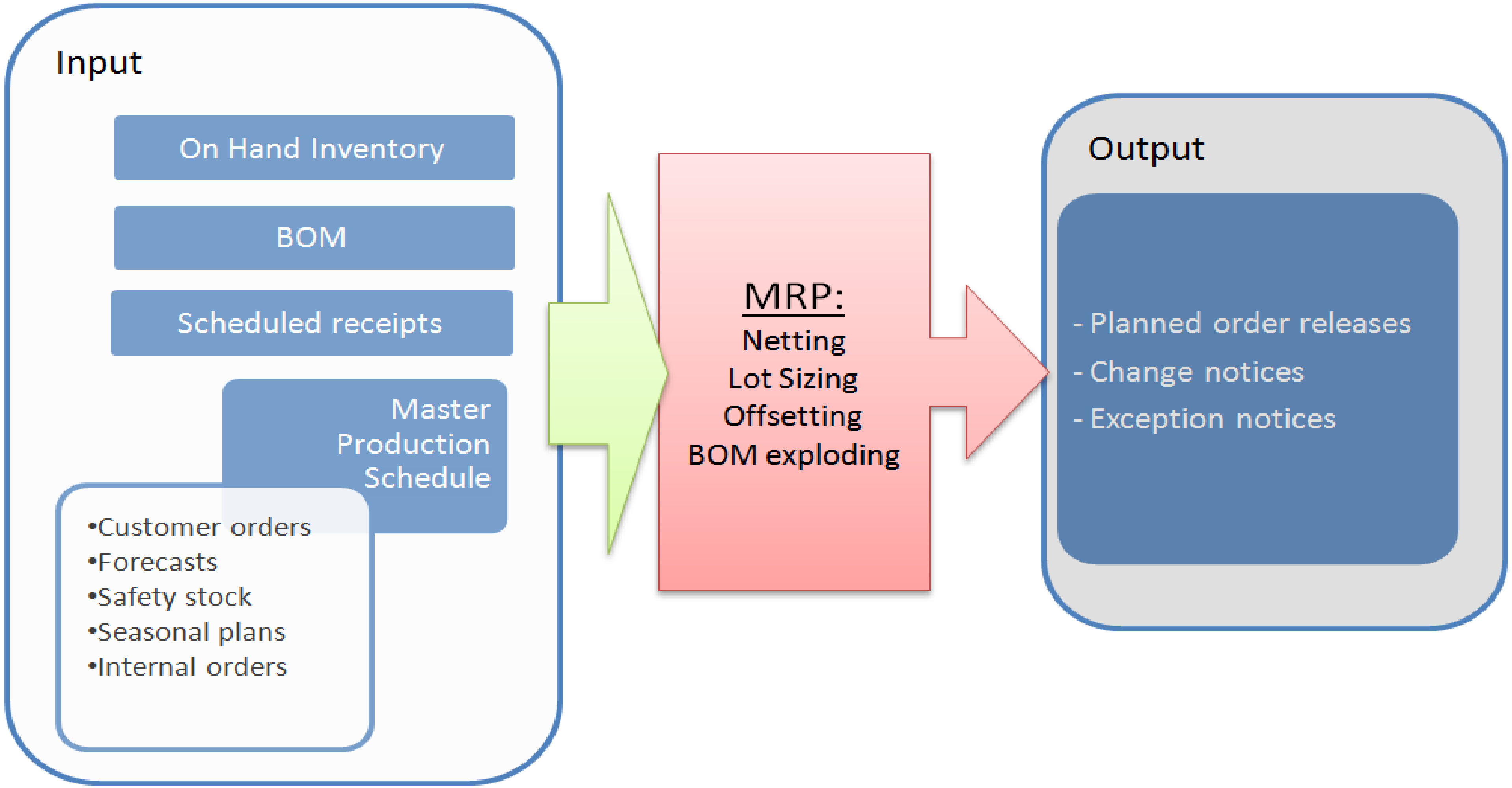


Discrete demand



- Consider:
  - there is an average demand of 100 tables per week
  - To fulfill this demand we require 400 table legs every Friday from our sub-supplier or another shop within our production facility

MRP input & outputs



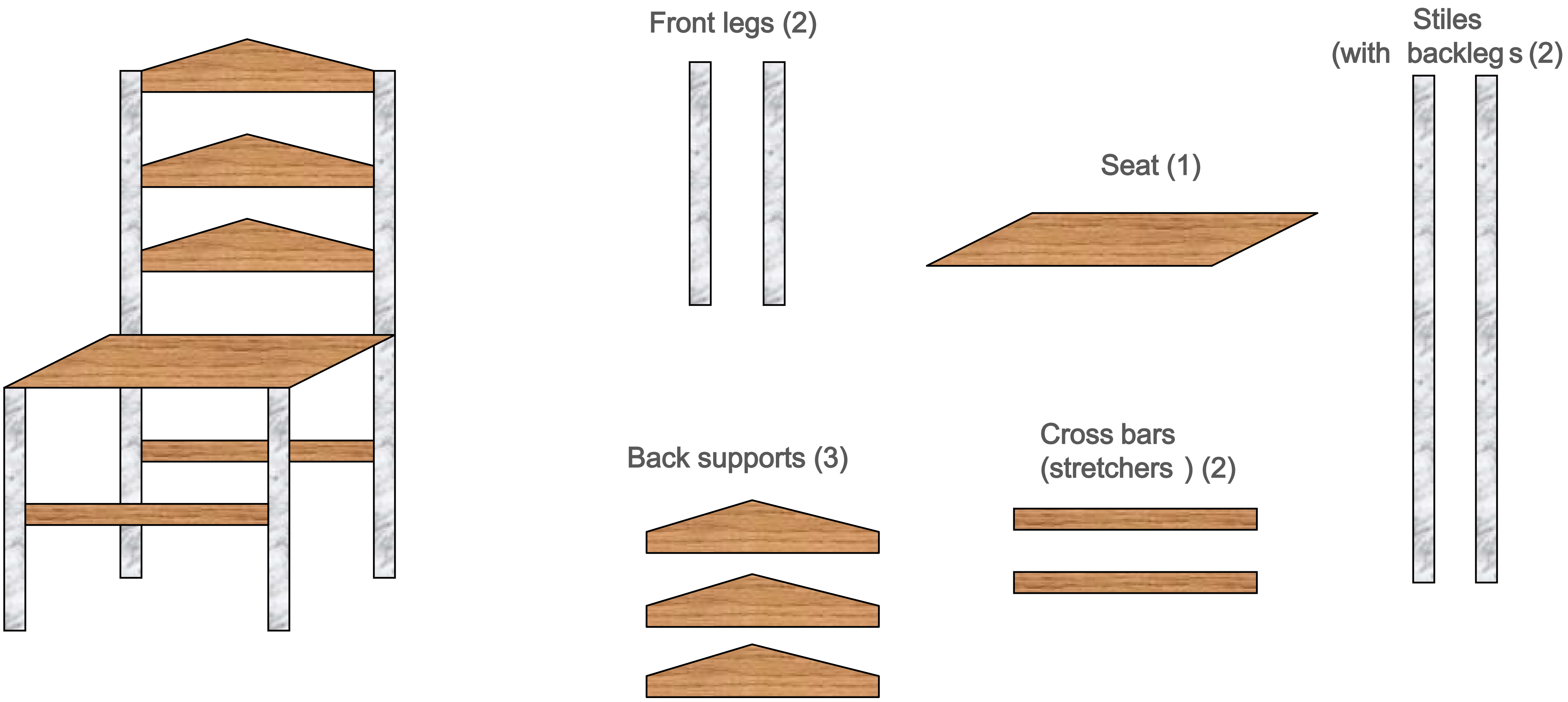
Bill of material (BOM)

–A structured list of all materials and parts to produce a particular finished product or subassembly

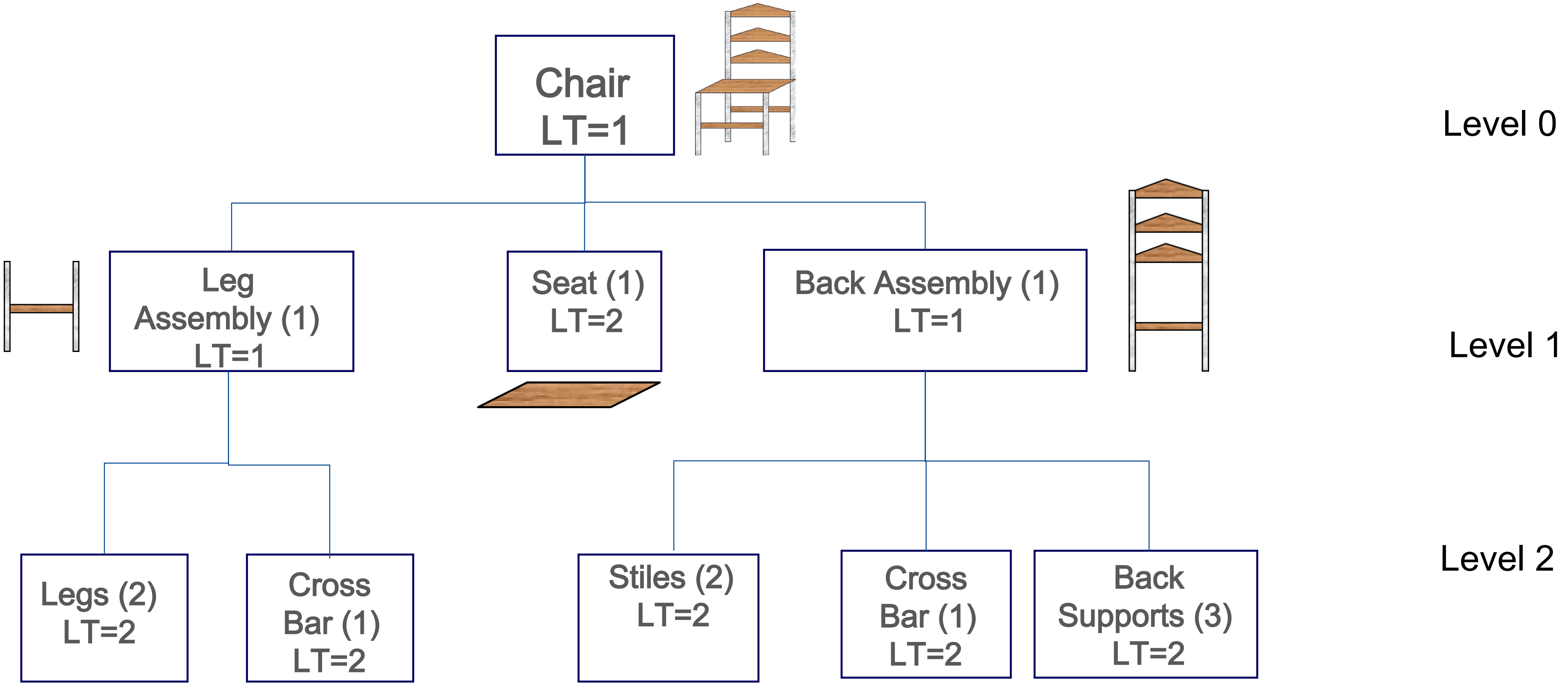
– It contains

- Quantity of the components that are required to produce one “parent” item
- The lead time to manufacture/purchase the component

Chair as an example

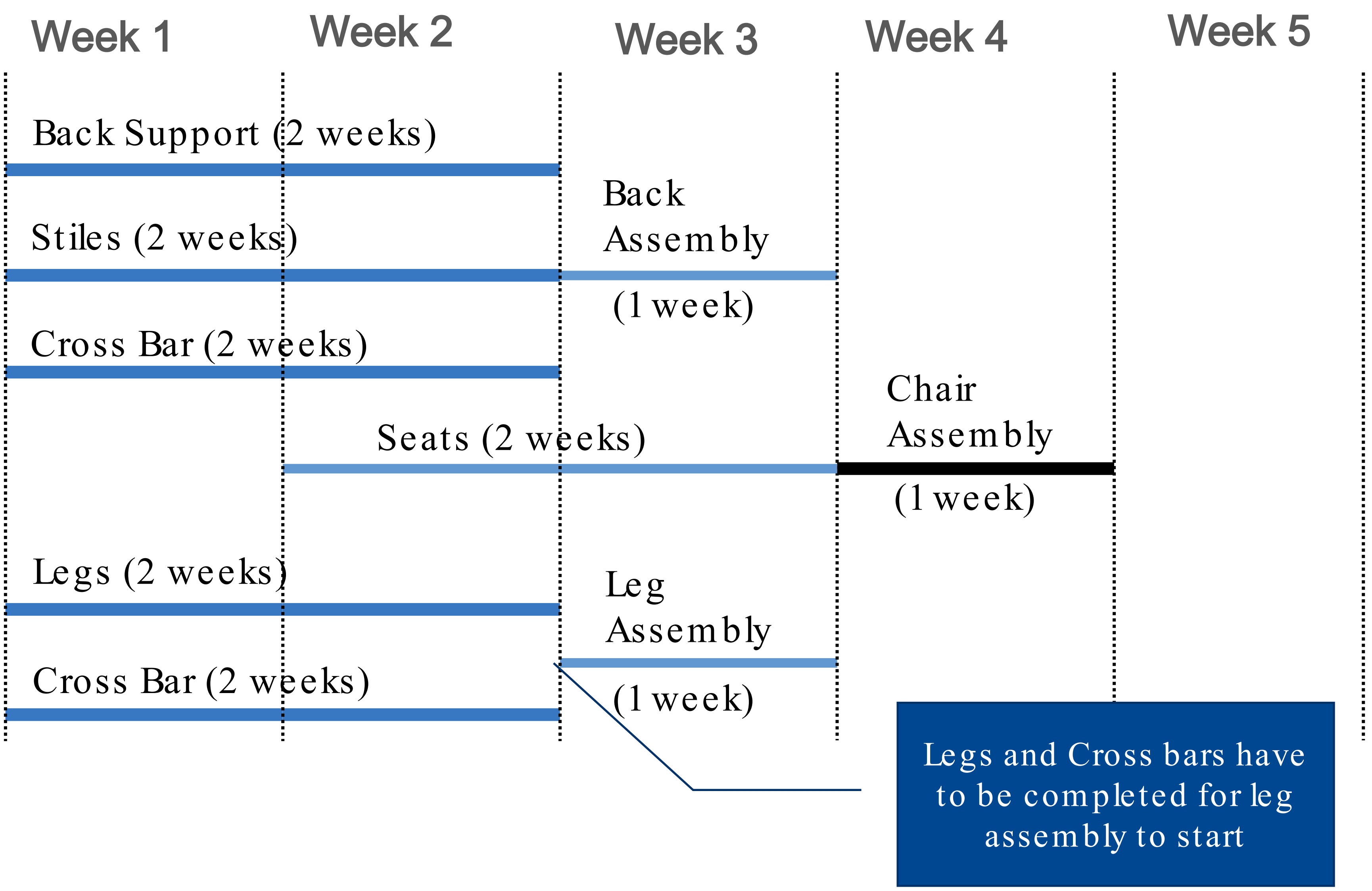


BOM for the chair



*Lead Time (LT) in weeks

Time phased product structure of chair using lead time



Basic MRP processes

1. Netting

-Determine net requirements by subtracting on -hand inventory and any scheduled receipts from gross requirements

-Gross requirements
comes from MPS for end items
comes from MRP results of parent items for a lower-level item

2. Time phasing

Offset the due dates of the jobs by lead times to determine the start times

3. Lot sizing

– divide the net requirements into lot sizes to form jobs.

For example; lot for lot (L4L), EOQ, etc.

4. BOM explosion

– Use the start times, lot sizes, and the BOM to generate gross requirements for any required component at the next level

5. **Repeat** this process for all levels

MRP starts with MPS

Assume that we've scheduled 90 chairs to be ready five weeks from now. And the forecasted demand of chair for the following weeks is as follows;

Week	5	6	7	8	9	10	11	12	13
Demand	90	48	29	38	37	110	45	25	65

Say, the firm receives returns from its suppliers due to minor mistakes and after repairing they are returned to finished good inventory to be shipped.

Week	5	6	7	8	9	10	11	12	13
Scheduled receipts	25			15		5			

MRP starts with MPS

MPS of end product (=chair)

It is expected to have 15 chairs in inventory at the end of week 4!

Item:Chair Lead t=1wk L4L	WEEKS												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross requirement					90	48	29	38	37	110	45	25	65
Scheduled receipts					25			15		5			
On hand inventory				15									
Net predicted demand					50	48	29	23	37	105	45	25	65
Planned order receipts					50	48	29	23	37	105	45	25	65
Planner order releases - Time-phased net requirements				50	48	29	23	37	105	45	25	65	

MRP for back assembly

Item:Back assm. Lead t=1wk L4L	WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross requirement					50	48	29	23	37	105	45	25	65	
Scheduled receipts					0	0	0	0	0	0	0	0	0	0
On hand inventory					0	0	0	0	0	0	0	0	0	0
Net predicted demand					50	48	29	23	37	105	45	25	65	
Planned order receipts					50	48	29	23	37	105	45	25	65	
Planned order releases				50	48	29	23	37	105	45	25	65		
Ending inventory					0	0	0	0	0	0	0	0	0	0

MRP for back supports

Minimum allowed order quantity is 200 and orders have to be in multiples of 200.

Assume that we predict to have 300 back supports at the end of week 2 in inventory.

Item:Back supports Lead t=2wk Order Q=200	WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross requirement				150	144	87	69	111	315	135	75	195		
Scheduled receipts				0	0	0	0	0	0	0	0	0		
On hand inventory			300	150	6									
Net predicted demand						81	69	111	315	135	75	195		
Planned order receipts						200		200	200	200		200		
Planned order releases				200		200	200	200		200				
Ending inventory						119	50	139	24	89	14	19		

Alternative lot sizing schemes

Lot for lot rule is not necessarily the optimal solution.

What do we have?

- A known set of time -varying demands
- Cost of setup (cost of giving order)
- Holding cost

What order/production quantities will minimize the total holding and setup cost over the planning horizon?

Alternative lot sizing schemes

Economic order quantity (EOQ)

Lets say, for **back assembly** ;

Fixed order cost, K = $200

Annual interest rate = 15%

1back assembly costs,c=100$

Weekly holding cost,h, = (0,15*100)/52 = $0,29

λ, average yearly demand, can be approximated by calculating the average of gross requirements.

λ = 50+48+29+….+25+65=427/9=47 units/week

$$Q = \sqrt{\frac{2K\lambda}{h}} = \sqrt{\frac{2 * 200 * 47}{0{,}29}} = 255$$

Alternative lot sizing schemes

Economic order quantity (EOQ)

Item:Back assm. Lead t=1wk Order Q=255	WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross requirement					50	48	29	23	37	105	45	25	65	
Scheduled receipts					0	0	0	0	0	0	0	0	0	0
On hand inventory					0	0	0	0	0	0	0	0	0	0
Net predicted demand					50	48	29	23	37	105	45	25	65	
Planned order receipts					255					255				
Planned order releases				255					255					
Ending inventory					205	157	128	105	68	218	173	148	83	

Cost comparison

What is the cost of L4L ordering for back assembly?

Item:Back assm. / Lead t=1wk / L4L	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	13
Planned order receipts				50	48	29	23	37	105	45	25	65	
Ending inventory				0	0	0	0	0	0	0	0	0	0

Cost for L4L= 9*200 = **$1800** Only setup cost, no inventory!

What is the cost of EOQ for back assembly?

Item:Back assm. / Lead t=1wk / Order Q=255	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	13
Planned order receipts				255					255				
Ending inventory				205	157	128	105	68	218	173	148	83	

Total inventory = 205+157+...+148+83=1285

Cost for EOQ=2*200 + 1285*0,29 = **$773**

Alternative lot sizing schemes

Silver – Meal Heuristic

=is any approach to problem solving that employs a practical methodology not guaranteed to be optimal or perfect, but sufficient for the immediate goals.

C(T) = average holding and setup cost per period if the current order spans the next T periods.

Let $(r_1, r_2, \ldots, r_n)$ be the net requirements over the n planning horizon.

$C(1) = K$, no holding cost since we order only for 1st period,

$C(2) = (K + h*r_2)/2$

$C(3) = (K + h*r_2 + 2*h*r_3)/3$

$C(j) = (K + hr_2 + 2hr_3 + \ldots + (j-1)hr_j)/j$

Once $C(j) > C(j-1)$, stop and set $y1 = r_1 + r_2 + \ldots + r_{j-1}$ and begin the process again!

Alternative lot sizing schemes

Silver – Meal Heuristic for back assembly

For the back assembly r=(50, 48, 29, 23, 37, 105, 45, 25, 65)

Starting from the first period,
C(1) = 200
C(2) = (200 + 0,29*48) / 2 = 107 (<200)
C(3) = (200 + 0,29*48 + 2*0,29*29)/3 = 77 (<107)
C(4) = (200 + 0,29*48 + 2*0,29*29 + 3*0,29*23)/4 = 62 (<77)
C(5) = (200 + 0,29*48 + 2*0,29*29 + 3*0,29*23 + 4*0,29*37)/5=58 (<62)
C(6) = 446/6 = **74** (>58) stop and restart.

y_1 = 50+48+29+23+37 = **187**; Lets continue starting from period 6

C(1) = 200
C(2) = (200 + 0,29*45)/2 = 106 (<200)
C(3) = (200 + 0,29*45 + 2*0,29*25)/3 = 76 (<106)
C(4) = (200 + 0,29*45 + 2*0,29*25 + 3*0,29*65)/4 = 71 (<76)

Y_2 = 105+45+25+65 = **240**

Alternative lot sizing schemes

Silver – Meal Heuristic for back assembly

See the cost of silver-meal heuristic solution

Item:Back assm. / Lead t=1wk / Silver-meal heur.	WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13
Net predicted demand					50	48	29	23	37	105	45	25	65	
Planned order receipts					187					240				
Ending inventory					137	89	60	37	0	135	90	65	0	

Total cost = 2*200 + 613*0,29 = **$578** Less than both L4L and EOQ

Alternative lot sizing schemes

Least unit cost for back assembly

Similar to silver-meal heuristic except that instead of dividing the cost by j periods we divide it by the total number of units demanded through the spanned period j, $r_1+r_2+...+r_j$. For back assembly;

C(1) = 200/50=4000
C(2) = (200+0,29*48)/ (50+48) = 2,183
C(3) = (200 + 0,29*48 + 2*0,29*29)/ (50+48+29) = 1,819
C(4) = (200 + 0,29*48 + 2*0,29*29 + 3*0,29*23)/(50+48+29+23)) = 1,653
C(5) = 1551
C(6) = 1527
C(7) = 1555 (>1,527) stop and restart. Y1 =**292**

C(1) = 200/45 = 4,444
C(2) = (200+0,29*25)/70 = 2,961
C(3) = (200+0,29*25+2*0,29*65)/135 = 1,814 Y2 = **135**

Alternative lot sizing schemes

Least unit cost for back assembly

Item:Back assm. / Lead t=1wk / Silver-meal heur.	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	13
Net predicted demand				50	48	29	23	37	105	45	25	65	
Planned order receipts				292						135			
Ending inventory				242	194	165	142	105	0	90	65	0	

Total cost = 2*200 + 1003*0,29 = **$691**

Alternative lot sizing schemes

Part Period balancing

Order horizon is set equal to the number of periods that most closely matches the total holding cost with the setup cost over that period .

Order horizon	Total holding cost
1	0
2	14
3	31
4	51
5	94
6	246
…	…

Setup cost is 200, which is closer to 246 than to 94. First order horizon is for 1, 2, ...,6.

Y1=292

Y2=135

Part period balancing gives the same result with least unit cost heuristic!

MRP in application, when to update?

Regenerative MRP

Regenerates all requirements

- All material requirements are regenerated once every planning period (usually a week)
- All previous plans are erased and replaced by new one
- Several parts are planned although there has not been changed in their plans

Net Change MRP

A Transaction Driven System

- The system only plans materials that have undergone a change relevant to MRP since the last planning run
- Only those parts needing re-planning are affected
- Computer processing time is significantly reduced
- More frequent run is required

MRP in application

Selection Criteria for Net Change and Regenerative MRP

A Net Change System is best for:

- Complicated product designs
- Short production runs for many products
- Frequent design changes
- Unstable purchased part supplies

A Regenerative System is best for:

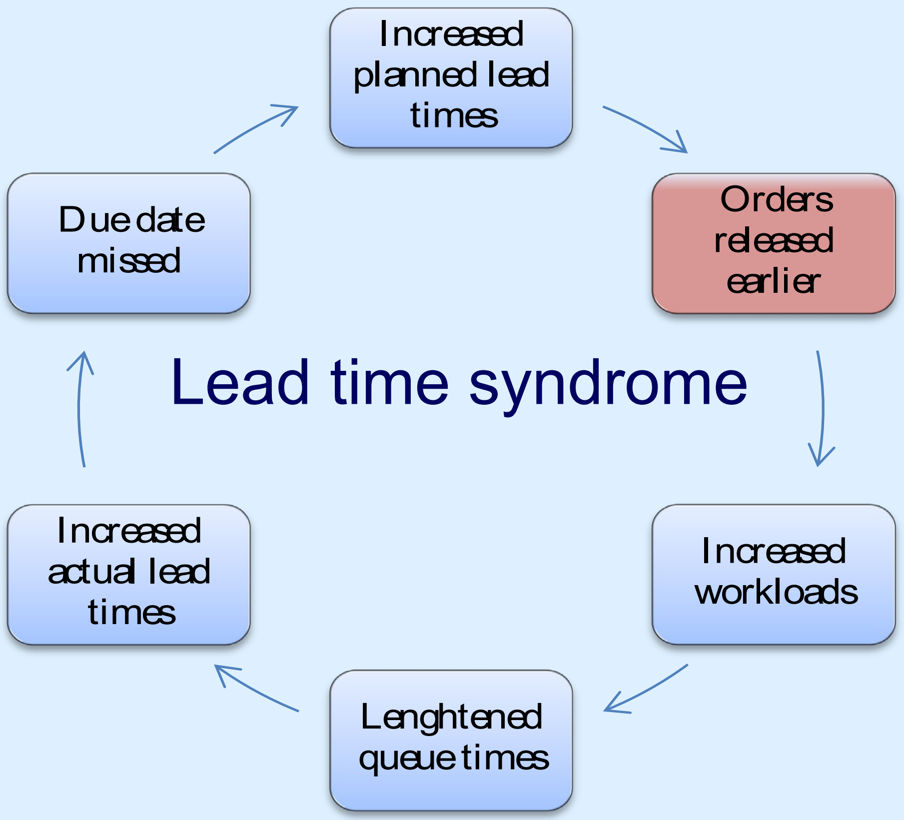
- Simple product designs
- Long and stable production runs
- Few design changes
- Stable purchased item supplies

Key points in MRP

- Maintain accurate data input
  - Forecasts, orders, on hand balances, and routing
- Proper treatment of expedited orders
  - e.g., the addition of extra resources
- Close collaboration between marketing and manufacturing
- Proper shop floor feed back and tracking
- Early notification of changes
- Absolute accuracy in Bill of Materials
- Accurate inventory records
- Accurate routings and purchasing records
- Full understanding of the system’s algorithms and logic

MRP shortcomings : Reality (uncertainty)

- MRP is deterministic but reality is not. Therefore, the system needs safety stock and safety lead times.
- Safety stock protects against quantity uncertainties.
  - You don't know how much you will make, so plan to make a little extra.
- Safety lead time protects against timing uncertainties.
  - You don't know exactly when you will make it, so plan to make it a little early.



MRP shortcomings : Capacity

- Capacity is not directly taken into consideration in MRP.
- Lot sizing methods with capacity constraints in equation deal with one level, do not solve the overall capacity problem.
- Capacity requirement planning (CRP) does
  - Schedule overtime for bottleneck stations
  - Revise MPS for planned order releases to fit into available capacity.

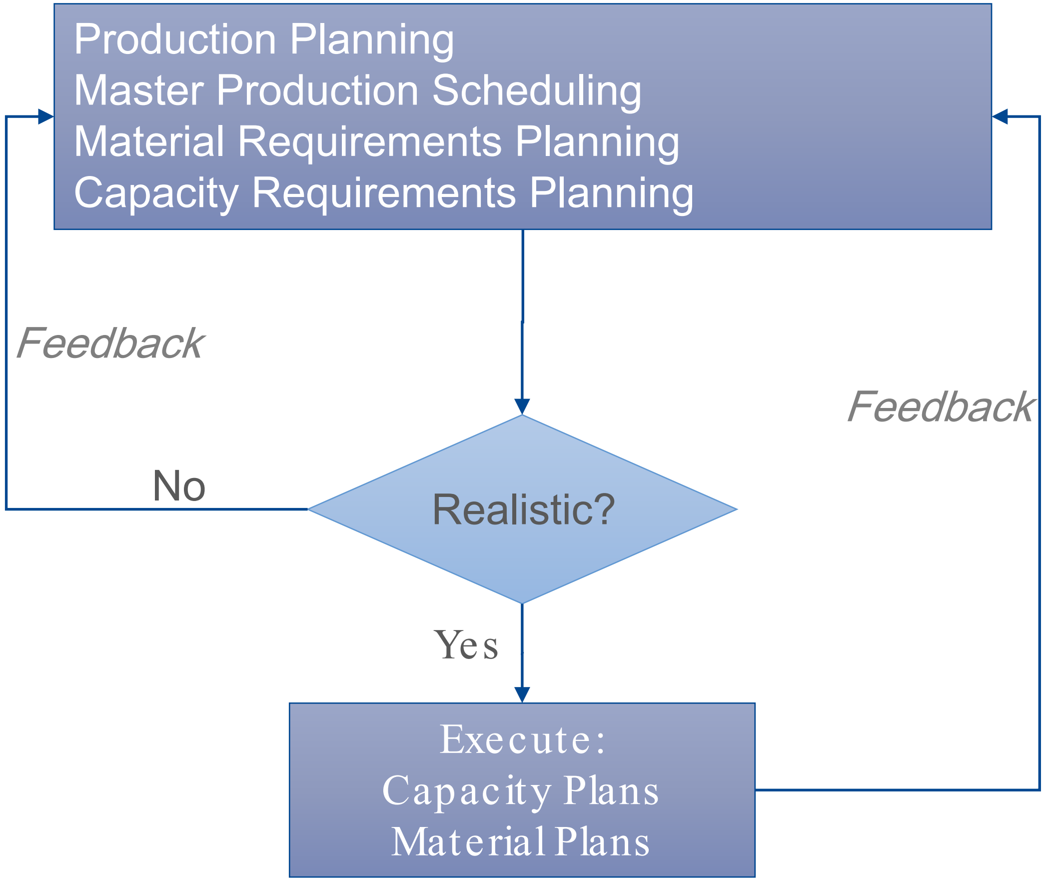
MRP shortcomings : Rolling horizon and system nervousness

- Rolling horizons refer to the situation in which only the first period decision of N -period problem is implemented. The full N-period is rerun each period to determine a new first period decision
- MRP nervousness occursas a result of the high frequency of updating the MRP system
  - If an MRP system is updated too frequently, the system becomes unstable and inefficient. On the other hand, if the system is not updated frequently enough, the system becomes inflexible and employs invalid data.

Extensions of MRP

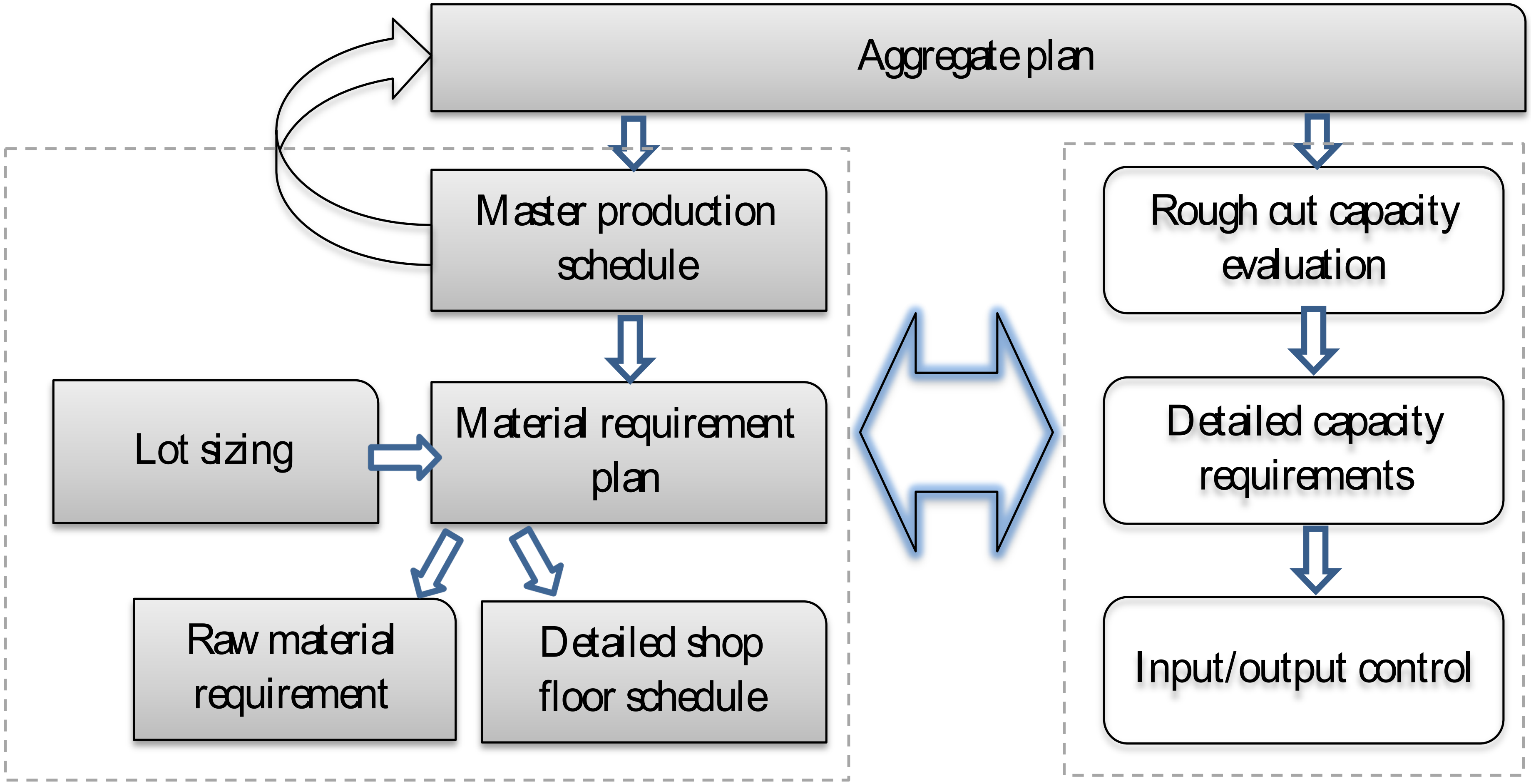
Closed-Loop MRP

- MRPsystem provides input to the capacity plan, MPS, and production planning process
- MRP system generates a load report which details capacity requirements
- This is used to drive the capacity planning process
- Changes pass back through the MRP system for rescheduling



Extensions of MRP

Closed-Loop MRP



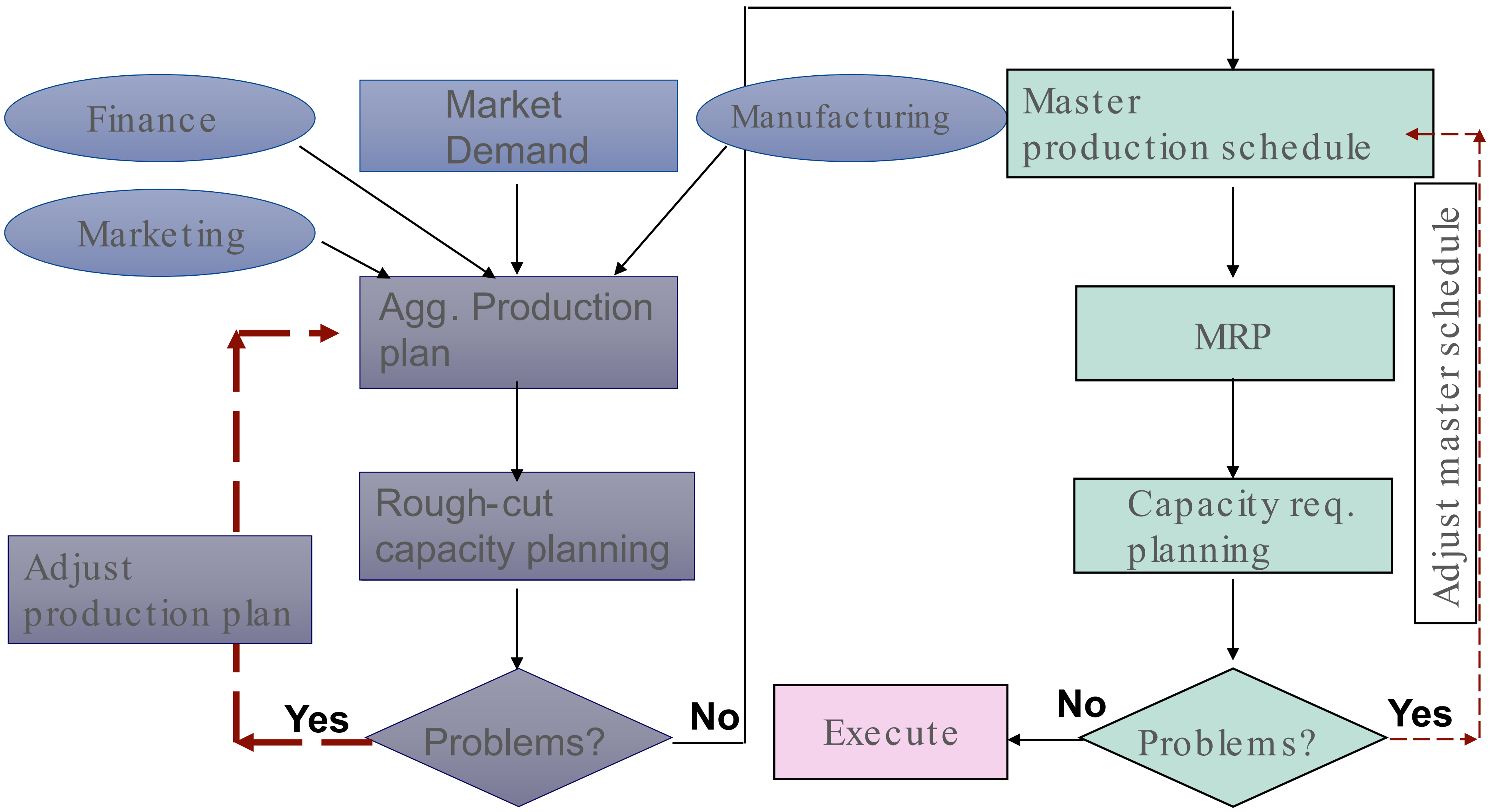
Extensions of MRP

Manufacturing Resource Planning (MRP II)

- Goal: Plan and monitor all resources of a manufacturing firm by integrating them together. (closed loop):
  - manufacturing
  - marketing
  - finance
  - engineering
- Simulate the manufacturing system

Extensions of MRP

Manufacturing Resource Planning (MRP II)



Extensions of MRP

Enterprise Resource Planning (ERP)

- The next step in the evolution that began with MRP and evolved into MRP II
- ERP system is a computer system that integrates application programs in accounting, sales, manufacturing, human resources and other functions in the firm.
- ERP provides a system to capture and make data available in real time to decision makers and other users in the organization
- MRP II with ties to customers and suppliers (connects with supply -chain and customer management applications)
- Provides tools for planning and monitoring various business processes

Extensions of MRP

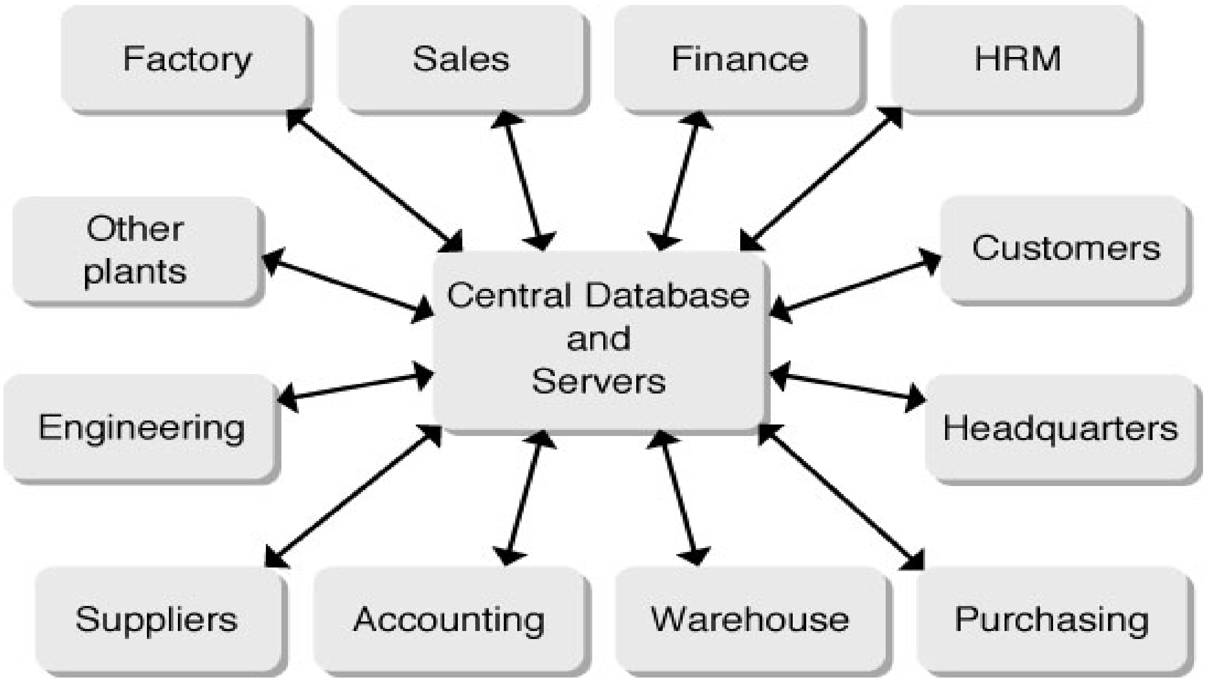
Enterprise Resource Planning (ERP)

- Attempts to integrate all departments and functions across a company onto a single computer system that can serve all those different departments' particular needs
- Organizes and manages a company's business processes by sharing information across functional areas
- Standardized record-keeping permit information sharing and communication throughout the organization

Extensions of MRP

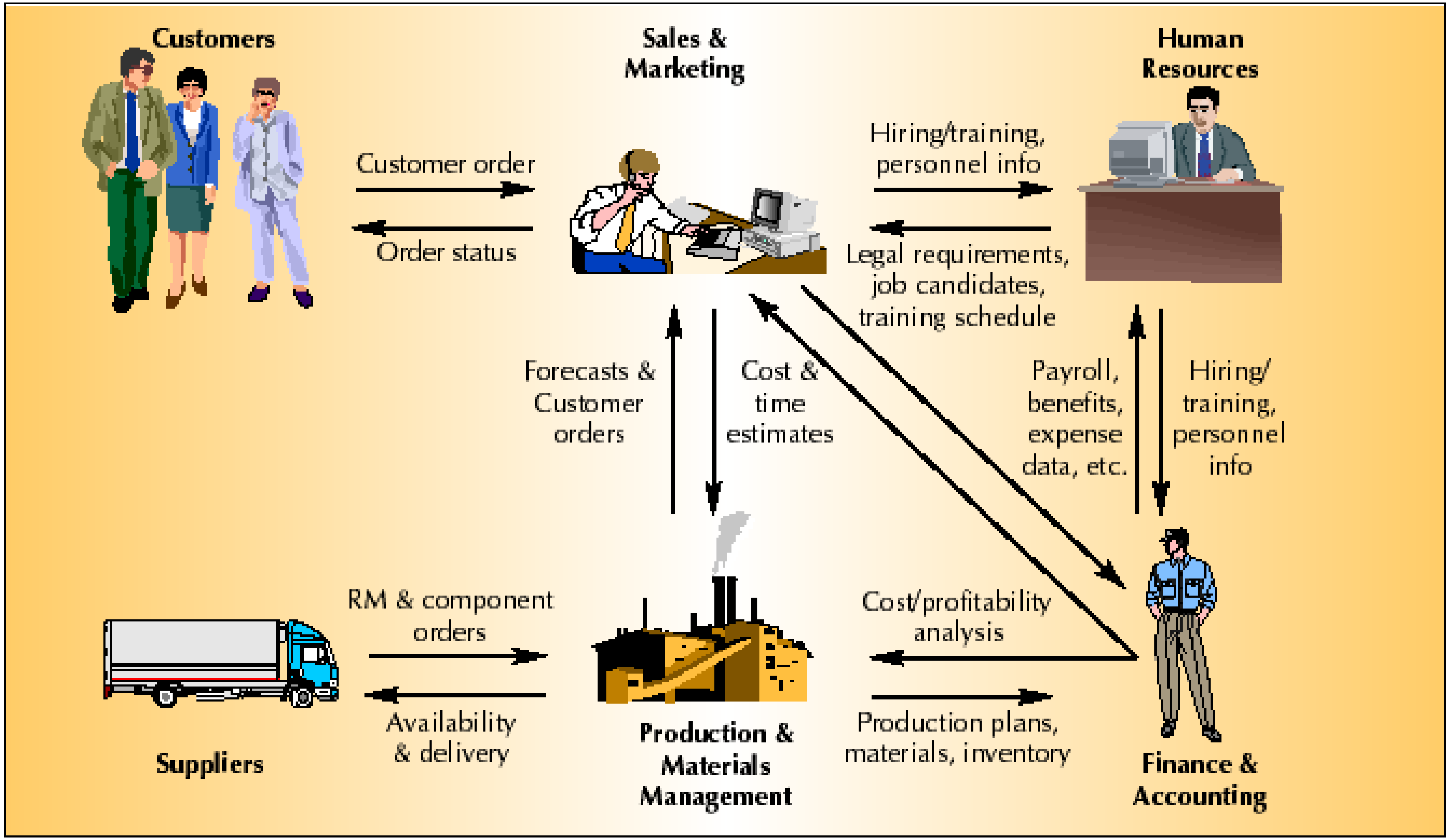
Enterprise Resource Planning (ERP)

- Such an integration is accomplished through a database shared by all the application programs



Extensions of MRP

ERP modules

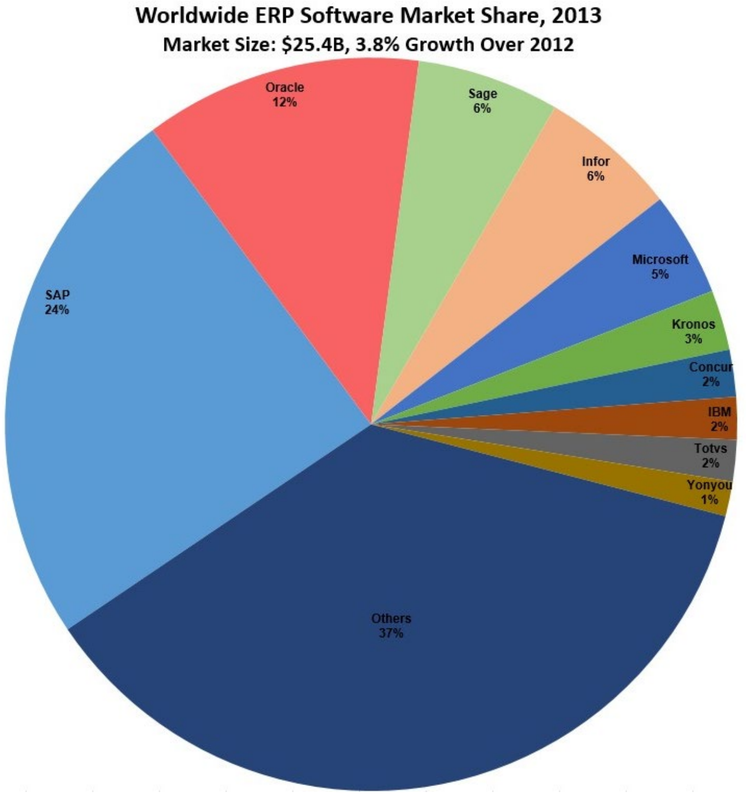


Extensions of MRP

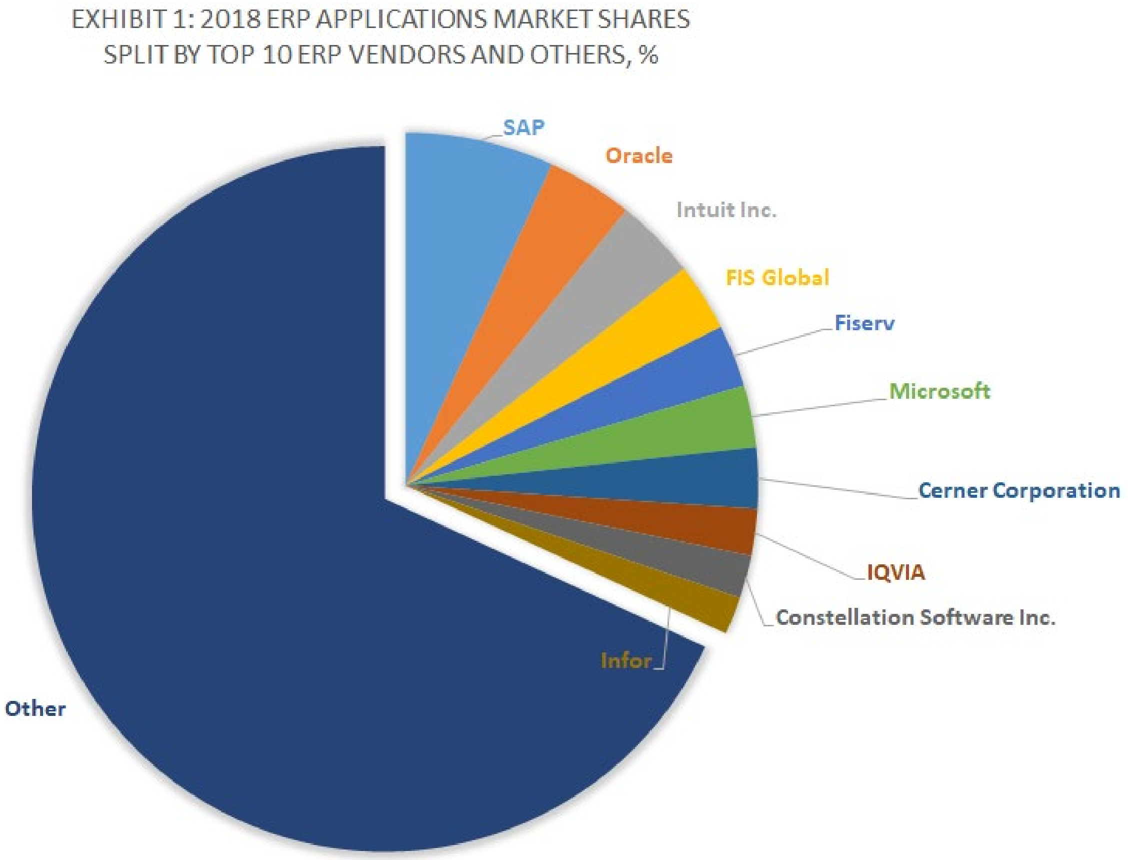
Enterprise Resource Planning (ERP)

- Reasons to Implement ERP
  - Desire to standardize and improve processes
  - To improve the level of systems integration
  - To improve information quality
- ERP Drawbacks
  - Cost
    - $250M+ for a Fortune 100 company
  - Transition pain
    - Implementation resources
    - Training
    - Upgrades
    - Resistance to change

Major ERP companies



2018 Market size $91.1 billion



PUSH vs PULL process control

Push vs Pull

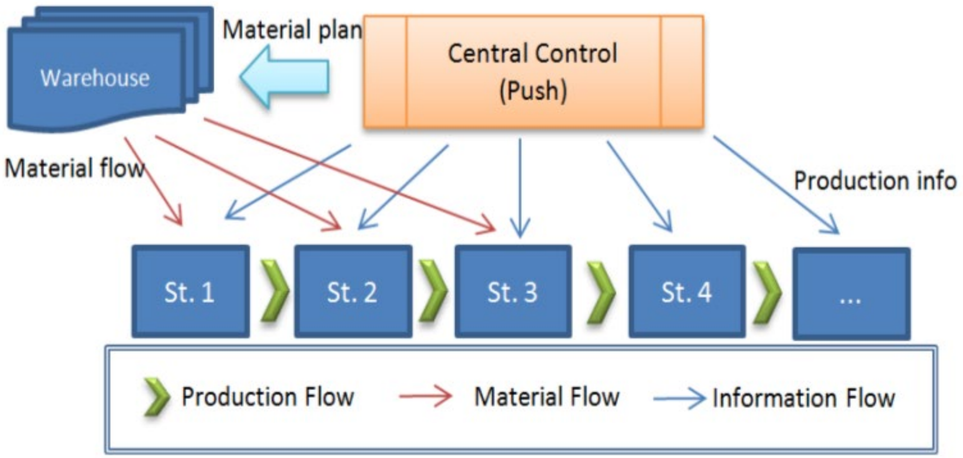
- MRP (Materials Requirements Planning). MRP is the basic process of translating a production schedule for an end product (MPS or Master Production Schedule) to a set of time based requirements for all of the subassemblies and parts needed to make that set of finished goods.
- JIT Just-in-Time. Derived from the original Japanese Kanban system developed at Toyota. JIT seeks to deliver the right amount of product at the right time. The goal is to reduce WIP (work-in-process) inventories to an absolute minimum.

Push vs Pull

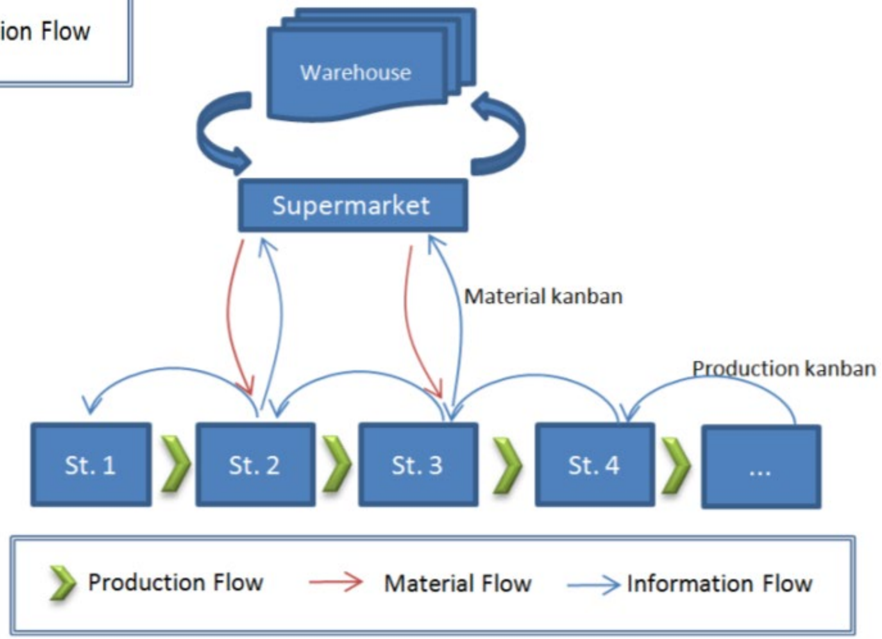
- MRP is the classic *push* system. The MRP system computes production schedules for all levels based on forecasts of sales of end items. Once produced, subassemblies are *pushed* to next level whether needed or not.

- JIT is the classic *pull* system. The basic mechanism is that production at one level only happens when initiated by a request at the higher level. That is, units are *pulled* through the system by request.

Push vs Pull



PUSH
Material Requirement
Planning - MRP



PULL
Just In Time - JIT

Push vs Pull

- These methods offer two completely different approaches to basic production planning in a manufacturing environment. Each has advantages over the other, but neither seems to be sufficient on its own. Both have advantages and disadvantages, suggesting that both methods could be useful in the same organization.
- Main Advantage of MRP over JIT: MRP takes forecasts for end product demand into account. In an environment in which substantial variation of sales are anticipated (and can be forecasted accurately), MRP has a substantial advantage.
- Main Advantage of JIT over MRP: JIT reduces inventories to minimum. In addition to saving direct inventory carrying costs, there are substantial side benefits, such as improvement in quality and plant efficiency.

JIT characteristics

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td colspan="2">JIT vs PULL</td></tr>
<tr><td>Limited and known final inventory</td><td>Every job is a ‘High Stress’ Rush order</td></tr>
<tr><td>Worker only consume their time & Raw Materials on what is actually needed</td><td>Balanced systems MUST be in place</td></tr>
<tr><td rowspan="2">Quality MUST be High – each piece has a definite place to go – else immediate feedback is given</td><td>Setup times will greatly impact throughput</td></tr>
<tr><td>Any problem will lead to unhappy customers (either internal or external)</td></tr>
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MRP characteristics

Advantages	Disadvantages
MRP vs PUSH	
Allows managers to manage, plan and control things	Can lead to large inventories
Requires intricate knowledge of production times & product flow	Can generate large quantities of scrap before errors are discovered
Can lead to economies of scale in purchasing and production	Requires diligence to maintain effective product flow
Allows for the planning and completion of complex assemblies as sub-components are delivered only by scheduled need	Requires maintenance of large and complex databases