Manufacturing Information System & Review of Operation Management

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Outline

Previously lecture...

- Change is everywhere and ever increasing, so does competition
- Effective response → Better communication → Right IT
- Issue surrounding IT in manufacturing
- Information technology is strategic advantage, not strategic necessity

This lecture...

- Realize important of Manufacturing System
- Review of key concepts of Operation Management, esp information flow in manufacturing system
- Illustrate how IS (i.e., MS Excel) helps with Aggregate planning, Inventory control, MRP, CRP

Manufacturing System, who care...

Criticism	Arguments
• Globalization	• Exposing to global shortage & geographic risk
• Large capital	• Yielding steady revenue
• Cooperate = Evil	• Similar to service industry
• Future is in service	• Relating to manufacturing (bank & software)

Manufacturing Classifications

- Business Classification
- Inventory Position
- Product & Process Matrix

Business Classification

- **What:** economic classification of industry and business
- **General:** Statistic & look for information
- **Pro MIS:** understand business, find implementation method

Sources

- North America Industry Classification System–www.census.gov
- Office of Industrial Economic (OIE)–www.oie.go.th
- Contract Directory– www.onbid.org

Office of Industrial Economic

สถิติอุตสาหกรรม

ISIC : 151110 ฆ่าสัตว์ เนื้อสัตว์แช่เย็น แช่แข็ง

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	พ.ค.	6,064.93	44,246.88	.00	21,482.87	20,303.94	2,575.00	41,786.81	5,950.00	65,526.00	1,423,681.58	7
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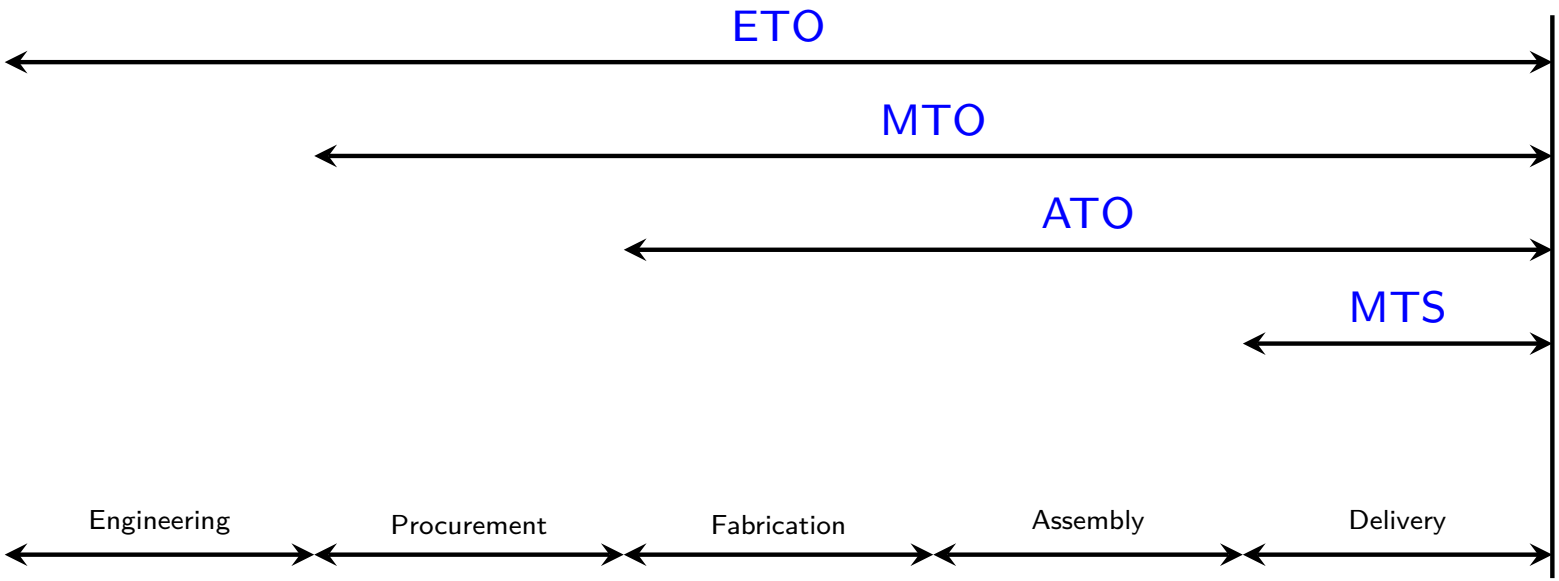
source: www.oie.go.th

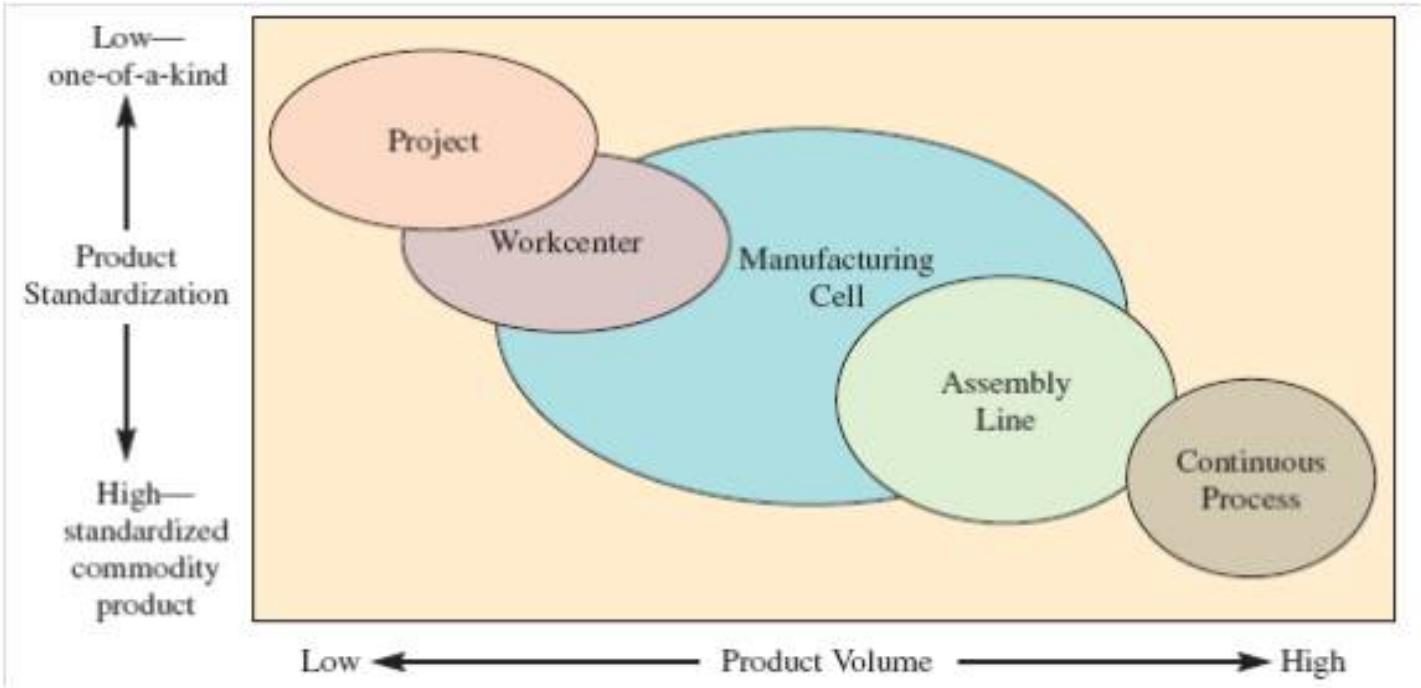
Inventory Position



source: Adopted from *Smith, S.* 1989.

- **Engineer to Order (ETO):** work with the customer to design and then make the product
- **Make to Order (MTO):** make the customer's product from raw mat'
- **Assemble to Order (ATO):** combine a number of preassembled modules to meet customer's specifications
- **Make to Stock (MTS):** serve customers from finished goods inventory

Production Process



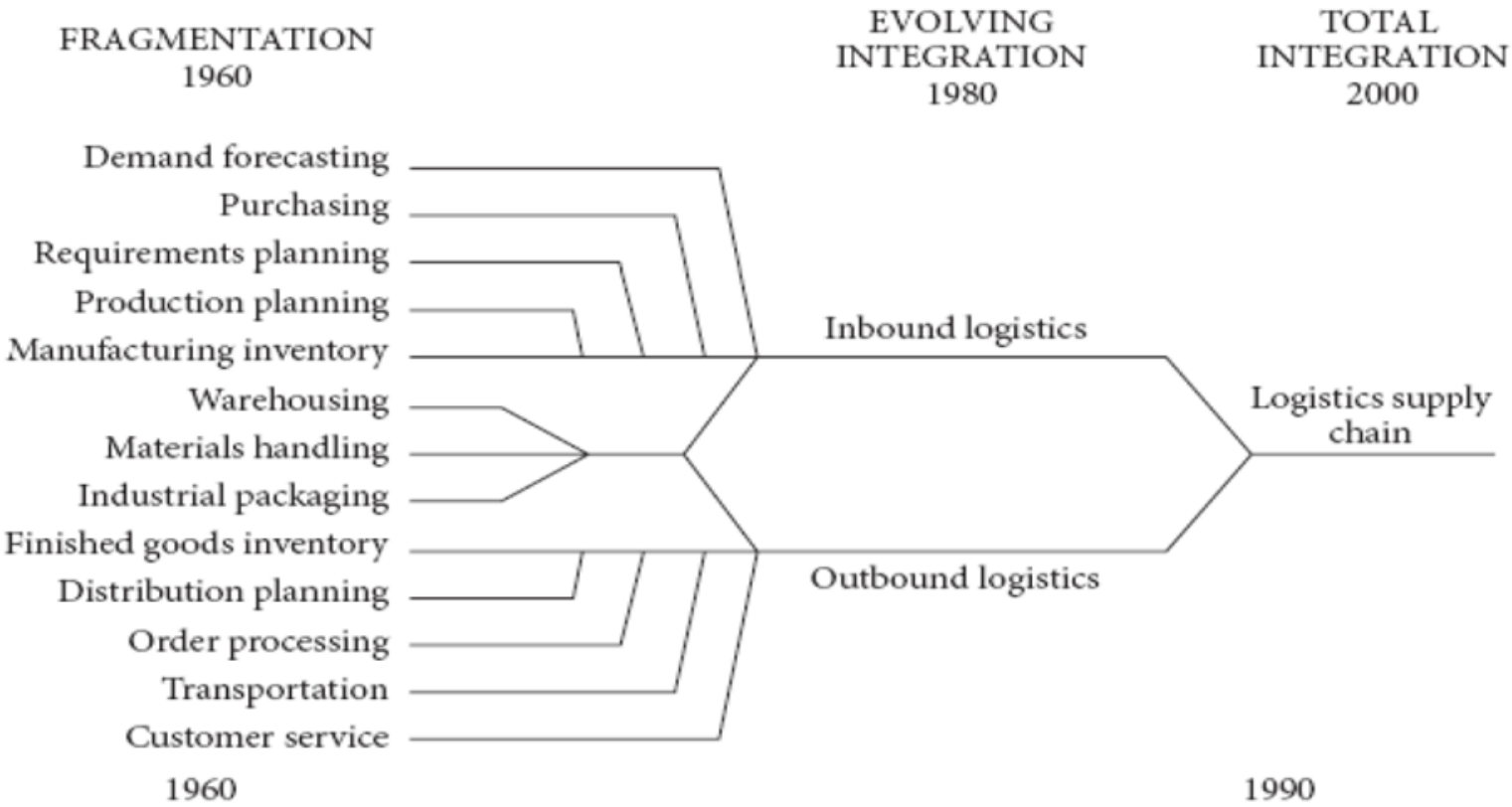
source: Chase & Jacabs. 2010. *Operation and Supply Chain Management*.

- **Project:** product remains in a fixed location
- **Work center:** similar equipment or functions are grouped together
- **Manufacturing Cell:** dedicated area where similar products are produced
- **Assemble line:** processes are arranged according to the progressive steps
- **Continuous process:** assembly line only the flow is continuous

System Structure

- **Hierarchical:** decision in upper-level $\rightarrow$ constraint in lower-level
- **Feedback:** systematic correction
- **Man-Machine interface:** $\nexists$ exceptions $\rightarrow$ including man
- **'Single' database & Integration:** maintaining data integrity and accuracy
- **Transparency:** understanding logic and algorithm behind system
- **Specific response time:** designing for improvement

Related issues with operation management

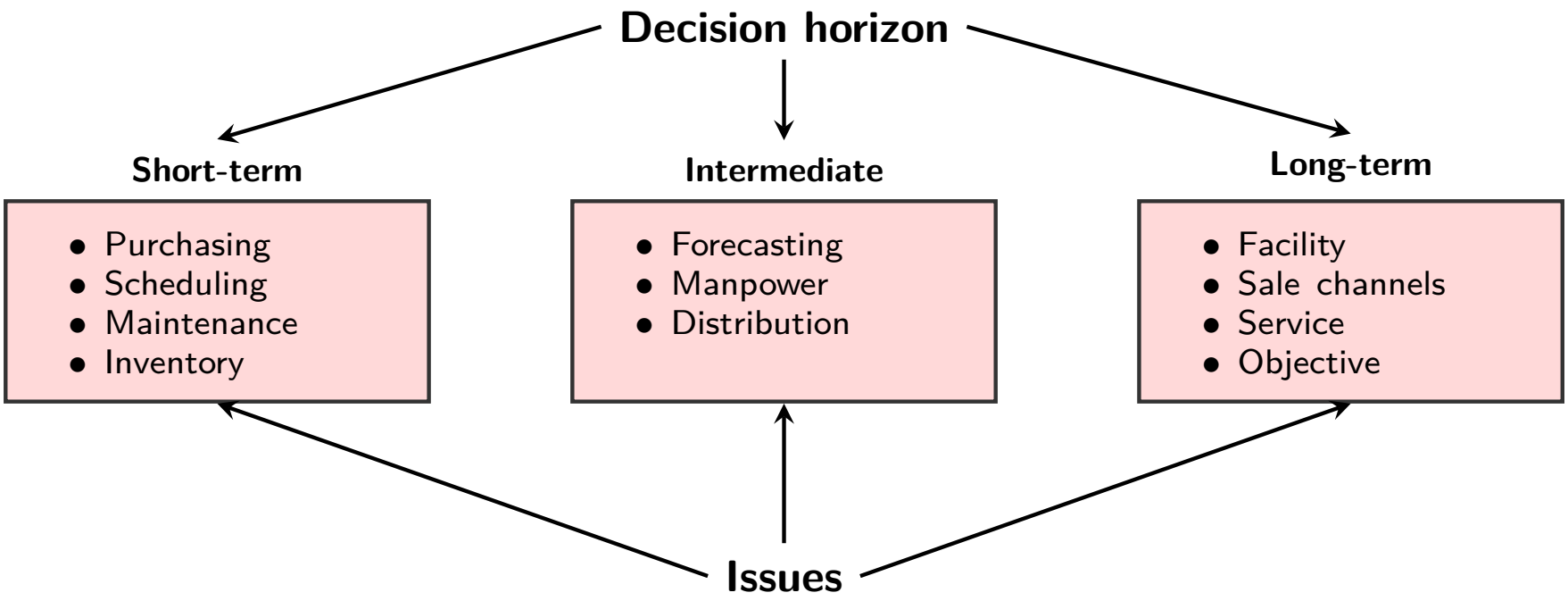


source: Center for Supply Chain Research, Penn State University

From Forecasting to Shipping...

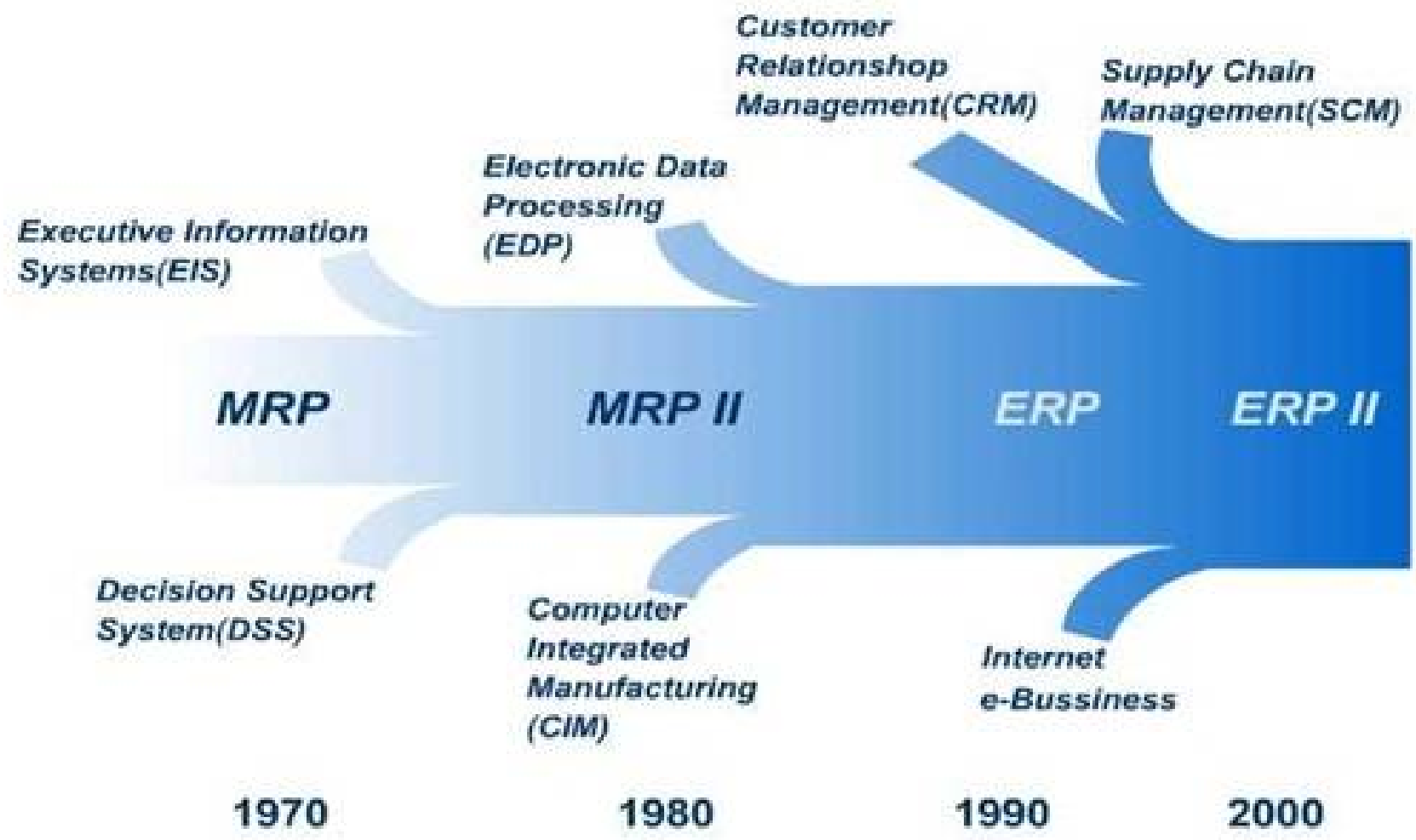
- Guessing customer's demands $\Longleftrightarrow$ Forecasting
- Smoothing resources $\Longleftrightarrow$ Aggregated planning & Demand management
- Sourcing R/M needed to produce $\Longleftrightarrow$ Purchasing & Material requirement
- Estimating producing time $\Longleftrightarrow$ Production planing
- Managing stocks $\Longleftrightarrow$ Warehousing & Inventory control
- Defining appropriated service level $\Longleftrightarrow$ Channel & Distribution management
- Ensuring commitment and delivery products$\Longleftrightarrow$ Shipping

Time Horizon



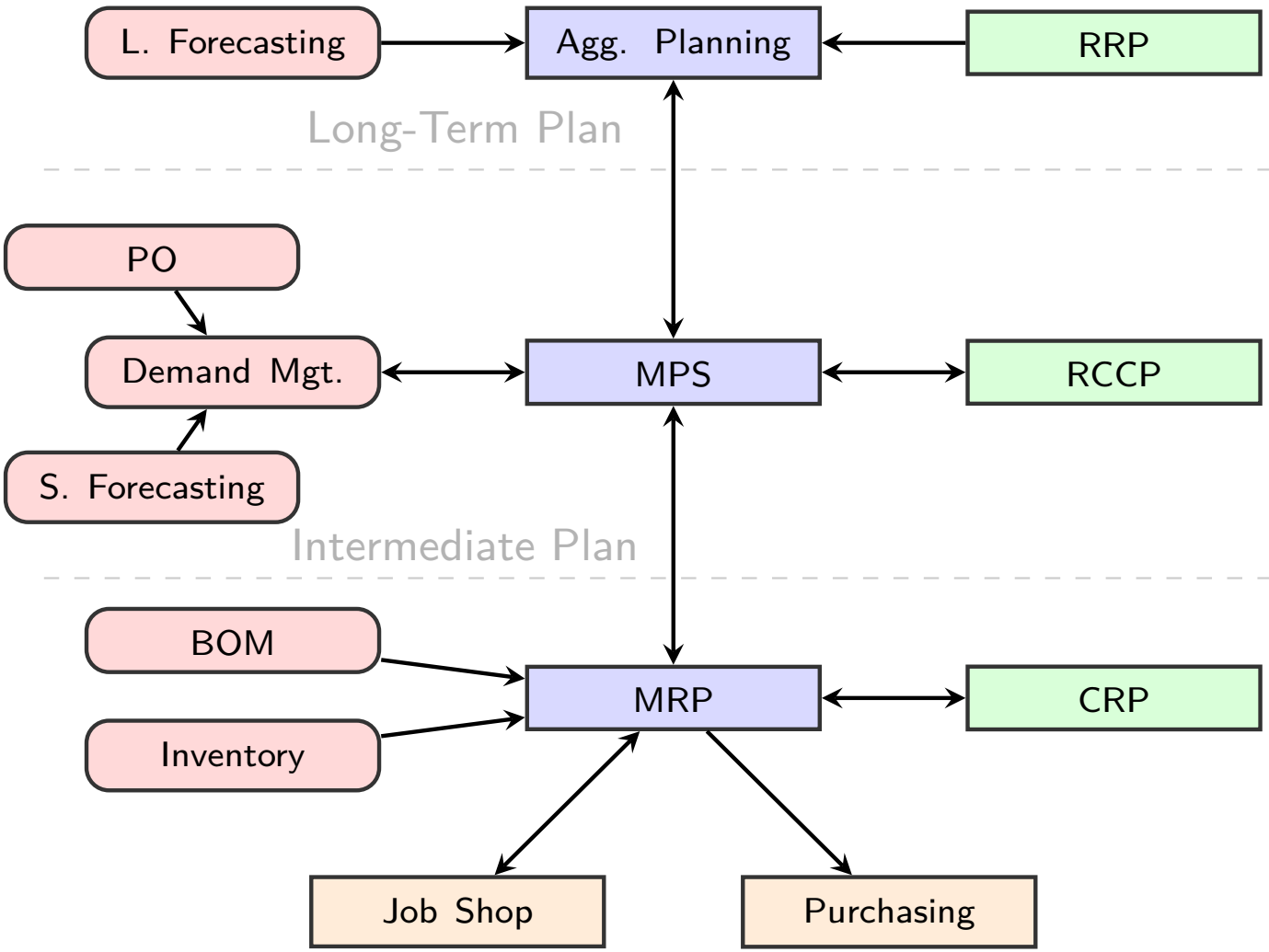
source: *Nahmias, S.* 2001.

Evaluation of Manufacturing IS



source: www.arhum.com

Closed-Looped Production Planning



source: *Smith, S.* 1989.

What is Forecasting?

- Predicting future value with data or information, e.g. weather forecasting

Forecasting affects all activities in organization

- **Workforce and Capacity:** hiring, training
- **Operation:** purchasing, scheduling, WIP, negotiation, planning
- **Accounting:** cash flow, equipment investment
- **Marketing:** pricing, promotion, place

How much products/services do we need and at which time (which location)?

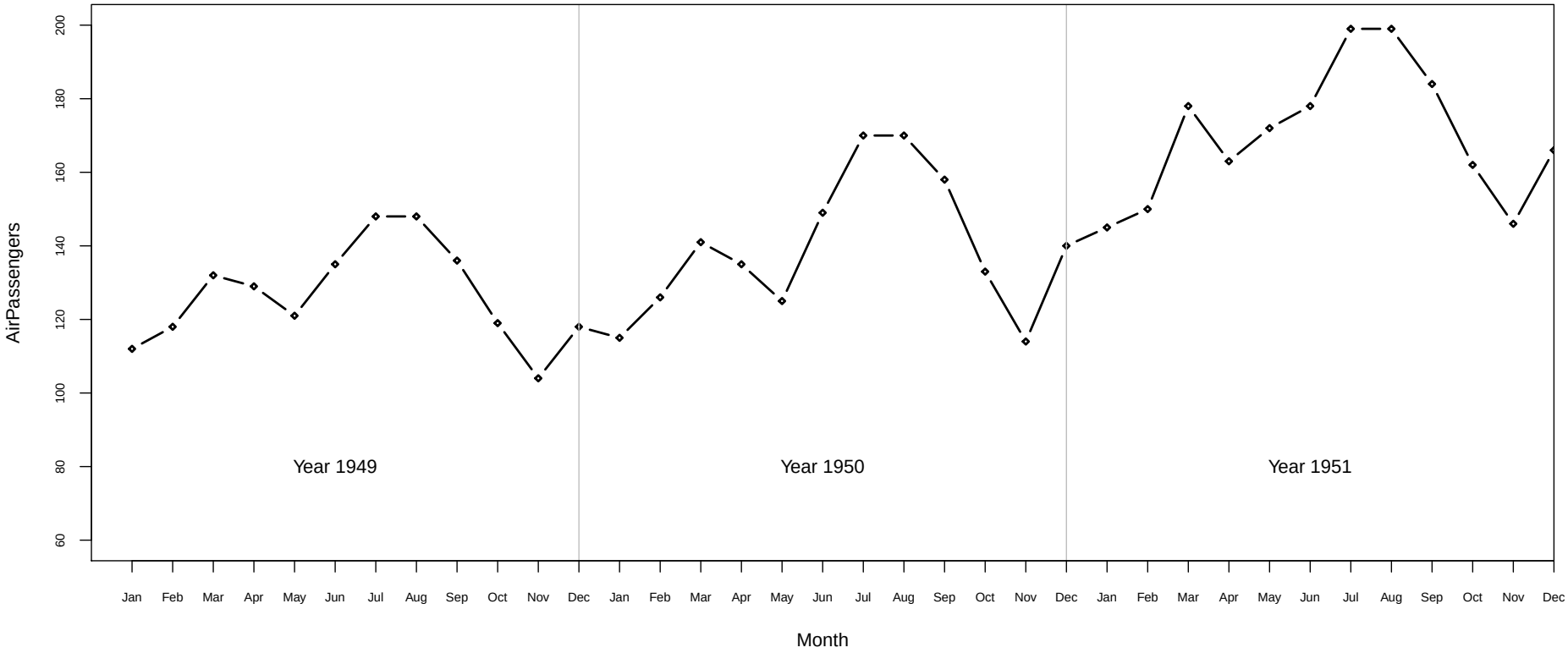
What should we aware before forecast?

- **Description:** story, relationship with other data
- **Time Horizon:** hour, day, week, year

  $$\text{Actual} = \text{Forecast} + \text{error}$$

- **Pattern of Data:** seasonal, trend, cycle
- **Forecasting Model:** assumption, data required, parameters, static VS dynamic
- **Accuracy:** measuring, how to improve

Example: US Air Passengers 1949-1951



Facts about Forecasting

- Forecasting is, typically incorrect
- Forecasting is suitable for a group of products
- Forecasting is inaccurate as time horizon increases

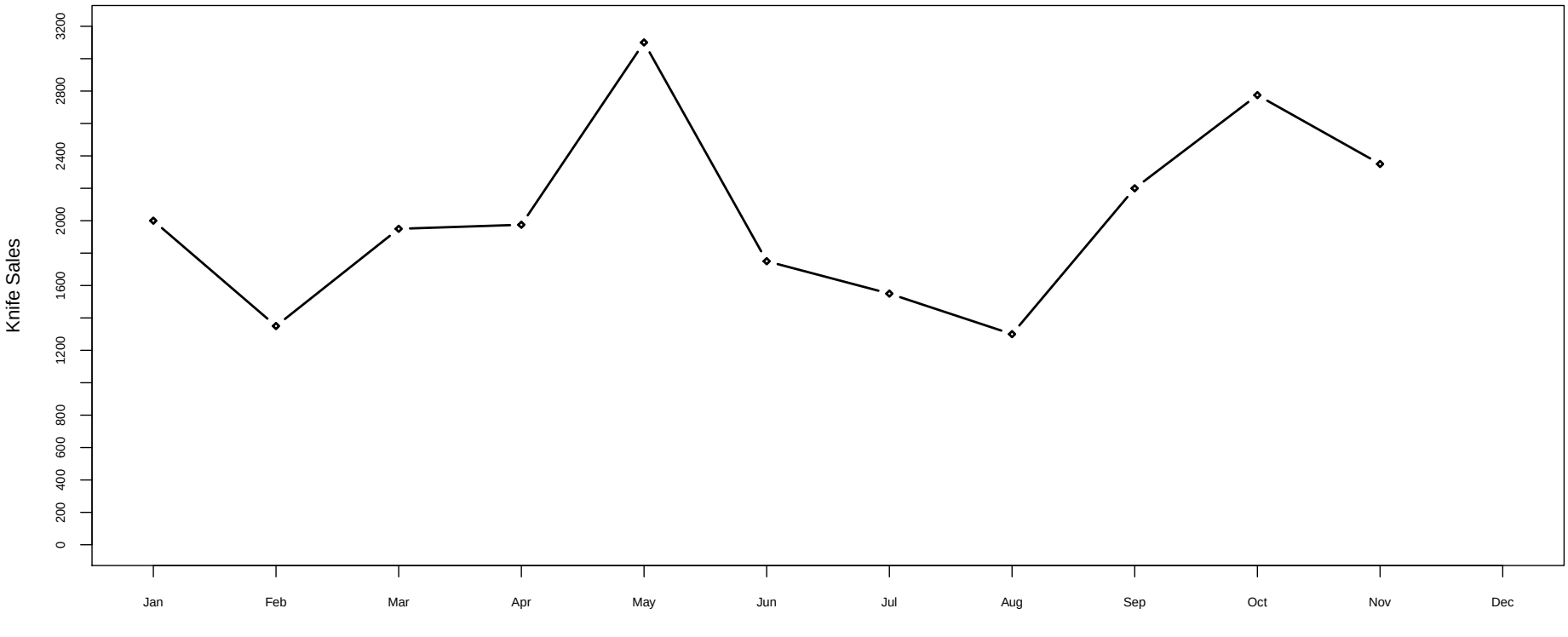
source: *Chopra, S. & Meindl* 2010. pp. 199

Why do we still need Forecasting?

- Incorrect future is better than knowing nothing
- Incorrect result is manageable

Smoothing: Simple Forecasting Methods

- **Assumption:** recent past $\approx$ future
- **Time Horizon:** short period
- **Data Pattern:** nearly constant
- **Benefit:** remove randomness, reduce sizes of data
- **Example:** Moving Average, Exponential Smoothing



Moving Average: MA(q)

- using average value of q pervious periods as forecast

$$F_t = \frac{1}{q}\sum_{i=1}^{q} A_{t-i}$$

F_t = Smoothing value at time t

A_t = Actual value at time t

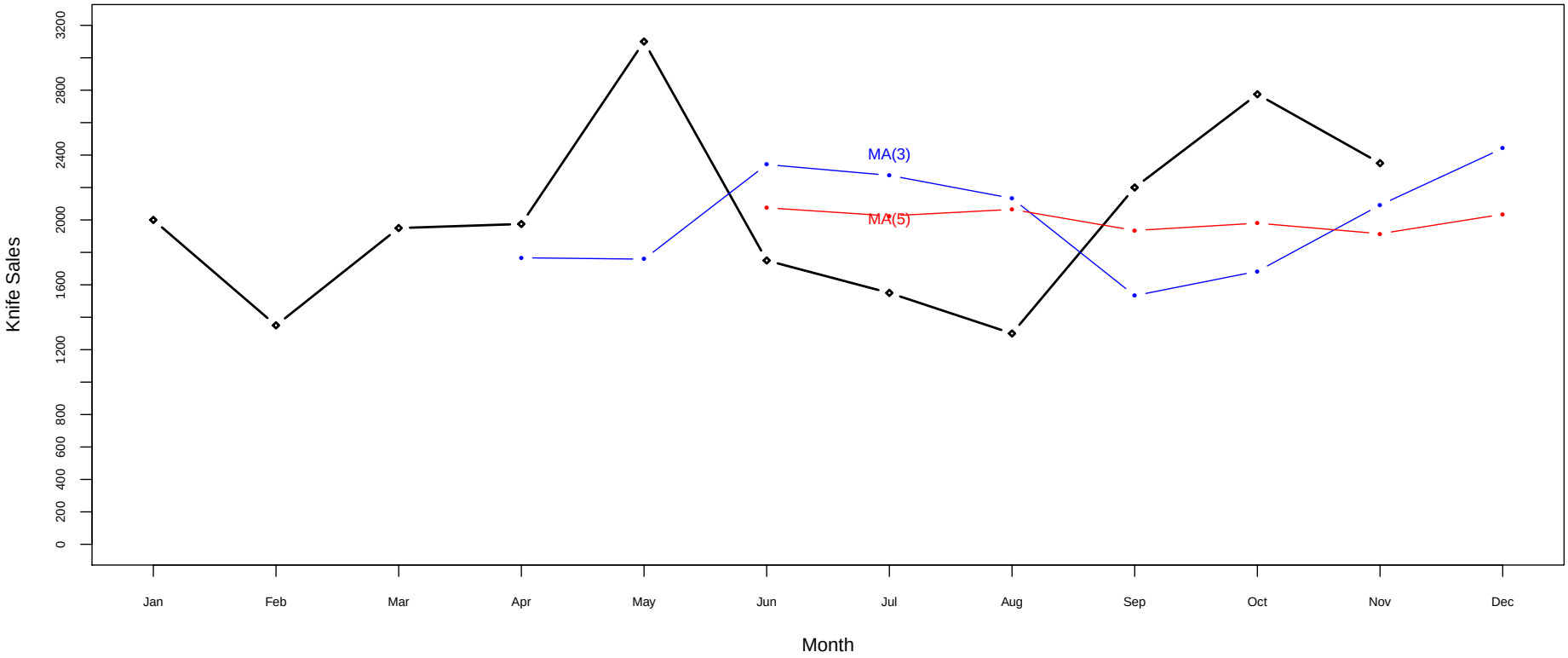
q = Numbers of interested period

Example of Moving Average

Month	Knife Demands	MA(3)	MA(5)
Jan	2000	-	-
Feb	1350	-	-
Mar	1950	-	-
Apr	1975	1767	-
May	3100	1758	-
Jun	1750	2342	2075
Jul	1550	2275	2025
Aug	1300	2133	2065
Sep	2200	1533	1935
Oct	2770	1683	1980
Nov	2350	2092	1915
Dec	-	2440	2034

source: Singkarlsiri C., 1997. pp.10-25

Which is a better MA model for Knife Sales?



Accuracy of Forecasting

- **Idea:**"average" of $\text{Actual}_t - \text{Forecast}_t$
- **Example:** Mean Error (ME), Mean Absolute Deviation (MAD), Mean Square Error (MSE), Mean Absolute Percentage Error(MAPE), Tracking signal (TS)

$$\text{ME} = \frac{1}{N}\sum_{t=1}^{N} A_t - F_t \qquad \text{MSE} = \frac{1}{N}\sum_{t=1}^{N} (A_t - F_t)^2$$

$$\text{MAD} = \frac{1}{N}\sum_{t=1}^{N} |A_t - F_t| \qquad \text{MAPE} = \frac{1}{N}\sum_{t=1}^{N} \frac{100\,|A_t - F_t|}{A_t}$$

$$\text{bias} = \sum_{t=1}^{N} A_t - F_t \qquad \text{TS} = \frac{\sum_{t=1}^{N} A_t - F_t}{\sum_{t=1}^{N} |A_t - F_t|}$$

Measurements of Error

If actual knife demand in Dec is 2400, Is MA(3) better than MA(5)?

	MA(3)	MA(5)
ME	152.59	41.71
MAD	639.3	488.9
MSE	567566.7	276407.4
MAPE	31.20	26.06

$$|\text{ME}| \leq \overbrace{\text{MAD} < \text{MSE}}^{\text{typically}}$$

Exponential Smoothing Model

- using a previous value and previous error as forecast

$$\begin{aligned} F_t &= F_{t-1} + \alpha\,(A_{t-1} - F_{t-1}) \\ &= \alpha\,A_{t-1} + (1-\alpha)F_{t-1} \end{aligned}$$

$$\begin{aligned} F_t &= \text{Smoothing value at time } t \\ A_t &= \text{Actual value at time } t \\ \alpha &= \text{Exponential factor}, \alpha \in [0,1] \end{aligned}$$

- **Idea:** Forecast $= \alpha$ Actual $+ (1-\alpha)$ Old Forecast

Why do we call "Exponential Smoothing"?

$$
\begin{aligned}
F_t &= \alpha\, A_{t-1} + (1-\alpha)\mathbf{F_{t-1}} \\
&= \alpha\, A_{t-1} + (1-\alpha)\left[\alpha\, A_{t-2} + (1-\alpha)F_{t-2}\right] \\
&= \alpha\, A_{t-1} + \alpha(1-\alpha)A_{t-2} + (1-\alpha)^2\mathbf{F_{t-2}}
\end{aligned}
$$

What does it mean?

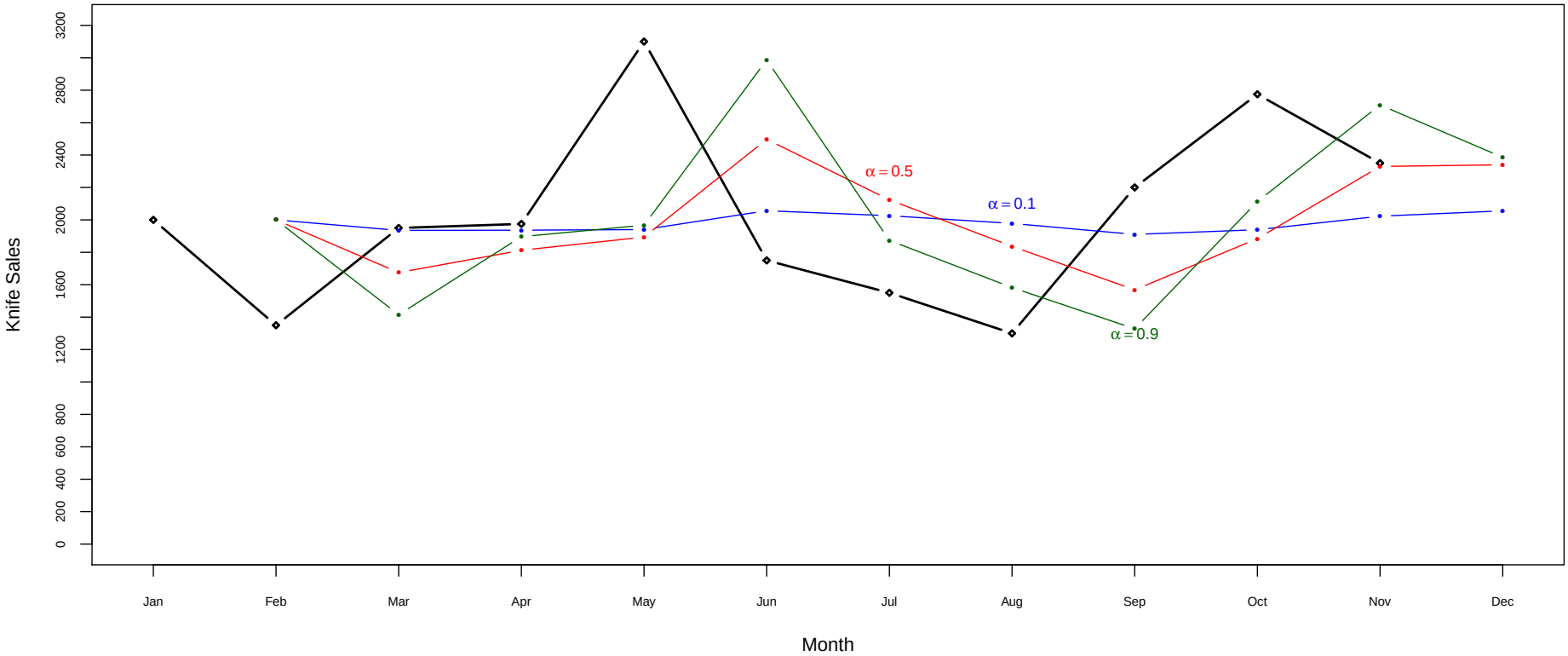
- Effects of actual value and error exponentially decay
- α controls the decay rate; F_1 is initial forecast value
- if $\alpha = 0$, no effect of actual value
- if $\alpha = 1$, no effect of forecast value

How to choose F_1 and α?

- **Good News**: effect of F_0 will decay; typically $F_1 = A_1$
- **Bad News**: select 'right' α is difficult $\rightarrow$ try out and error

Month	Knife Demands	$\alpha = 0.1$	$\alpha = 0.5$	$\alpha = 0.9$
Jan	2000	-	-	-
Feb	1350	2000	2000	2000
Mar	1950	1935	1675	1415
Apr	1975	1937	1813	1897
May	3100	1940	1894	1967
Jun	1750	2056	2497	2987
Jul	1550	2026	2123	1874
Aug	1300	1978	1837	1582
Sep	2200	1910	1568	1328
Oct	2770	1939	1884	2113
Nov	2350	2023	2330	2709
Dec	-	2056	2340	2386

Which α is a better?



Model Selection: Which one is better?

	Moving Avg.		Expo		
	MA(3)	MA(5)	$\alpha = 0.1$	$\alpha = 0.5$	$\alpha = 0.9$
ME	152.59	41.71	55.11	67.71	42.83
MAD	639.3	488.9	477.13	569.12	612.23
MSE	567566.7	276407.4	343032.73	433846.25	502956.28
MAPE	31.20	26.06	24.57	29.20	30.78

- What is the best parameter of these two models?
- What do they suggest?
- Fluctuation comes from randomness?

Guideline for Selection

Method	Observations	Patterns	Ranges
Regression	10-20	stationary, trend, seasonality	2-18 months
Moving average or Exponential smoothing	6-12	stationary	$\leq$ 3 months
Weighted moving average	5-10	stationary	$\leq$ 3 months
Exponential smoothing with trend	5-10	stationary trend	$\leq$ 3 months

source: *Jacob. etal* 2011.

What if data is not stationary?

Item Master File

- **Item number:**
- **Sale ID.** UPC Barcode (12 digits in US and 13 digits in other)
- **Lot/batch number:** e.g., pharmaceutical, ceramic tiles
- **Color/size code:** shade color, (UF case)
- **Buyer code:** link to receivable bank a/c
- **Supplier code:** link to payable bank a/c
- **SKU ID.** shortage and retrieving code
- **Drawing code:** link to engineering database
- **Family group:** category, e.g.,
- **Group technology code:** dimension, # holes, type material, strength

BOM & Routing File

BOM File: describing qtys to manufacturing item

- **Component item number:**
- **Parent item number:**
- **Quantity & Unit:**
- **Scrap allowance:**

Routing file: describing work to manufacturing item

- **Routing number:**

  for each operation

  - **Operation number:**
  - **Machine number & Tool number & WC number:**
  - **Drawing number:**
  - **Shrinkage:**
  - **Std labor & Std. setup time**

Work Center & Tool File

Work center: describing groups of machine/tool

- **Work center number:**
- **Location:**
- **Efficient & Utilization:**
- **Hours & Shift:**
- **Rate**

Tool File: describing machines/tool and their status $\rightarrow$ maintainace

- **Tool number:**
- **Status:**
- **Storage location:**
- **Current assignment:**
- **Tool life & Use since last repair:**
- **Next repair date**

Aggregated Planning

- **What:** planning for family of product
- **Idea:** smoothing demands & key resources (workers, # machine)
- **Occurred:** beginning of fiscal year (*unit:* month of sale)
- **Input:** long-term forecasting + key resources, policy (overtime, subcontract, backlog, machine capacity)
- **Output:** production plan, capacity, inventory

SkyCell: Aggregated planning

SkyCell, a European cell phone manufacturer, and its customers, service providers, come up with monthly forecast (in thousand cell phone) as follow:

Month	Demand	Month	Demand	Month	Demand
Jan.	1000	May	1500	Sep.	1100
Feb.	1100	Jun	1600	Oct.	800
Mar.	1000	Jul	1600	Nov.	1400
Apr.	1200	Aug	900	Dec.	1700

The manufacturing process is govern by numbers of assembly worker, totally 1250 workers. Each worker can assemble each cell phone every 10 minute. The plant operate 20 days a month, 8 hours a day and paid \$20 per hour and 1.5 time wage for any overtime (maximum 20 hour per worker-month). Total raw materials cost \$20, and handling cost is \$3 per unit-month. At the mean time, the company has no-lay off policy. SkyCell has inventory of 50,000 units in Jan and like to have the same level of inventory.

source: *Chopra, S. & Meindl* 2010. pp. 243

SkyCell: Question

Answer with following questions.

1. Assuming no backlog, no subcontractor, and no new hire/leave, what is optimal production scheduling?
2. Is any value to increase overtime from 20 hours per worker-month to 40 hour per worker-month
3. How the solution in (a) and (b) change if the numbers of assembly workers is 1200 and 1300 workers, respectively
4. What SkyCell can do to smooth its production (*open-end question*)?

source: *Chopra, S. & Meindl* 2010. pp. 243

SkyCell: Formulation

- **Objective Function:** minimize total costs of production, inventory, and wages
- **Decision Variables:** units produced, units storage, overtime

  x_t^{prod} = units produced in month t
  x_t^{inv} = units storage at the ending of month t
  y_t^{reg} = man-hours of regular-time in month t
  y_t^{over} = man-hours overtime in month t

- **Constraints:**
  - cell phone balancing each month
  - regular-time and overtime workloads of assembly worker each mouth
  - workloads required to produce cell phones in each month

SkyCell: Formulation

$$\min \; z = 20\sum_t x_t^{prod} + 3\sum_t x_t^{inv} + (20)(8)(20)\sum_t w_t \quad + 30\sum_t y_t^{over}$$

s.t.

balancing;	$x_t^{prod} + x_{t-1}^{inv}$	$= D_t + x_t^{inv}$	$\forall\ t \in\ \mathcal{T}$
production;	$10x_t^{prod}$	$= y_t^{over} + y_t^{reg}$	$\forall\ t \in\ \mathcal{T}$
limit overtime;	y_t^{over}	$\leq 20w_t$	$\forall\ t \in\ \mathcal{T}$
limit regular-time;	y_t^{reg}	$\leq 160w_t$	$\forall\ t \in\ \mathcal{T}$
non neg.;	x_t^{inv}	≥ 0	$\forall\ t \in\ \mathcal{T} \cup \{0\}$
non neg.;	$x_t^{prod}, y_t^{reg},\ y_t^{over}$	≥ 0	$\forall\ t \in\ \mathcal{T}$

Trial & Error 1: No Inventory

		1	2	3	4	5	6
Demand		1000	1100	1000	1200	1500	1600
RT prod.		950	1100	1000	1200	1200	1200
OT prod.						150	150
Outsource						150	250
Inventory	50	0	0	0	0	0	0

		7	8	9	10	11	12
Demand		1600	900	1100	800	1400	1700
RT prod.		1200	900	1100	800	1200	1200
OT prod.		150				150	150
Outsource		250				50	400
Inventory		0	0	0	0	0	50

Trial & Error 2: Constant Workforce

		1	2	3	4	5	6
Demand		1000	1100	1000	1200	1500	1600
RT prod.		1200	1200	1200	1200	1200	1200
OT prod.		42	42	42	42	42	42
Outsource							
Inventory	50	292	434	676	718	460	102

	7	8	9	10	11	12
Demand	1600	900	1100	800	1400	1700
RT prod.	1200	1200	1200	1200	1200	1150
OT prod.	42					
Outsource	256					
Inventory	0	300	400	800	600	50

Optimal

		1	2	3	4	5	6
Demand		1000	1100	1000	1200	1500	1600
RT prod.		950	1200	1200	1200	1200	1200
OT prod.			50	150	150	150	150
Outsource							
Inventory	50	0	150	500	650	500	250

	7	8	9	10	11	12
Demand	1600	900	1100	800	1400	1700
RT prod.	1200	900	1100	1200	1200	1200
OT prod.	150			50	150	150
Outsource						
Inventory	0	0	0	450	400	50

SkyCell: Analysis

Pre-solve analysis

- **Capacity Reg_time:** $1250 \times 160 \times 60/10 = 1{,}200{,}000$ units/ month
- **Capacity over_time:** $1250 \times 20 \times 60/10 = 150{,}000$ units/ month
- **Average Demands:** $\approx 1{,}242{,}000$ unit/month
- **Inventory VS Overtime VS Outsource:** minimize outsource

  Inventory: $\$20 + \frac{\$20}{6} + \$3 \times t = \$\ 23.33 + 3t$

  Overtime: $\$20 + \frac{\$20}{6} \times 1.5 = \$25$

  Outsource: $\$40$

Cost Comparison

	No Inv.	Const Prod	Optimal
Material	276,000	292,880	298,000
RT Labor	43,500	47,833	45,833
OT Labor	3,750	1,470	5,750
Inventory	150	14,496	8,850
Outsouce	66,000	15,360	0
Total	389,400	372,039	358,433

Problems with aggregated planning

Method

- **Price taker:** price can influence demand or negotiation (what if) → S&OP
- **Inventory of component:** lack of components → MPS & MRP
- **Capacity issues:** simplified production constraints → RCCP & CRP

Application

- **Aggregated product:** no information on exact product → communication
- **Delivery plan:** frequency, product mixed, lot size → communication

Sales and Operations Planning (S&OP)

- **What:** manage supply or demand to smooth production given predictable variability by involving related parties
- **Idea:** seasonal consumer demand, but fixed plant capacity
- **Who:** marketing, production, logistic, finance, HR
- **Man-Power Strategy:** chasing (hire VS fire), constant workforce, level (build inventory)
- **Managing supply:** capacity (flexible workforce & machine, subcontracting), investing (common component)
- **Managing demand:** shift or manipulate demand (using price) or promotion; may result to

  LOW DEMAND: smooth demand $\rightarrow$ low margin/ high inv. cost items
  PEAK DEMAND: steal share, expansion $\rightarrow$ high margin items

SkyCell: S&OP Question

Answer with following questions.

5 How solution in (a) change if backlog is allowed? The estimated cost of backlog is $70 per unit-month

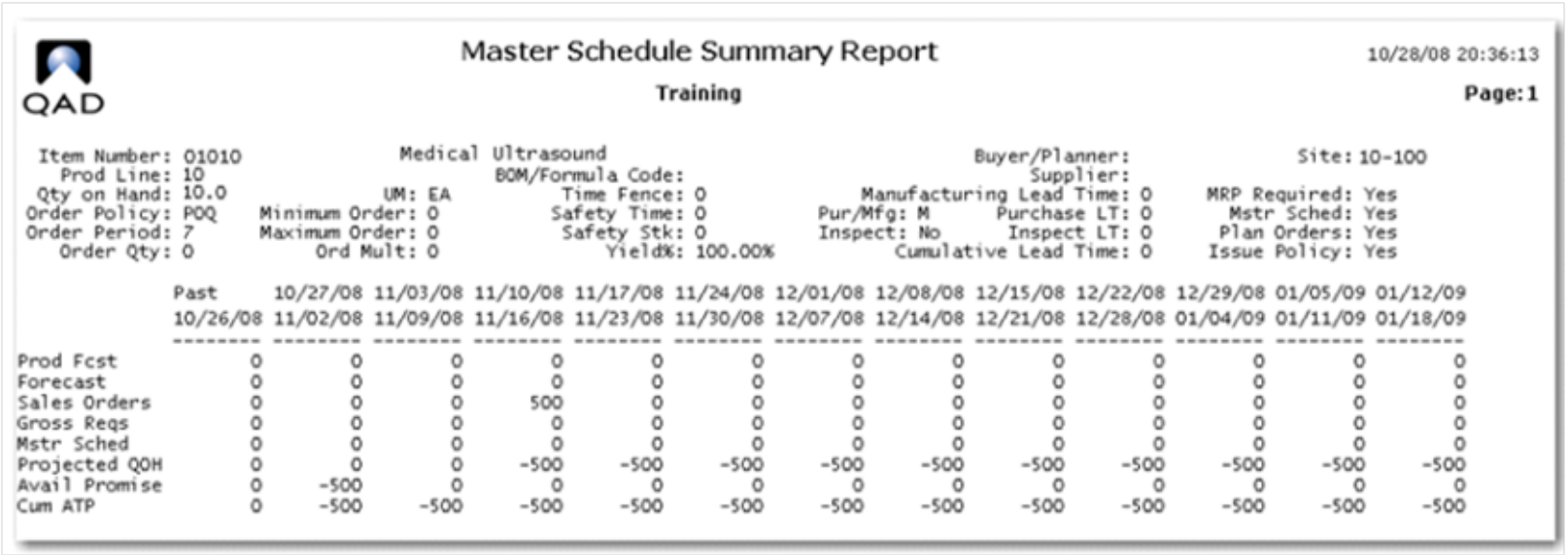
6 How solution in (a) change if temporary worker is allowed? Assuming that each new hire costs $500 and has 50% of productivity in his first month

7 If SkyCell has a promotion that can increase 25% of one month demand but decreases 20% of demands next two months. Which month should SkyCell apply the promotion?

source: *Chopra, S. & Meindl* 2010. pp. 243

Master Production Schedule (MPS)

- **What:** planning for finish good (end-item Planning)
- **Idea:** rough plan for produce or stock, time, capacity
- **Occurred:** beginning of each quarter (*unit:* week of sale)
- **Output:** time, production quantity



QAD

Master Schedule Summary Report

10/28/08 20:36:13

Training

Page:1

Item Number: 01010 Medical Ultrasound — Buyer/Planner: — Site: 10-100
Prod Line: 10 — BOM/Formula Code: — Supplier:
Qty on Hand: 10.0 — UM: EA — Time Fence: 0 — Manufacturing Lead Time: 0 — MRP Required: Yes
Order Policy: POQ — Minimum Order: 0 — Safety Time: 0 — Pur/Mfg: M — Purchase LT: 0 — Mstr Sched: Yes
Order Period: 7 — Maximum Order: 0 — Safety Stk: 0 — Inspect: No — Inspect LT: 0 — Plan Orders: Yes
Order Qty: 0 — Ord Mult: 0 — Yield%: 100.00% — Cumulative Lead Time: 0 — Issue Policy: Yes

	Past	10/27/08	11/03/08	11/10/08	11/17/08	11/24/08	12/01/08	12/08/08	12/15/08	12/22/08	12/29/08	01/05/09	01/12/09
	10/26/08	11/02/08	11/09/08	11/16/08	11/23/08	11/30/08	12/07/08	12/14/08	12/21/08	12/28/08	01/04/09	01/11/09	01/18/09
Prod Fcst	0	0	0	0	0	0	0	0	0	0	0	0	0
Forecast	0	0	0	0	0	0	0	0	0	0	0	0	0
Sales Orders	0	0	0	500	0	0	0	0	0	0	0	0	0
Gross Reqs	0	0	0	0	0	0	0	0	0	0	0	0	0
Mstr Sched	0	0	0	0	0	0	0	0	0	0	0	0	0
Projected QOH	0	0	0	-500	-500	-500	-500	-500	-500	-500	-500	-500	-500
Avail Promise	0	-500	0	0	0	0	0	0	0	0	0	0	0
Cum ATP	0	-500	-500	-500	-500	-500	-500	-500	-500	-500	-500	-500	-500

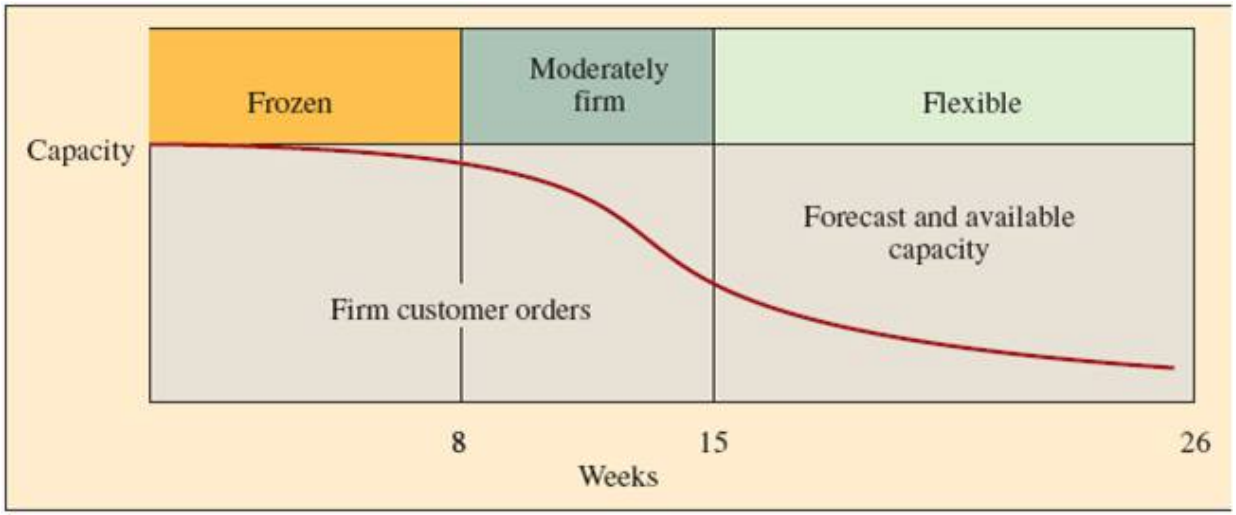
Linkage between S&OP and MPS

Aggregate Production Plan for Mattresses

Month	1	2
Mattress production	900	950

Master Production Schedule for Mattress Models

	1	2	3	4	5	6	7	8
Model 327	200			400		200	100	
Model 538		100	100		150		100	
Model 749			100			200		200



source: *Jacob. et al* 2011.

Which item should we do its MPS?

- **Customer oriented:** focus on FG & sub. assembly → smoothing production & communicating with customer
- **Resources:** consist of small & manageable (# → times)
- **Structure:** have BOM
- **Capacity:** address key capacity of factory (WD)

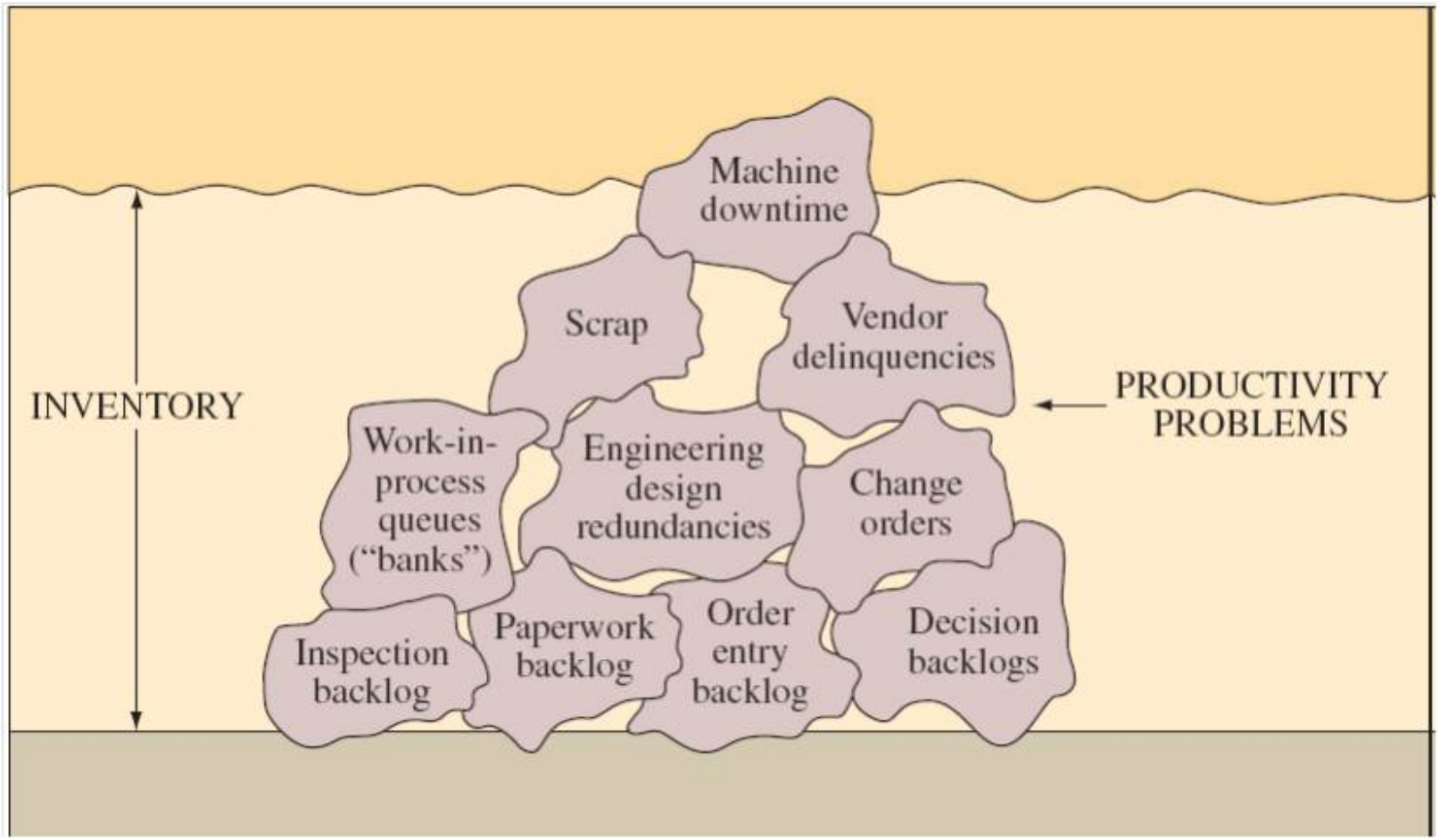
Role and Responsibility of MPS?

- **Planning:** create/maintain MPS
- **Production:** verify MPS, check capacity
- **Purchasing:** ensure & track inventory receiving
- **Warehouse/ Store:** ensure quantity & quality of inventory

Key components in MPS

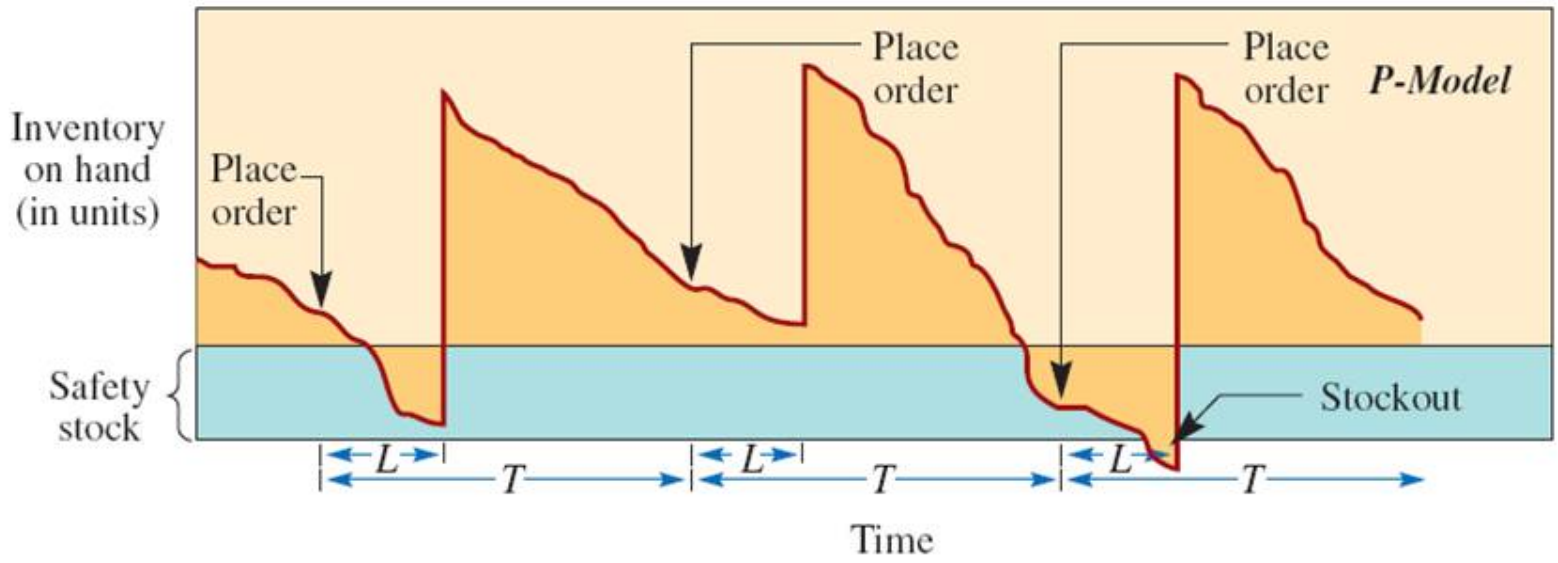
- **Production constraints:** lead time, site
- **Demands:** same time scale
  - **Sale forecast:** (MTS), e.g., forecast & prod. forecast
  - **Customer order:** (MTO), e.g., actual demand
  - **Safety stock:**
  - **Seasonal build:** SongKran, X-mas (QAD)
- **Inventory:** on-hand VS on-order, received all?
- **Planning BOM:**
- **Ordering policy:** how to lump order together

Why does inventory = evil?



source: *Jacob. etal* 2011.

Real World: Random Demand and Lead Time



source: Chase and Jacob. 2011.

Review Methods:

- **Periodic review:** check inventory using chronological criteria, e.g., every fixed period
- **Non-Periodic review:** check inventory non-chronological criteria, e.g., quantity, order from customer, visual inspection,

Popular lot Sizing Rules

Excluding Costs (QAD):

- **Lot-for-Lot (LFL):** order = demand in each period
- **Period Order Quantity (POQ):** order = total demand in fixed periods; LFL $\stackrel{?}{\neq}$ POQ(t=?)
- **Fixed Order Quantity (FOQ):** order = fixed quantity follow condition, e.g, min, max, multiple
- **One Time Only (OTO):** order one unit and one time

Including Costs: handling cost & ordering cost

- **Economic Order Quantity (EOQ):** FOQ @ handling + ordering
- **Wagner-Whitin:** Optimal of handling + ordering
- **Part Period Balancing (PPB):** order = total demand in period @ handling $\approx$ ordering
- **Silver-Meal/least period cost:** total demand in period @ min($\frac{handling+ordering}{period}$)

Important constraints in lot sizing rule

- **Batch:** ensuring color or expiration date, e.g., textiles, leather, chemical
- **Multiple:** easy to handling, economic of scale, e.g., boxes, chemicals,
- **Min-Max:** similar to *multiple* or *batch*
- **Spoilage:** order qty. $= \frac{\text{req qty}}{1-\text{spoil rate}}$

Example: Comparing lot sizing rule

Consider this net requirement:

week	1	2	3	4	5	6	7	8	9	10	11	12
item A	40	15		35	50	30		60	35	80		15

If, the handling cost is \$1 per week and ordering cost is \$100 per order, compare the released order and total cost of the following lot sizing rule: lot-for-lot, EOQ, POQ, S-M, W-W, LUC, LPC

Example: Lot sizing rules

EOQ: $Q = \sqrt{\frac{2\,(100)\,(30\text{units per week})}{1\$\text{ per week}}} = 77.45 \approx 77$

POQ: $t = \frac{77\text{units per order}}{30\text{units per week}} = 2.58$; 2 or 3 periods

Part Period Balancing:

week	net req.	week holding	handling cost	ordering cost	total cost	total units
1	40	0	0	100	100	40
2	15	1	15	100	115	55
3	0	2	15+0	100	115	55
4	35	3	15+105	100	220	90

Example: Lot sizing rules

Least Unit Cost:

week	net req.	week holding	handling cost	ordering cost	total cost	total units	unit cost
1	40	0	0	100	100	40	2.5
2	15	1	15	100	115	55	2.09
3	0	2	15+0	100	115	55	2.09
4	35	3	15+105	100	220	90	2.44

Least Period Cost/ Silver-Meal

week	net req.	week holding	handling cost	ordering cost	total cost	total units	period cost
1	40	0	0	100	100	40	100
2	15	1	15	100	115	55	57.5
3	0	2	15+0	100	115	55	38.3
4	35	3	15+105	100	220	90	55.0

Example: Comparing lot sizing rule

	1	2	3	4	5	6	7	8	9	10	11	12
Lot-for-lot	40	15		35	50	30		60	35	80		15
EOQ	77			77		77			77	77		
POQ	55			115				175				15
W-W	55			115				95		95		
PPB	90				80			95		95		
LUC	55			85		90			115			15
LPC	55			115			95		95			

Character item affecting inventory

- **Item value:** high value → low cycle stock
- **Impact of shortage:** → safety stock,
- **Frequency of requests:**
- **Lead time:** custom made → long lead time → high safety stock
- **Other:** e.g., alternative shipping, substitution product, price change, variation

Bill of Material (BOM)

- **What:** qty of components needed for FG

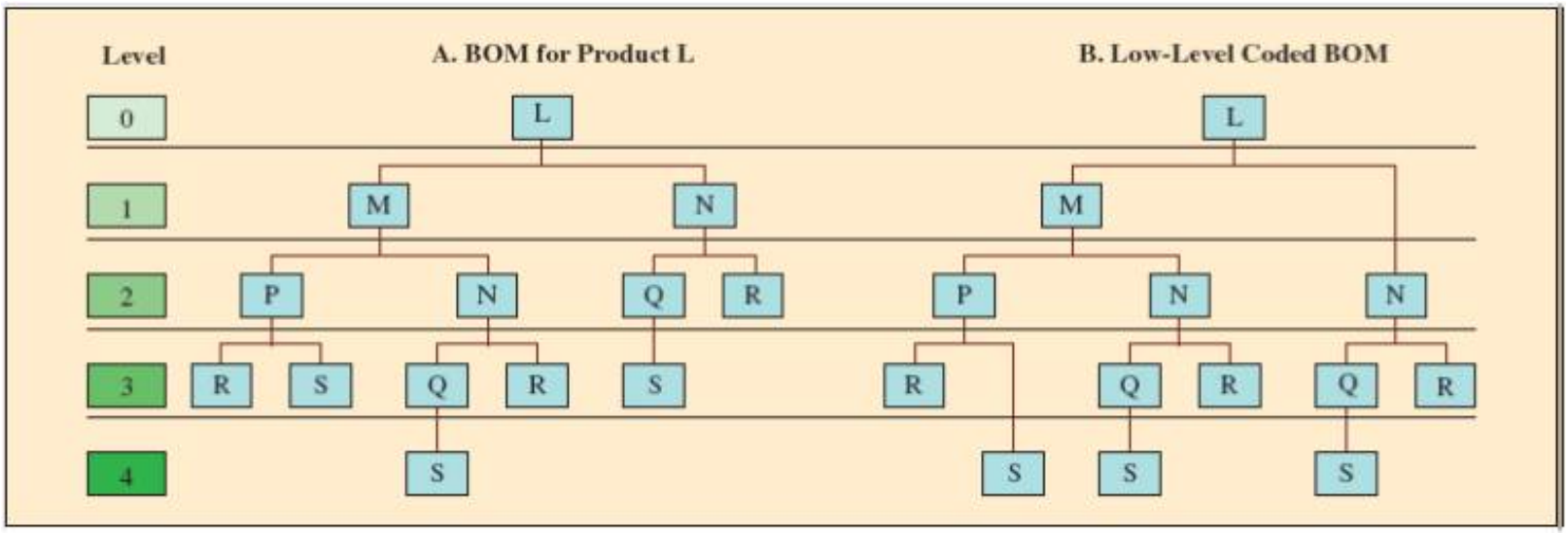
  total demand = independents demand + dependent demands
- **Warning:** low-level code → time to run in MRP

BOM Terminology

- **Low-Level Code:** lowest level that a component is assembled
- **Summarized BOMs:** BOM listed total quantity of components
- **Indented BOMs:** BOM listed order of components
- **Modular BOMs:** BOM listed group of components
- **Phantom assembly:** sub-assembly that sometime available
- **Point of use:** material at specific location in production

source: *Jacob. etal* 2011.

Example of Bill of Material

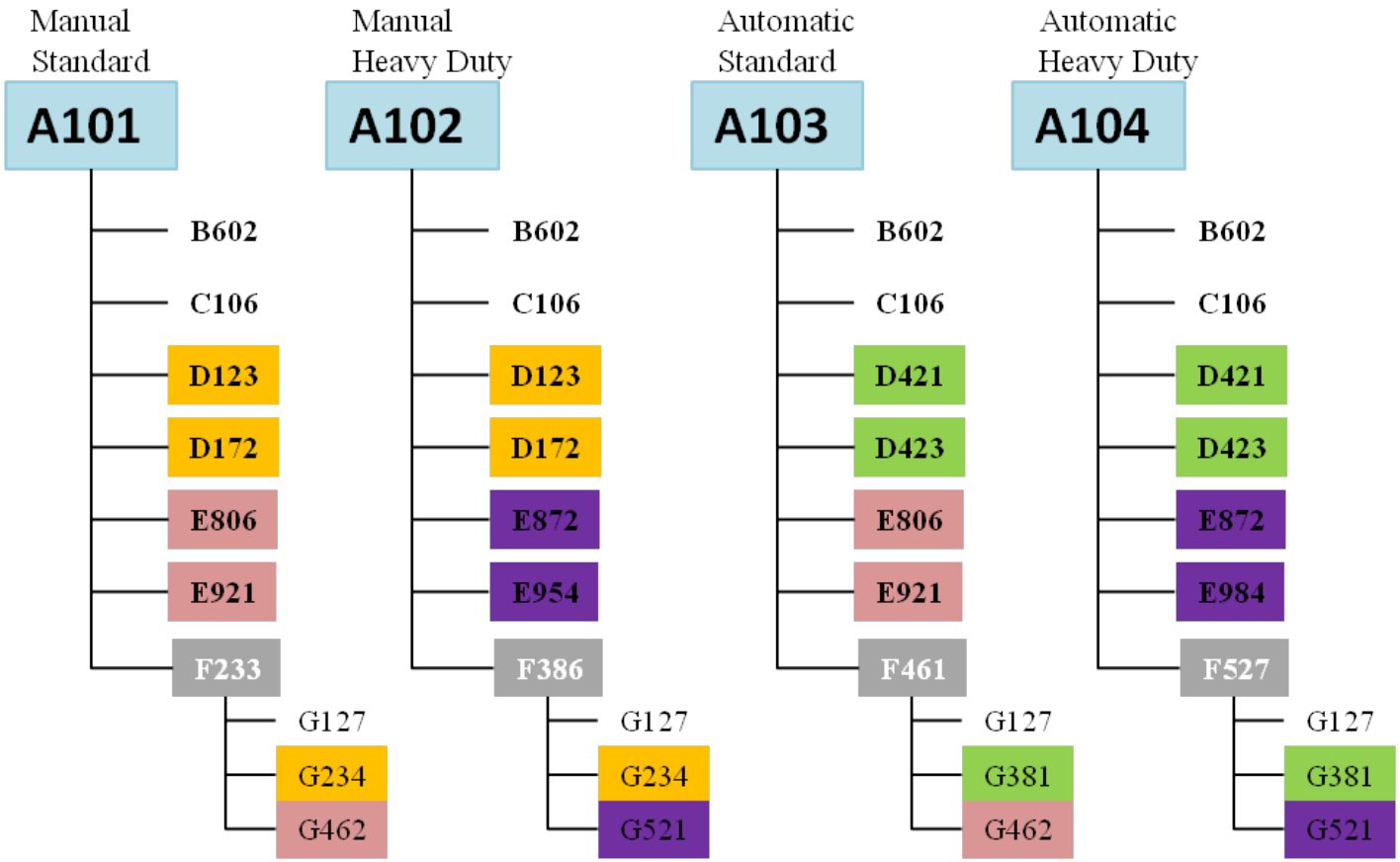


source: *Jacob. etal* 2011.

Summarized BOM			
Level	Item No.	Quantity	Unit
1	M	1	each
.2	P	1	each
.2	N	2	each
.3	R	3	each
.3	Q	2	each
.4	S	3	each

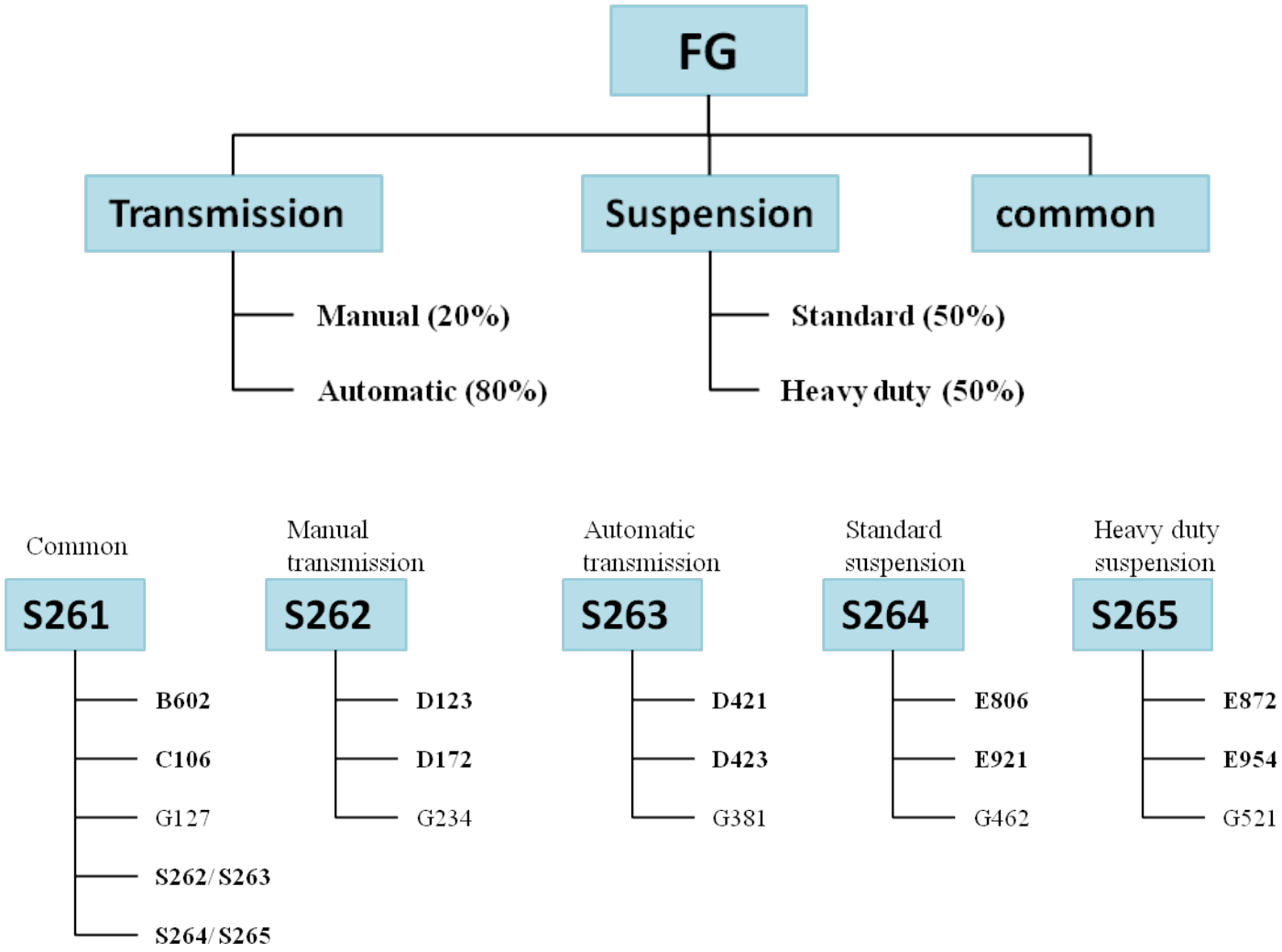
Extended BOM			
Level	Item No.	Quantity	Unit
1	M	1	each
.2	P	1	each
.3	R	1	each
.4	S	1	each
.2	N	2	each
.3	Q	1	each
.4	S	1	each
.3	R	1	each

Regular BOM



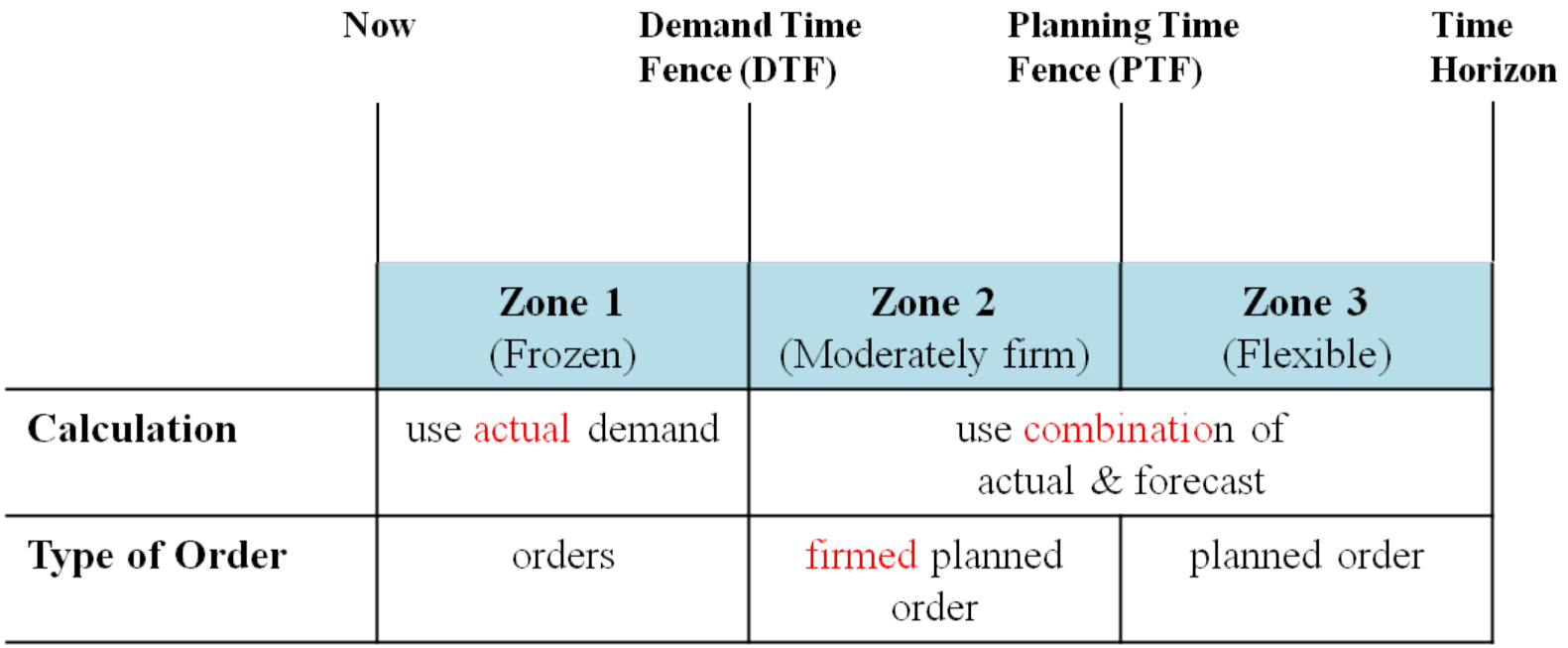
source:*Smith, S. B.* 1989.

Modular BOM/ Multilevel BOM



source:*Smith, S. B.* 1989.

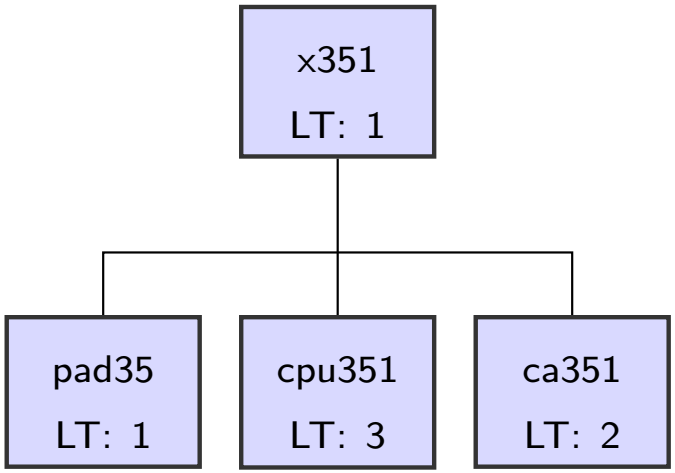
Time Fence

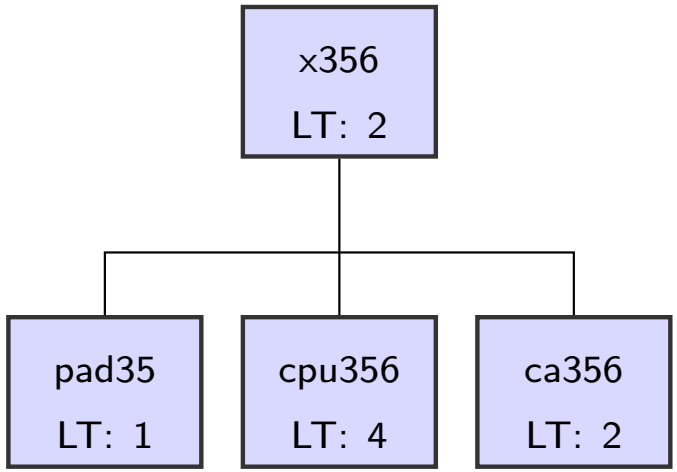


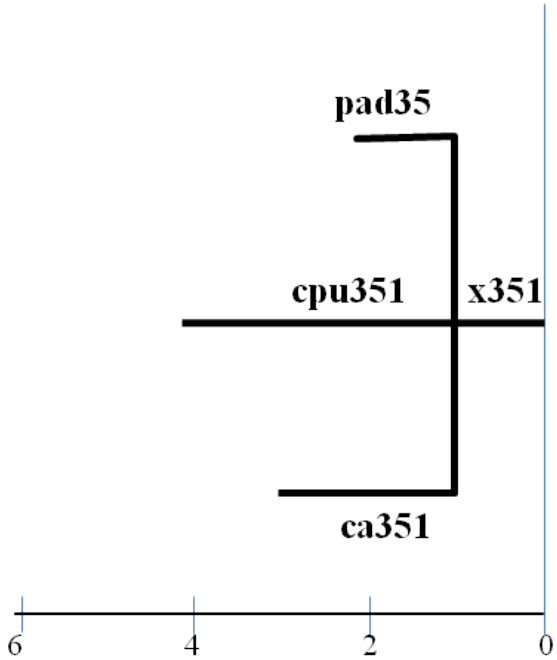
source: *Smith, S. B.* 1989.

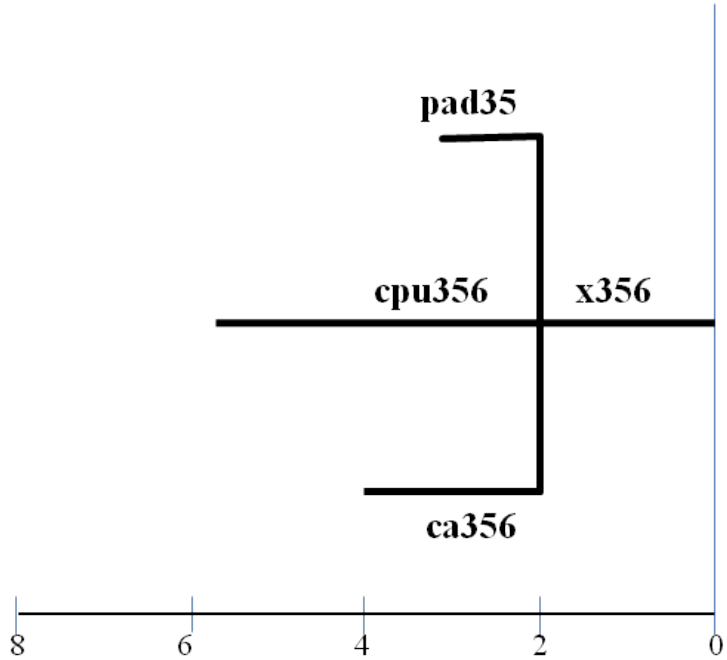
- **Demand Time Fence (DTF):** changing order is very expensive
- **Production Time Fence (PTF):** changing order is annoying
- **Time Horizon:** forecasting time period

SkyCell: Time Fence (DTF & PTF)









MPS Terminology

Requirement Related

- **Gross requirements:**total requirements (MRP term)
- **Net requirements:** requirements after calculating scheduled receipt (MRP term)

Inventory Related:

- **Planned order release:** releasing period of an order (back scheduling of planned order due)
- **Planned order due:** received period of an order
- **Scheduled receipts:** actual delivery period of an order
- **On-Hand inventory/ Projected available:** WIP that should have if nothing wrong
- **Available to promise (ATP):** available qty. for other additional customers
- **Available to located:** qty. less than orders

source:*Jacob. etal* 2011.

SkyCell: Firmed order & BOM

item no.	inventory (1000 unit) on-hand	on-order	safety	policy
x351	140	$150_{t=3}$	30	$\text{POQ}_{t=3}$
x356	110	$180_{t=3}$ $280_{t=6}$	0	$\text{POQ}_{t=4}$

		1	2	3	4	5	6	7	8	9	10
x351 (MTS)	forecast	50	30	80	20	70	50	80	40	100	70
	order	70									
x356 (MTS/MTO)	forecast	70	80	50	50	100	110	60	90	150	80
	order	40	60	50	30/60	20/40	10/20	10			

SkyCell: x351 week 01-09

Item no.:	x351		**Despription:**		Lower-End Cell Phone						
Lead time:			**Safty Stock:**		**30** unit						
Order quantity	3 periods		**DTP:**		-	weeks					
			PTF:		4	weeks					
						PTF					Time Horz.
Period	past	1	2	3	4	5	6	7	8	9	
Prod. Forecast											
Forecasts		50	30	80	20	70	50	80	40	100	
Actual Demand											
Gross Req.											
MPS				150							
Proj. Avail	140										
ATP											
Cumm ATP											
Planned Order											

source:*Smith, S. B.* 1989.

SkyCell: x356 week 01-09

Item no.:	x356		**Despription:**	High-End Cell Phone							
Lead time:	3 periods		**Safty Stock:**	0 unit							
Order quantity	4 periods		**DTP:**	2 periods							
			PTF:	6 periods							
			DTF				PTF			Time Horz.	
Period	past	1	2	3	4	5	6	7	8	9	
Prod. Forecast											
Forecasts		70	80	50	50	100	110	60	90	150	
Actual Demand		40	60	50	30	20	10				
Gross Req.											
MPS				180		280					
Proj. Avail	110										
ATP											
Cumm ATP											
Planned Order											

source:*Smith, S. B.* 1989.

Concepts of MRP

Principle of dependent demand

Total quantities required = independent + dependent quantities required

Clarification

- **Gross requirement:** total qty. after netting process
- **Net requirement:** total qty. after considering inventory and scheduled receipts
- **planned receipts:** projected qty receipted
- **planned inventory:** projected on-hand inventory according to *planned receipts*

Differences btw MPS & MRP

	MPS	MRP
What	master production	material requirement
Scope	Level 0	all components
Process	find lot sizing	expand & combine net req
Input	forecasting/order	MPS + BOM + distribution
Output	MRP	PO & job shop plan
Update	new forecast	any changes

SkyCell: Inventory Information

	inventory (1000 unit)		
item no.	on-hand	on-order	policy
x351	-	-	lot-for-lot
x356	-	-	lot-for-lot
pad35	400	-	min=300, max=1000
cpu351	100	1000 (week 10)	(q,Q) = (200,1000)
cpu356	520	-	(q,Q) = (200,1000)
ca351	200	300 (week 11)	min=200, max=1000
ca356	350	-	min=200, max=1000

SkyCell: MRP

cpu356: (q,Q) = (200,1000)

6	*cpu356*		Lead time		8	weeks	(q,Q)=(200,1000)									
Week		Overdue	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
6	x356		0	100	100	100	150	150	200	200	200	150	150	150	150	0	0
gross req			0	100	100	100	150	150	200	200	200	150	150	150	150	0	0
sch reciepts																	
on hand		520	520	420	320	220	70	0	0	0	0	0	0	0	0	0	0
net req			0	0	0	0	0	80	200	200	200	150	150	150	150	0	0
planned reciepts																	
planned onhand																	
planned order																	

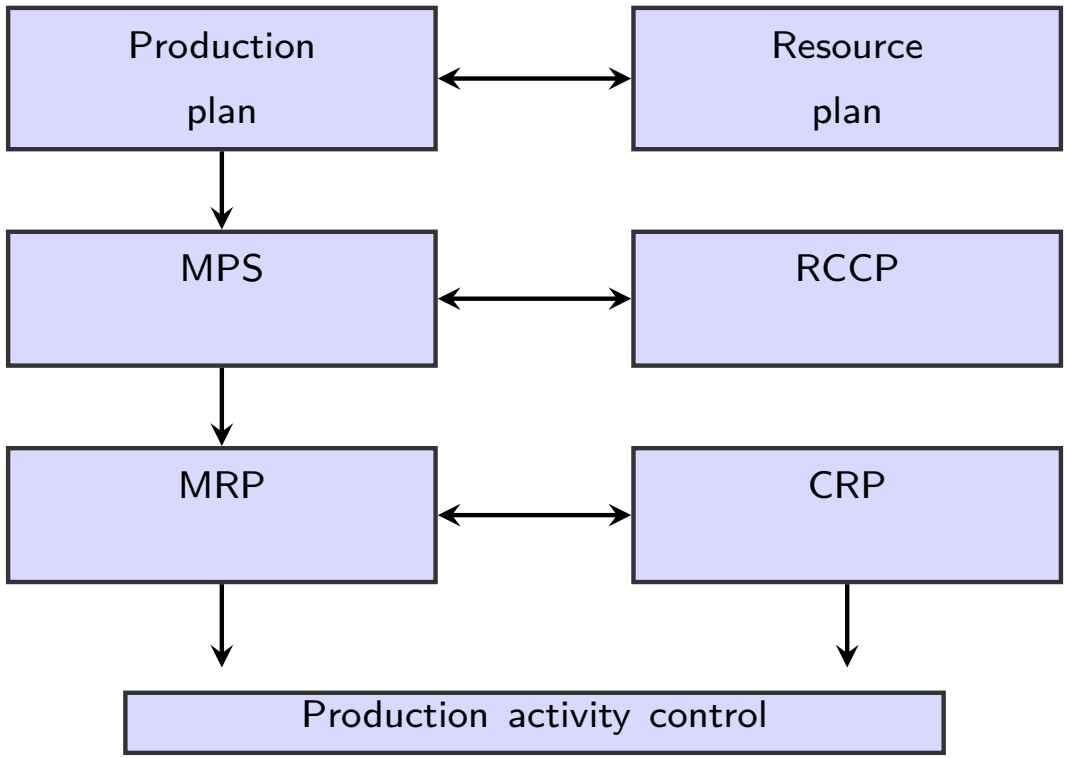
ca356: min = 200, max = 1000

8	*ca356*		Lead time		2	weeks	min=200, max=1000									
Week		Overdue	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
8	x356		0	100	100	100	150	150	200	200	200	150	150	150	150	0	0
gross req			0	100	100	100	150	150	200	200	200	150	150	150	150	0	0
sch reciepts																	
on hand		350	350	250	150	50	0	0	0	0	0	0	0	0	0	0	0
net req			0	0	0	0	100	150	200	200	200	150	150	150	150	0	0
planned reciepts																	
planned onhand																	
planned order																	

Limitation MRP

- **Deterministic data:** assuming that every parameters is deterministic, including 'firm order'
- **Capacity planning:** assuming that key constraint is material requirement or infinite capacity
- **System nerviness:** rolling horizon and lot-sizing rule $\rightarrow$ different MRP
- **Lead time depends on quantities:**
- **Data integration:** purchasing forgets to order; supplier delays

RRP vs RCCP vs CRP



- **RRP:** long-term (3-5 years/month), purchasing machines, expansion
- **RCCP:** mid-time (one year/week), hiring permanent staff, ignore components, using std man-hour
- **CRP:** short time (one year/week), over-time, consider components, using exact lot size

SkyCell: Standard time & lot size

	WC #	# MC	Run time (hr/batch)	Run time (hr/unit)	Setup time (hr/lot)	Avg. lot size (unit)
pad35	10	5	0.5	-	-	1000
ca351	20	3	0.20	-	-	1000
	30	500	-	0.01	-	∞
ca356	20	3	0.25	-	-	1000
	30	500		0.03	-	∞
x351	30	500		0.10	0.1	∞
x356	30	500		0.20	0.1	100

Bill of Capacity

Bill of Capacity Average hour used to produce each product

	Avg cycle time	
Work center	x351	x356
10	0.0005	0.0005
20	0.0002	0.00025
30	0.01+0.1	0.03+0.201

SkyCell: MPS & RCCP

	11	12	13	14	15	16	17	18	19	20	21	22
x351	100	100	150	150	100	100	100	100	100	100	100	100
x356	100	100	100	150	150	200	200	200	150	150	150	150

If MPS using lot-for-lot policy, then RCCP (resource of each work center) becomes

		week					
	$\text{Cap}_{\max}$	11	12	13	14	15	16
10	40×5	100	100	125	150	125	150
20	40×3	45	45	55	67.5	57.5	70
30	$40 \times 500 \times 3$	34100	34100	39600	51150	45650	57200

	Max	17	18	19	20	21	22
10	40×5	150	150	125	125	125	125
20	40×3	70	70	57.5	57.5	57.5	57.5
30	$40 \times 500 \times 3$	57200	57200	45650	45650	45650	45650

Limitation of RCCP and Extension

Assumption of RCCP

- not consider queuing in each work center → lead time in BOC
- not address efficiency and switch-over time → lead time in BOC
- transition time from one WC to other WC → lead time in BOC
- excluding time that need each component → CRP

Time Phased Bill of Capacity (TPBOC)

- **What:** create rough & realistic schedule of each WC to modify the standard time
- **Idea:** queue & transition time impacts lead time, not standard time
- **Elapsed time:** minimal working time for first lot

$$\text{Elapsed time} = \frac{\text{std hour/unit} \times \text{lot size}}{\text{util.} \times \text{eff}}$$

- **Offset time:** minimal completed time for first lot

$$\text{transit}_{to} + \text{queue time} + \text{elapsed time} + \text{transit}_{from}$$

Quiz I

1. Name companies and explain their operations that enables its information technology (IT)/information system (IS) to gain following strategic advantages:
   - Cost reduction
   - Creating new products/services
   - Enhance products/services
2. What are factors contribute to a low success rate of information technology in manufacturing environment?
3. Explain similarities and differences between Material Requirement Planning (MRP) and Enterprise Resource Planning (ERP)