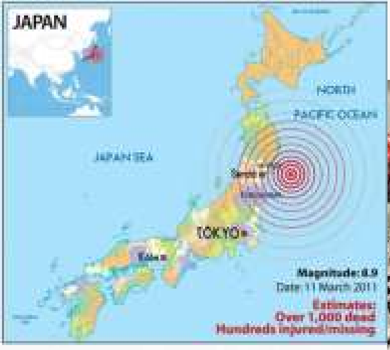
مدیریت تولید–عملیات پیشرفته

دانشگاه صنعتی شاهرود

دانشکده مدیریت و مهندسی صنایع

گروه مدیریت

پاییز ۱۳۹۸

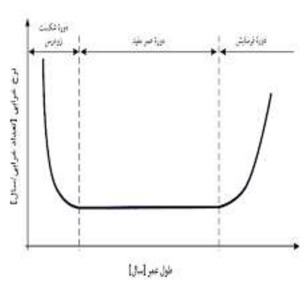


Production Management and Facility Location

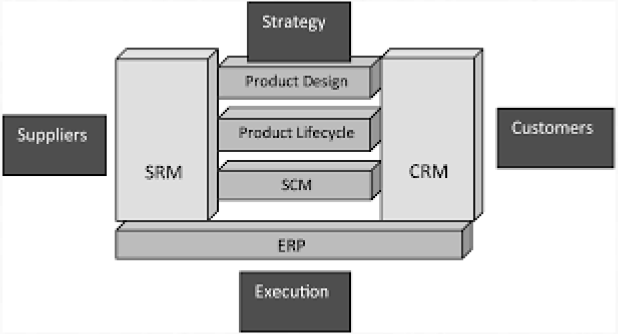
Production Management and Supplier Selection

Production Management and Customer Relationship Management

Production Management and Quality Control Management



Production Management and Maintenance Management

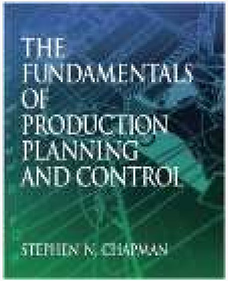

Strategy
Product Design
Product Lifecycle
SCM
Suppliers
SRM
CRM
Customers
ERP
Execution

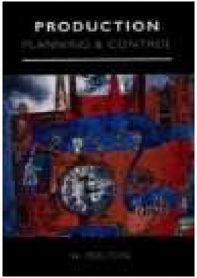
سرفصل مطالب

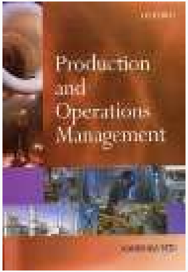
عناوین کلی

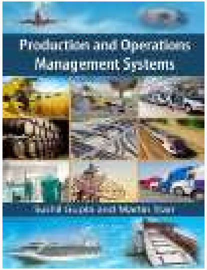
نیم‌سال اول تحصیلی ۹۸-۹۹ دانشگاه صنعتی شاهرود

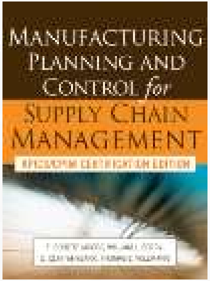
برخی از منابع درس مدیریت تولید پیشرفته









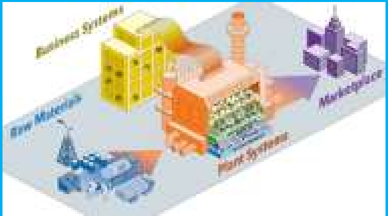


نحوه ارزیابی

- امتحان پایان ترم (+۱۵) – جزوه باز
- ارائه یک مقاله (+۵)
  - حداکثر مدت زمان انتخاب مقاله ۱۱ مهرماه
  - آغاز ارائه از ۲ آبان‌ماه
  - انتخاب مقاله معتبر علمی فارسی از ۹۷به بعد و لاتین از ۲۰۱۸به بعد
- ارائه مطالب آزاد (+۲)

INTRODUCTION TO PRODUCTION AND OPERATION MANAGEMENT

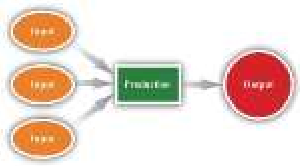
CHAPTER OUTLINE



1-1 INTRODUCTION

Production/operations management is the process, which combines and transforms various <u>resources</u> used in the production/operations subsystem of the organization into <u>value added</u> product/services in <u>a controlled manner</u> as per the policies of the organization.

Therefore, it is that part of an organization, which is concerned with the <u>transformation</u> of a <u>range of inputs into the required (products/services)</u> having the requisite quality level.

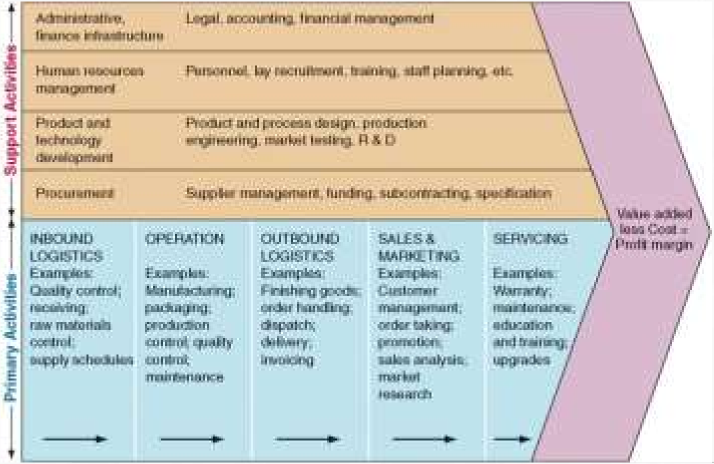


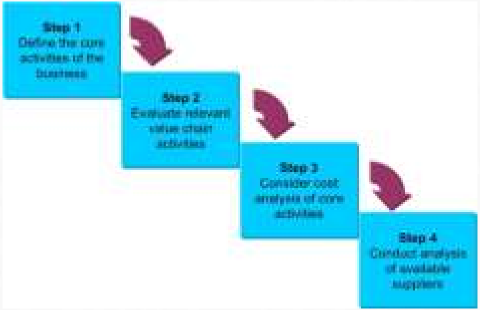
Value added

1. The amount by which the value of an article is increased at each stage of its production, exclusive of initial costs.
2. Any activity that is adding value to the part and the customer is <u>paying for</u>.


REDSTONE
INSIDE THE FAMILY FEUD
WHO TO BLAME FOR
COLLEGE
COSTS
$60 OIL?
BELIEVE IT
RETIREMENT GUIDE
REMARRY OR SHACK UP?
DYING WITHOUT A WILL
Forbes
Nokia
ONE BILLION
CUSTOMERS—
CAN ANYONE
CATCH THE
CELL PHONE KING?
PLUS
11 GADGETS WE LOVE

Value added chain





Outsourcing

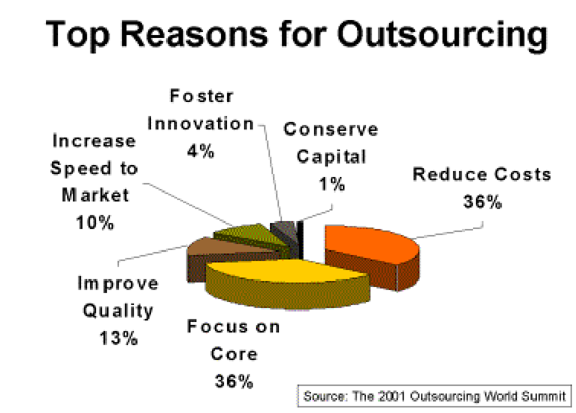
1. Outsourcing -

   "the strategic use of outside resources to perform activities traditionally handled by internal staff and resources" Dave Griffiths

2. Why Outsource?

   Provide services that are scalable, secure, and efficient, while improving overall service and reducing costs

Outsourcing



Reason for outsourcing

1. Traditional role - reaction to problem

   Reduction and control of costs

   Avoid large capital investment costs

   Insufficient resources available

2. Modern role – business strategy

   Allows company to focus on their core competencies

   Keeping up with cutting-edge technology

   Creating value for the organization and its customers

   Building partnerships

When to outsource

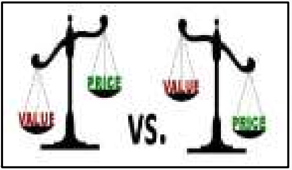
	Strategic	Non-Strategic
Competitive	Not Outsourced	Grey Area
Non-Competitive	In House if Possible	Outsource

Value added & Pricing

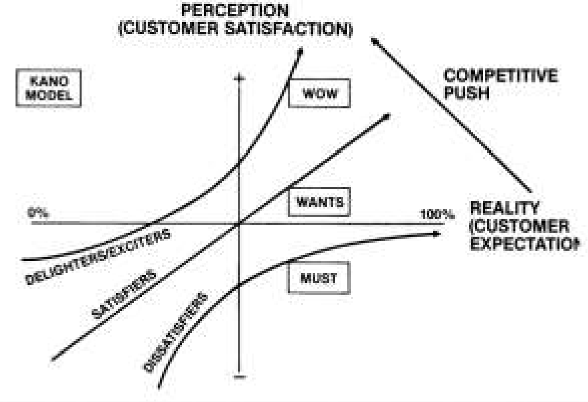
The two basic models of pricing goods and services are:

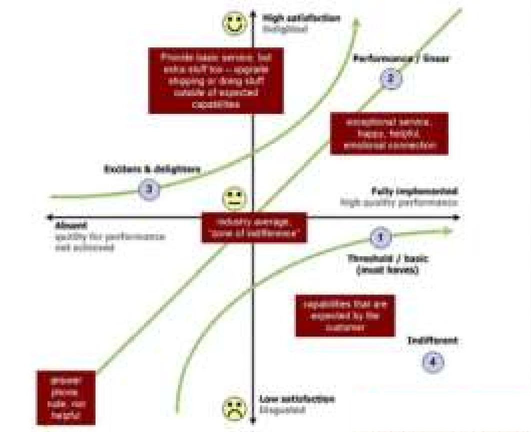
- cost-plus pricing, and
- value-based pricing.

Value-based pricing is more to come up with a price that your customers are willing to pay and it is one of the most highly recommended pricing techniques where price is set to capture the majority of what your customers are ready to invest to get products and services.



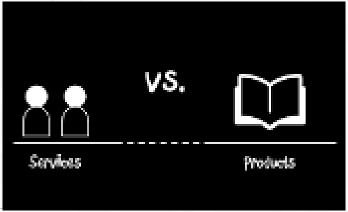
Value added & Pricing & Satisfaction





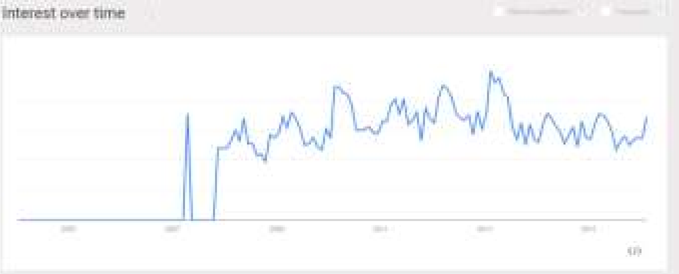
1-1 INTRODUCTION

- The set of interrelated management activities, which are involved in manufacturing certain products, is called as **production management**. If the same concept is extended to services management, then the corresponding set of management activities is called as **operations management**.
- Five Differences Between Service and Manufacturing Organizations
  - Goods
  - Inventory
  - Customers
  - Labor
  - Location



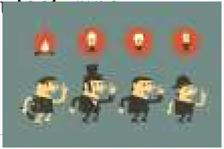
1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

For over two centuries operations and production management has been recognized as an important factor in a country’s economic growth.



1-2 HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

The traditional view of manufacturing management began in eighteenth century when Adam Smith recognized the economic benefits of specialization of labor. He recommended breaking of jobs down into subtasks and recognizes workers to specialized tasks in which they would become highly skilled and efficient. In the early twentieth century, F.W. Taylor implemented Smith's theories and developed scientific management. From then till 1930, many techniques were developed prevailing the traditional view. Brief information about the contributions to manu management is shown in aforementioned table.



1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

Historical summary of operations management

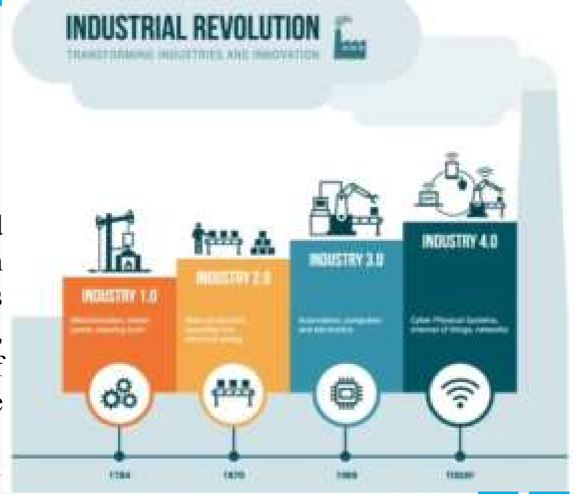
Date	*Contribution*	*Contributor*
1776	Specialization of labour in manufacturing	Adam Smith
1799	Interchangeable parts, cost accounting	Eli Whitney and others
1832	Division of labour by skill; assignment of jobs by skill; basics of time study	Charles Babbage
1900	Scientific management time study and work study developed; dividing planning and doing of work	Frederick W. Taylor
1900	Motion of study of jobs	Frank B. Gilbreth
1901	Scheduling techniques for employees, machines jobs in manufacturing	Henry L. Gantt
1915	Economic lot sizes for inventory control	F.W. Harris
1927	Human relations; the Hawthorne studies	Elton Mayo
1931	Statistical inference applied to product quality: quality control charts	W.A. Shewart

1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

Historical summary of operations management

Date	*Contribution*	*Contributor*
1935	Statistical sampling applied to quality control: inspection sampling plans	H.F. Dodge & H.G. Roming
1940	Operations research applications in World War II	P.M. Blacker and others.
1946	Digital computer	John Mauchlly and J.P. Eckert
1947	Linear programming	G.B. Dantzig, Williams & others
1950	Mathematical programming, on-linear and stochastic processes	A. Charnes, W.W. Cooper & others
1951	Commercial digital computer: large-scale computations available.	Sperry Univac
1960	Organizational behaviour: continued study of people at work	L. Cummings, L. Porter
1970	Integrating operations into overall strategy and policy, Computer applications to manufacturing, Scheduling and control, Material requirement planning (MRP)	W. Skinner J. Orlicky and G. Wright
1980	Quality and productivity applications from Japan: robotics, CAD-CAM	W.E. Deming and J. Juran.

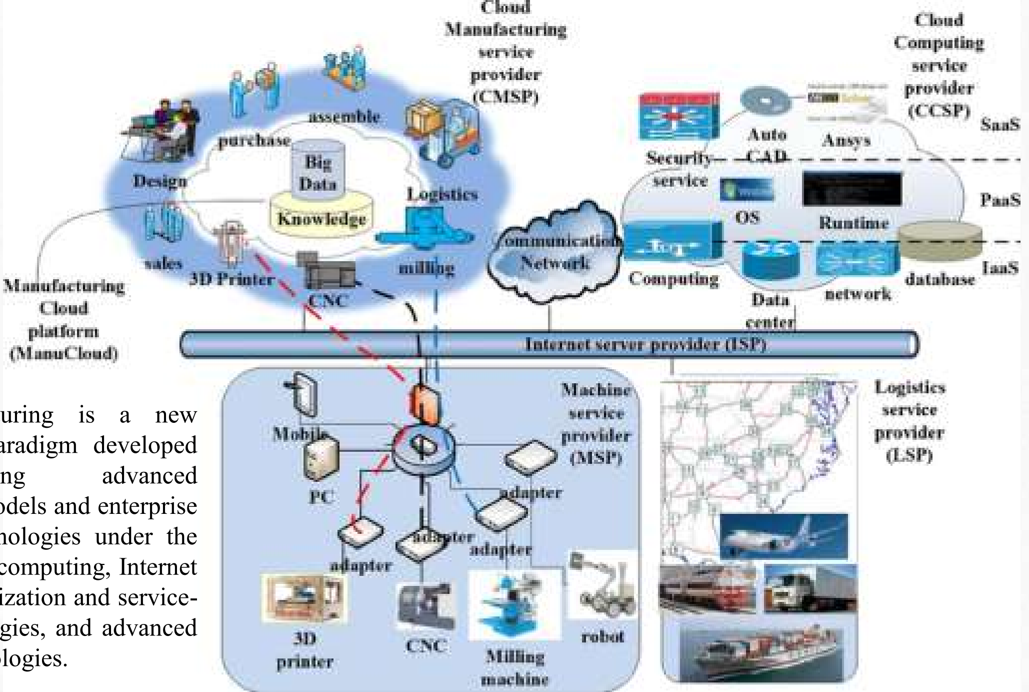
1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT



In essence, industry 4.0 describes the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the internet of things (IoT), industrial internet of things (IIOT), cloud computing, cognitive computing and artificial intelligence.

1-4 PRODUCTION SYSTEM

- IoT is fundamentally changing the way we do business. By connecting devices and sensors to the internet, we are entering an age where data analytics, connectivity, and automation are creating innovations and progress previously out of reach.
- As the Industry 4.0 and home automation movements gain more traction, we will see IoT devices and embedded systems become more and more prevalent in our daily lives.



Cloud manufacturing is a new manufacturing paradigm developed from existing advanced manufacturing models and enterprise information technologies under the support of cloud computing, Internet of Things, virtualization and service-oriented technologies, and advanced computing technologies.

1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

- Now: 3D printer:
    - How 3D printing impacts manufacturing
    - 3D Printing and the Future of Manufacturing
    - How 3D Printing Will Affect Manufacturing Jobs
    - 3D Printing's Impact on Modern Manufacturing
    - Disruptive manufacturing The effects of 3D printing
    - ….

3D PRINTING'S ECONOMIC IMPACT

AT Kearney's "3D Printing and the Future of the US Economy" report looks at the number of manufacturing jobs that 3D printing (3DP) could help reshore for a wave of economic growth across industrial sectors.

ECONOMY

$80+ TRILLION GLOBAL ECONOMY
Traditional manufacturing: $12.8 trillion, 16%
3DP: $8.8 billion, <1%

$26 BILLION 3DP FORECAST FOR 2021

In the next 10 years, 3DP could affect up to 42% of production in five sectors, with total economic value of 3DP-based on-shoring from **$600 to $900 billion.**

INDUSTRIALS: 6,357,000
CONSUMER PRODUCTS: 969,000
AUTOMOTIVE: 919,000
HEALTHCARE, MEDICAL DEVICES: 593,000
AEROSPACE: 350,000

JOBS BY 2027

3 MILLION TO 5 MILLION
Potential for skilled job creation in the U.S.

POTENTIAL JOB CREATION 2017-2027 BY CATEGORY

42%↑ OPERATIONS

64%↑ ENGINEERING

21%↑ LOGISTICS


The impact of
3D printing
on supply chains

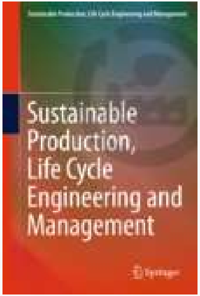
1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

Production management becomes the acceptable term from 1930s to 1950s. As F.W. Taylor's works become more widely known, managers developed techniques that focused on economic efficiency in manufacturing. Workers were studied in great detail to eliminate wasteful efforts and achieve greater efficiency. At the same time, psychologists, socialists and other social scientists began to study people and human behavior in the working environment. In addition, economists, mathematicians, and computer socialists contributed newer, more sophisticated analytical approach

1-2HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

Now, sustainable production management

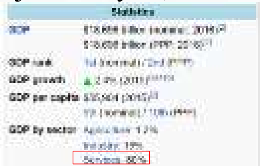
Reverse and closed-loop supply chain management

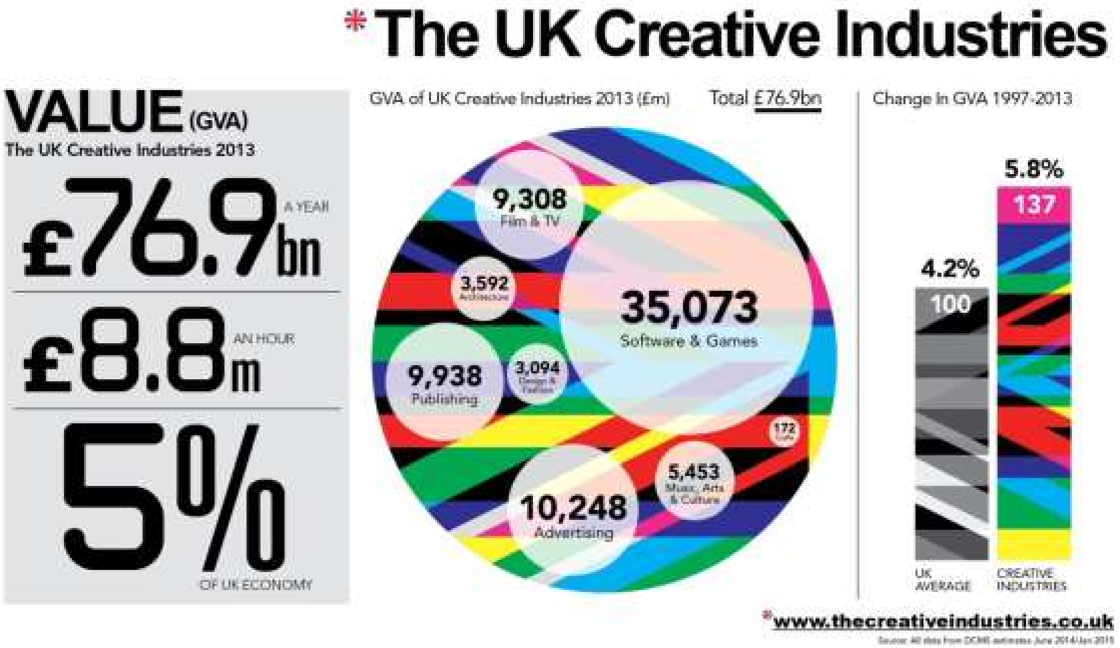


1-2 HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

With the 1970s emerges two distinct changes in our views. The most obvious of these, reflected in the new name operations management was a shift in the service and manufacturing sectors of the economy.

As service sector became more prominent, the change from 'production' to 'operations' emphasized the broadening of our field to service organizations. The second, more suitable change was the beginning of an emphasis on synthesis, rather than just analysis, in management practices.





*The UK Creative Industries
VALUE (GVA)
The UK Creative Industries 2013
£76.9bn A YEAR
£8.8m AN HOUR
5% OF UK ECONOMY
GVA of UK Creative Industries 2013 (£m)
Total £76.9bn
9,308 Film & TV
3,592
35,073 Software & Games
9,938 Publishing
3,094
172
5,453 Music, Arts & Culture
10,248 Advertising
Change in GVA 1997-2013
4.2%
100
UK AVERAGE
5.8%
137
CREATIVE INDUSTRIES
*www.thecreativeindustries.co.uk

* The UK Creative Industries

EXPORTS (Services)

UK Creative Industries Exports 2012

£17.3bn

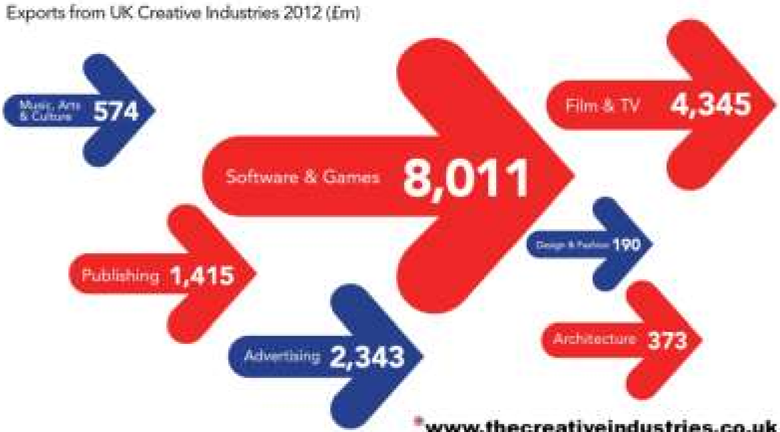
VALUE OF EXPORTS A YEAR

8.8%

PERCENTAGE OF TOTAL UK EXPORTS

+11.3%

CHANGE IN VALUE OF UK EXPORTS 2012 v 2011

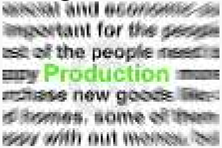


*www.thecreativeindustries.co.uk

1-3 CONCEPT OF PRODUCTION

Production function is that part of an organization, which is concerned with the transformation of a range of **inputs** into the required **outputs** (products) having the requisite **quality level**.

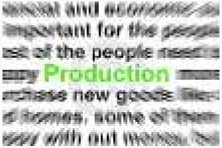
Production is defined as "the step-by-step conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the user." Thus production is a value addition process. At each stage of processing, there will be value addition.



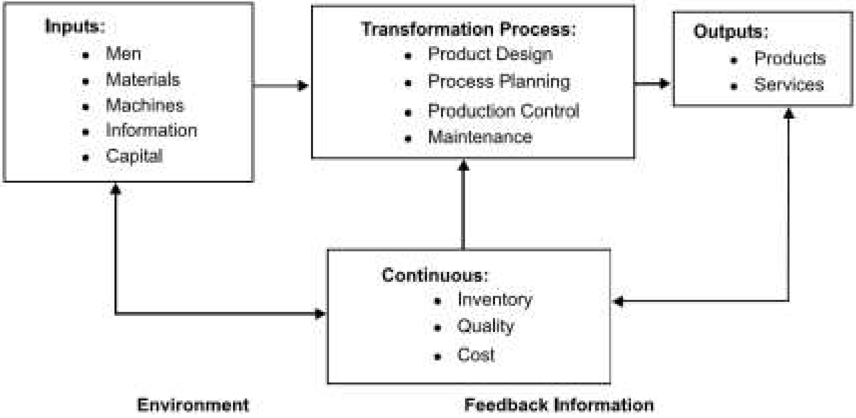
1-3 CONCEPT OF PRODUCTION

Edwood Buffa defines production as ‘a process by which goods and services are created’.

Some examples of production are: manufacturing custom-made products like, boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers, etc., and manufacturing standardized products like, car, bus, motor cycle, radio, television, etc.



1-3 CONCEPT OF PRODUCTION



Schematic production system

1-4 PRODUCTION SYSTEM

The <u>production system</u> of an organization is that part, which produces products of an organization.

It is that activity whereby resources, flowing within a defined system, are combined and transformed in a <u>controlled manner</u> to add value in accordance with the policies communicated by management. A simplified production system is shown in the previous slide.

1-4 PRODUCTION SYSTEM

The production system has the following characteristics:

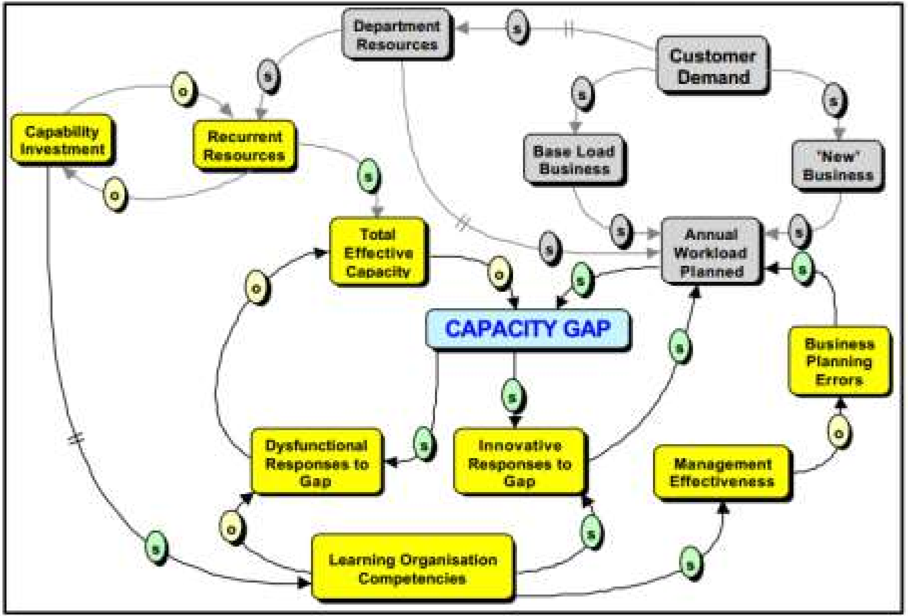
1. Production is an <u>organized</u> activity, so every production system has an objective.

2. The system <u>transforms</u> the various inputs to useful outputs.

3. It <u>does not operate in isolation from the other organization system</u>.

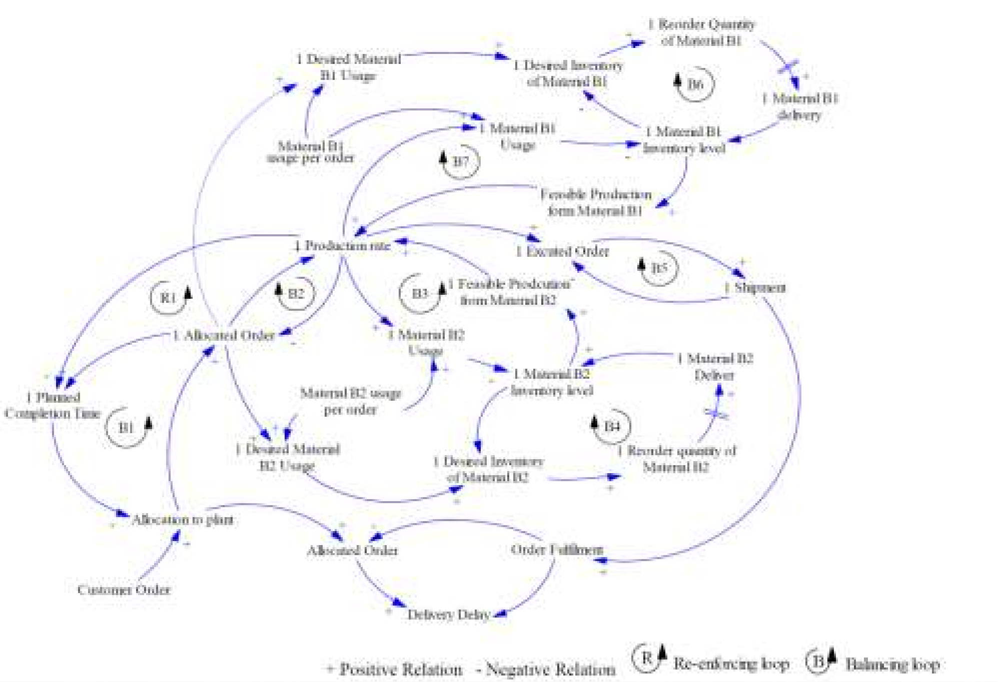
4. <u>There exists a feedback about the activities</u>, which is essential to control and improve system performance.

Key Resource Sector Interdependencies in Federal Departments



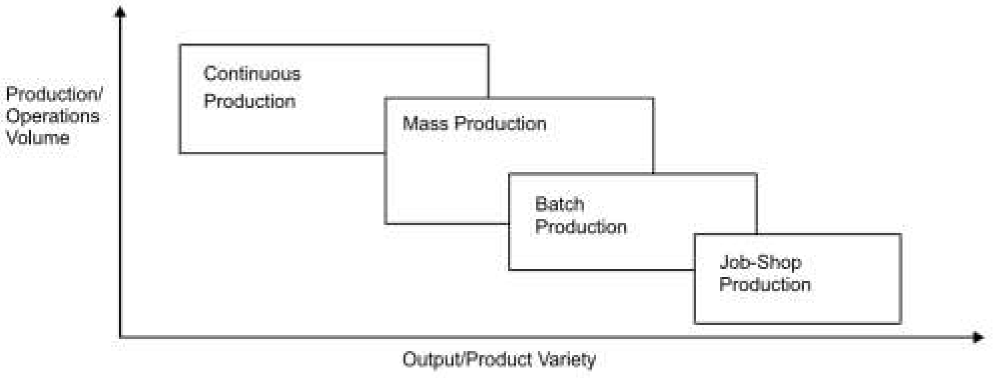
System dynamics

System Dynamics (SD) is an approach to understanding the nonlinear behavior of complex **systems** over time using stocks, flows, internal feedback loops, table functions and time delays.


I Reorder Quantity of Material B1
I Desired Material B1 Usage
I Desired Inventory of Material B1
B6
I Material B1 delivery
I Material B1 Usage
I Material B1 Inventory level
Material B1 usage per order
B7
Feasible Production form Material B1
I Production rate
I Excuted Order
B5
I Shipment
R1
B2
B3
I Feasible Production from Material B2
I Allocated Order
I Material B2 Usage
I Material B2 Deliver
I Material B2 Inventory level
I Planned Completion Time
Material B2 usage per order
B1
B4
I Desired Material B2 Usage
I Desired Inventory of Material B2
I Reorder quantity of Material B2
Allocation to plant
Allocated Order
Order Fulfilment
Customer Order
Delivery Delay
+ Positive Relation
- Negative Relation
R Re-enforcing loop
B Balancing loop

1-4 PRODUCTION SYSTEM

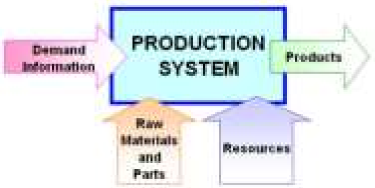
1-4-1 Classification of Production System



Classification of production systems

1-4 PRODUCTION SYSTEM

The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. A simplified production system is shown above.



JOB SHOP PRODUCTION

Characteristics

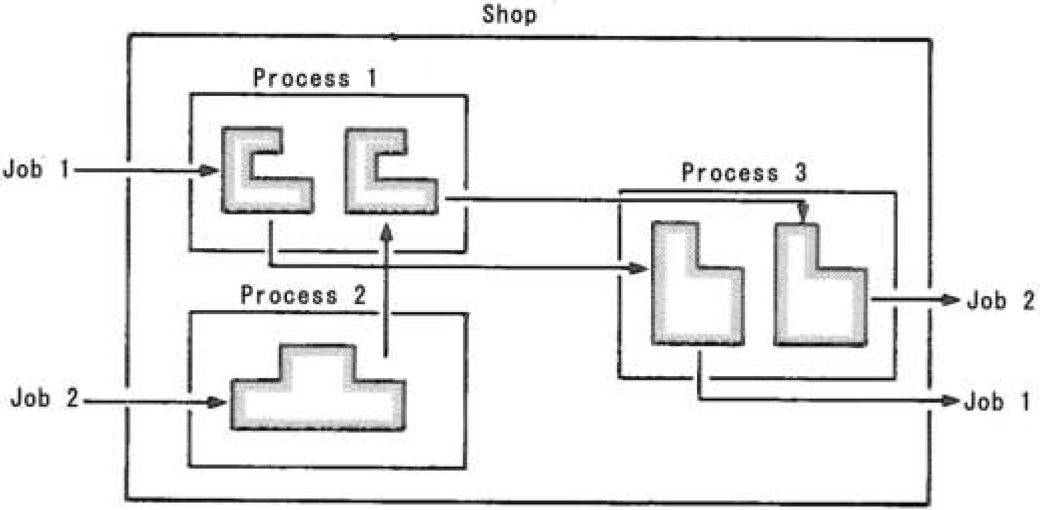
1. High variety of products and low volume.
2. Use of general purpose machines and facilities.
3. Highly skilled operators who can take up each job as a challenge because of uniqueness.
4. Large inventory of materials, tools, parts.
5. Detailed planning is essential for sequencing the requirements of each product, capacities for each work center and order priorities.

Advantageous

1. Because of general purpose machines and facilities variety of products can be produced.
2. Operators will become more skilled and competent, as each job gives them learning opportunities.
3. Full potential of operators can be utilized.
4. Opportunity exists for creative methods and innovative ideas.

Limitations

1. Higher cost due to frequent set up changes.
2. Higher level of inventory at all levels and hence higher inventory cost.
3. Production planning is complicated.
4. Larger space requirements.


Shop
Process 1
Job 1
Process 3
Process 2
Job 2
Job 2
Job 1

Batch PRODUCTION

Characteristics

1. When there is shorter production runs.
2. When plant and machinery are flexible.
3. When plant and machinery set up is used for the production of item in a batch and change of set up is required for processing the next batch.
4. When manufacturing lead time and cost are lower as compared to job order production.

Advantageous

1. Better utilization of plant and machinery.
2. Promotes functional specialization.
3. Cost per unit is lower as compared to job order production.
4. Lower investment in plant and machinery.
5. Flexibility to accommodate and process number of products.
6. Job satisfaction exists for operators.

Limitations

1. Material handling is complex because of irregular and longer flows.
2. Production planning and control is complex.
3. Work in process inventory is higher compared to continuous production.
4. Higher set up costs due to frequent changes in set up.

Mass PRODUCTION

Characteristics

1. Standardization of product and process sequence.
2. Dedicated special purpose machines having higher production capacities and output rates.
3. Large volume of products.
4. Shorter cycle time of production.
5. Lower in process inventory.
6. Perfectly balanced production lines.
7. Flow of materials, components and parts is continuous and without any back tracking.
8. Production planning and control is easy.
9. Material handling can be completely automatic.

Advantageous

1. Higher rate of production with reduced cycle time.
2. Higher capacity utilization due to line balancing.
3. Less skilled operators are required.
4. Low process inventory.
5. Manufacturing cost per unit is low.

Limitations

1. Breakdown of one machine will stop an entire production line.
2. Line layout needs major change with the changes in the product design.
3. High investment in production facilities.
4. The cycle time is determined by the slowest operation.

Continuous PRODUCTION

Characteristics

1. Dedicated plant and equipment with zero flexibility.
2. Material handling is fully automated.
3. Process follows a predetermined sequence of operations.
4. Component materials cannot be readily identified with final product.
5. Planning and scheduling is a routine action.

Advantageous

1. Standardization of product and process sequence.
2. Higher rate of production with reduced cycle time.
3. Higher capacity utilization due to line balancing.
4. Manpower is not required for material handling as it is completely automatic.
5. Person with limited skills can be used on the production line.
6. Unit cost is lower due to high volume of production.

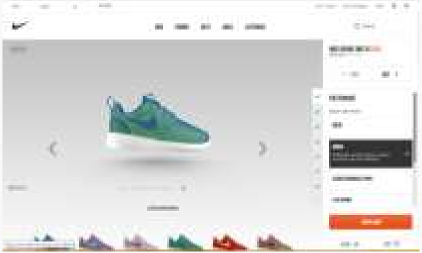
Limitations

1. Flexibility to accommodate and process number of products does not exist.
2. Very high investment for setting flow lines.
3. Product differentiation is limited.

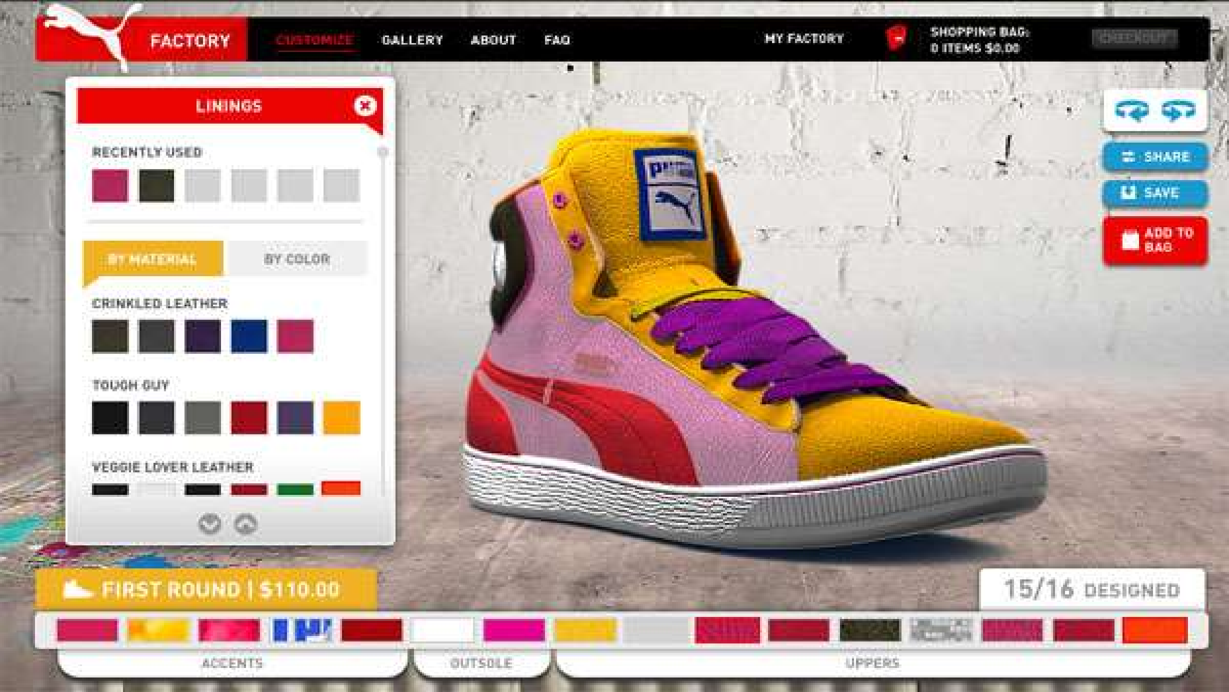
Fixed location production

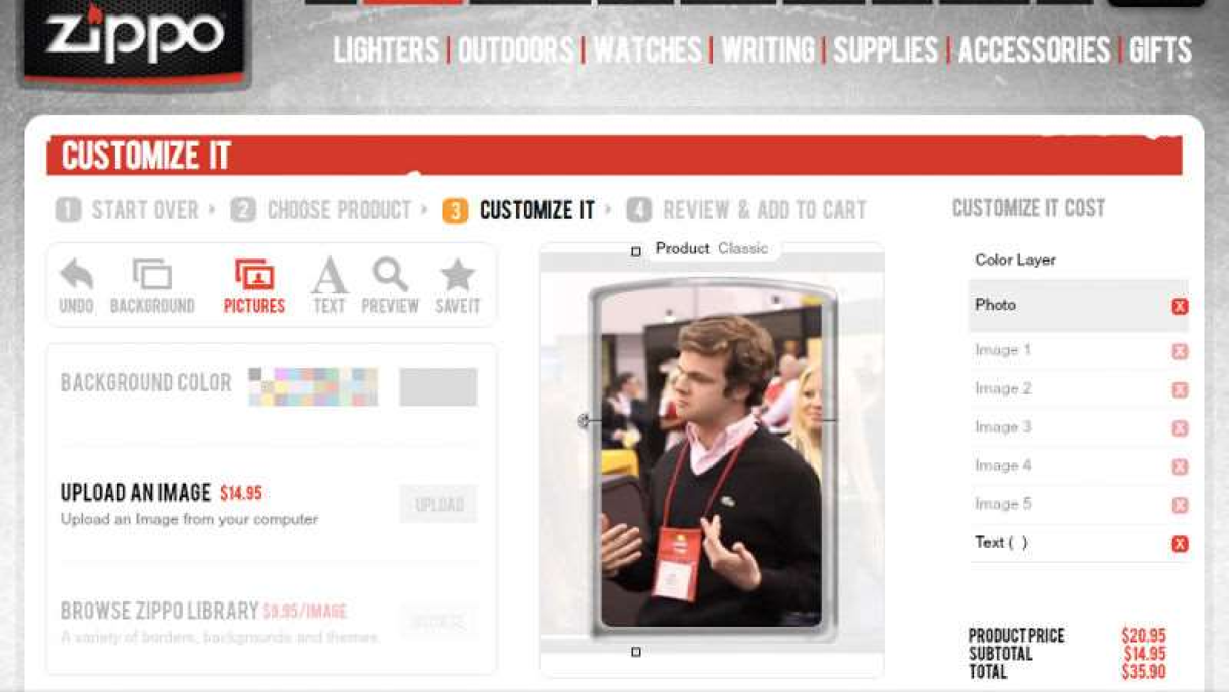

CUSTOMIZE
More ways to create
CONTENT

Custom product line Nike




customize
eyewear


FACTORY
CUSTOMIZE
GALLERY
ABOUT
FAQ
MY FACTORY
SHOPPING BAG:
0 ITEMS $0.00
CHECKOUT
LININGS
RECENTLY USED
BY MATERIAL
BY COLOR
CRINKLED LEATHER
TOUGH GUY
VEGGIE LOVER LEATHER
SHARE
SAVE
ADD TO BAG
FIRST ROUND | $110.00
15/16 DESIGNED
ACCENTS
OUTSOLE
UPPERS

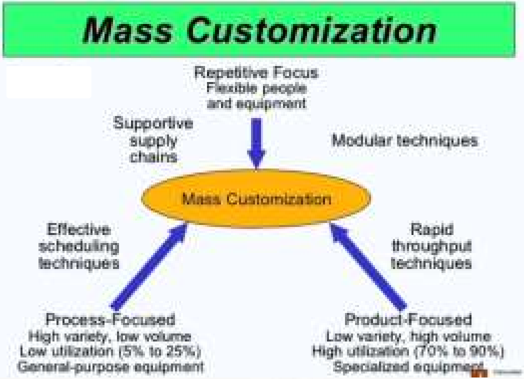


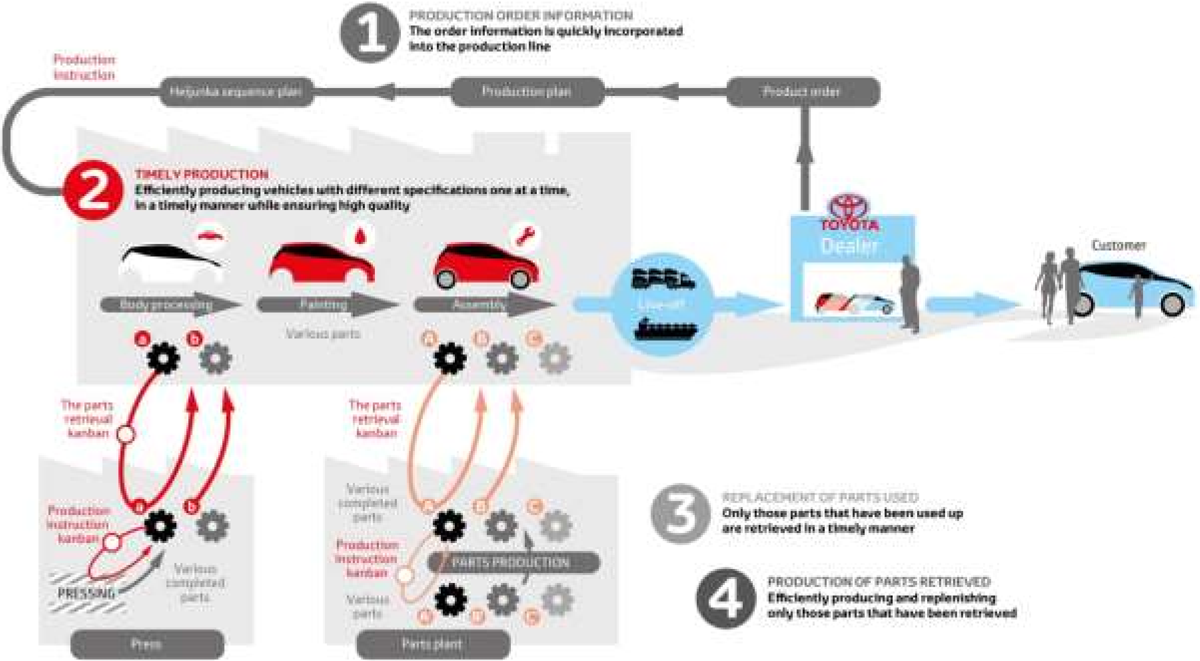
zippo
LIGHTERS | OUTDOORS | WATCHES | WRITING | SUPPLIES | ACCESSORIES | GIFTS
CUSTOMIZE IT
1 START OVER › 2 CHOOSE PRODUCT › 3 CUSTOMIZE IT › 4 REVIEW & ADD TO CART
CUSTOMIZE IT COST
UNDO
BACKGROUND
PICTURES
TEXT
PREVIEW
SAVE IT
BACKGROUND COLOR
UPLOAD AN IMAGE $14.95
Upload an Image from your computer
UPLOAD
BROWSE ZIPPO LIBRARY
Product Classic
Color Layer
Photo
Image 1
Image 2
Image 3
Image 4
Image 5
Text ( )
PRODUCT PRICE $20.95
SUBTOTAL $14.95
TOTAL $35.90

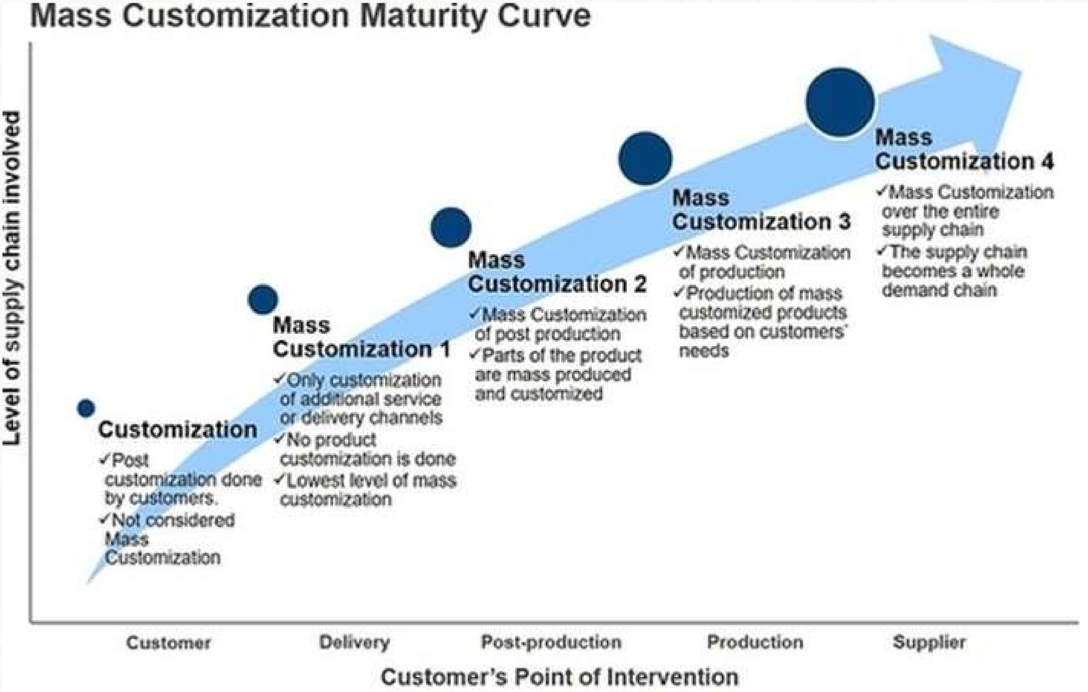
MASS CUSTOMIZATION PRODUCTION

Mass customization is a marketing and manufacturing technique that combines the flexibility and personalization of "custom-made" with the low unit costs associated with mass production.

TOYOTA




1
PRODUCTION ORDER INFORMATION
The order information is quickly incorporated into the production line
Production instruction
Heijunka sequence plan
Production plan
Product order
2
TIMELY PRODUCTION
Efficiently producing vehicles with different specifications one at a time, in a timely manner while ensuring high quality
Body processing
Painting
Assembly
Various parts
TOYOTA
Dealer
Customer
The parts retrieval kanban
The parts retrieval kanban
Production instruction kanban
PRESSING
Various completed parts
Various completed parts
Production instruction kanban
PARTS PRODUCTION
Various parts
Press
Parts plant
3
REPLACEMENT OF PARTS USED
Only those parts that have been used up are retrieved in a timely manner
4
PRODUCTION OF PARTS RETRIEVED
Efficiently producing and replenishing only those parts that have been retrieved


Mass Customization Maturity Curve
Level of supply chain involved
Customization
✓Post customization done by customers.
✓Not considered Mass Customization
Mass Customization 1
✓Only customization of additional service or delivery channels
✓No product customization is done
✓Lowest level of mass customization
Mass Customization 2
✓Mass Customization of post production
✓Parts of the product are mass produced and customized
Mass Customization 3
✓Mass Customization of production
✓Production of mass customized products based on customers' needs
Mass Customization 4
✓Mass Customization over the entire supply chain
✓The supply chain becomes a whole demand chain
Customer
Delivery
Post-production
Production
Supplier
Customer's Point of Intervention

The 5 Levels Of Mass Customization

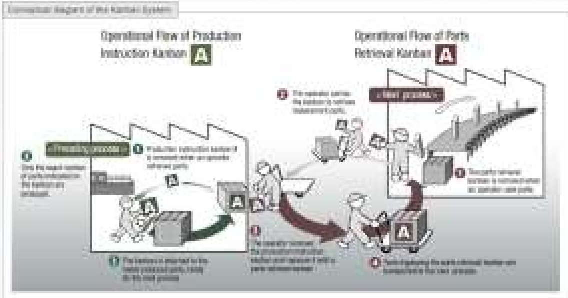
There are 5 levels of mass customized of production:

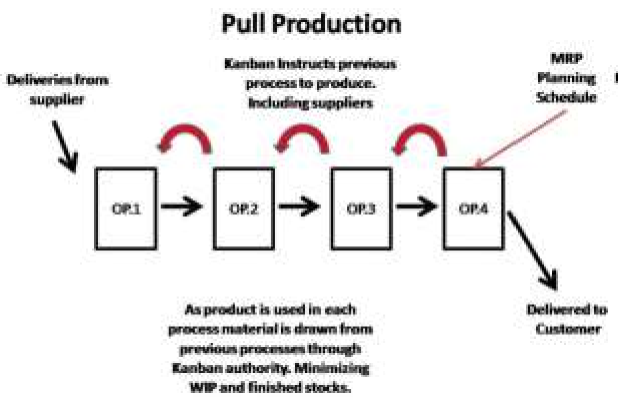
- **No Mass Customization**: customization is only done by customers.
- **Mass Customization Level 1**: No product mass customization. Mass customization is done in additional services or delivery channel.
- **Mass Customization Level 2**: Post-production Mass Customization. Parts of the product are mass produced and customized post-production adjusts the product to customers needs.
- **Mass Customization Level 3:** Mass Customization of Production. Production of mass customized products based on customers' needs. Unique products are produced to satisfy unique needs.
- **Mass Customization Level 4**: The entire supply chain network is transparent to the customers. Customized CAD, CAE, CAM are used by customers to design their products. Mass customization over the entire supply chain requires binding companies into network in order to satisfy the needs of the customers.

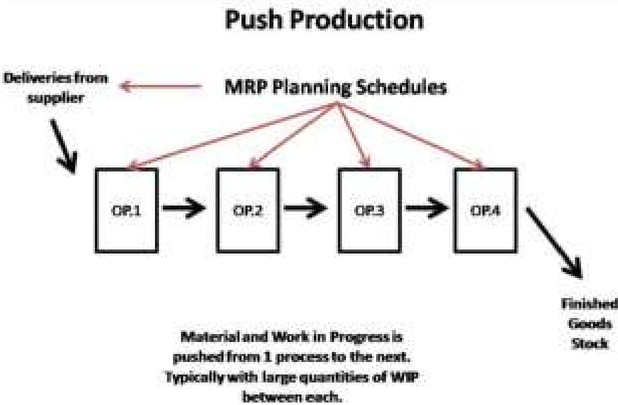
1-4 PRODUCTION MANAGEMENT

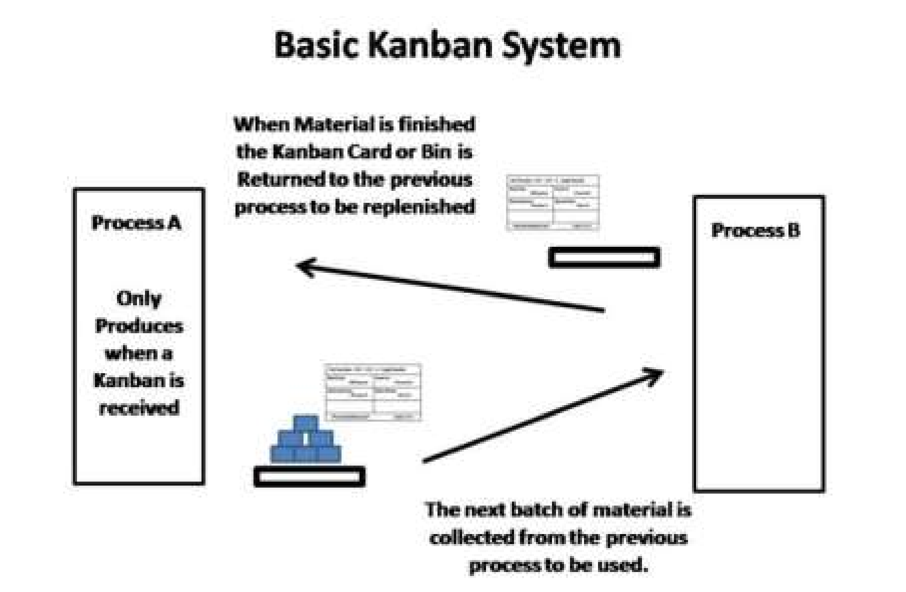
- kanban

a Japanese manufacturing system in which the supply of components is regulated through the use of an instruction card sent along the production line.




Pull Production
Kanban Instructs previous process to produce. Including suppliers
Deliveries from supplier
MRP Planning Schedule
OP.1
OP.2
OP.3
OP.4
Delivered to Customer
As product is used in each process material is drawn from previous processes through Kanban authority. Minimizing WIP and finished stocks.


Push Production
Deliveries from supplier
MRP Planning Schedules
OP.1
OP.2
OP.3
OP.4
Finished Goods Stock
Material and Work in Progress is pushed from 1 process to the next. Typically with large quantities of WIP between each.


Basic Kanban System
When Material is finished the Kanban Card or Bin is Returned to the previous process to be replenished
Process A
Only Produces when a Kanban is received
Process B
The next batch of material is collected from the previous process to be used.

Part Description				Part Number	
Smoke-shifter, left handed.				14613	
Qty	20	Lead Time	1 week	Order Date	9/3
Supplier	Acme Smoke-Shifter, LLC			Due Date	9/10
Planner	John R.		Card 1 of 2		
			Location	Rack 1B3	

Supplier:	**PU1**	Customer:	**PU2**
Description:	**Production Unit 1**	Location:	**Loc02**
		Container:	**Box 1**
Kanbans:	**5**	Qty:	**100**

created: 9/20/2018 21:20:00

printed: 10/9/2018 12:30:15

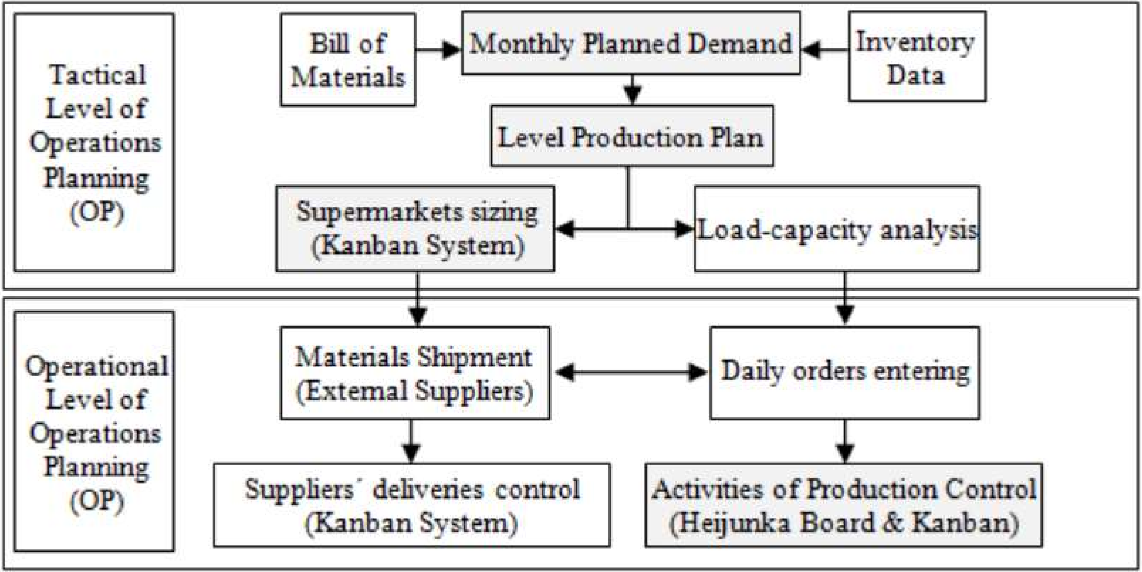
Description:

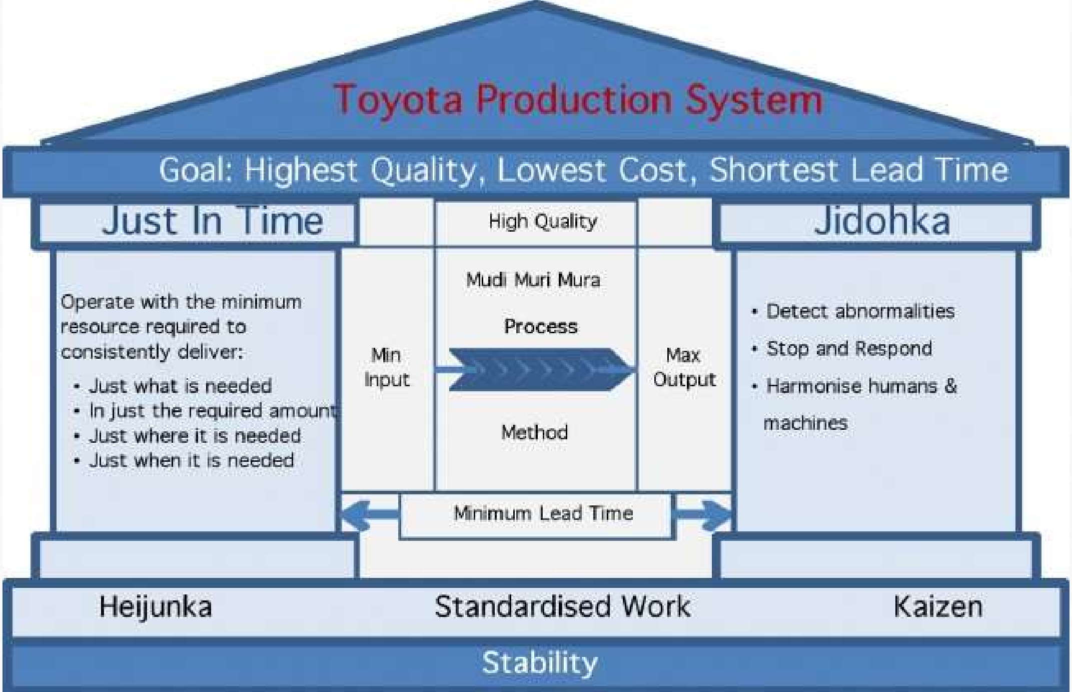
Item 012345

Item ID:

012345

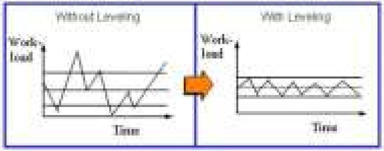
A Conceptual Model for Production Leveling (Heijunka) Implementation in Batch Production Systems




Toyota Production System
Goal: Highest Quality, Lowest Cost, Shortest Lead Time
Just In Time
High Quality
Jidohka
Operate with the minimum resource required to consistently deliver:
• Just what is needed
• In just the required amount
• Just where it is needed
• Just when it is needed
Mudi Muri Mura
Process
Min Input
Max Output
Method
• Detect abnormalities
• Stop and Respond
• Harmonise humans & machines
Minimum Lead Time
Heijunka
Standardised Work
Kaizen
Stability

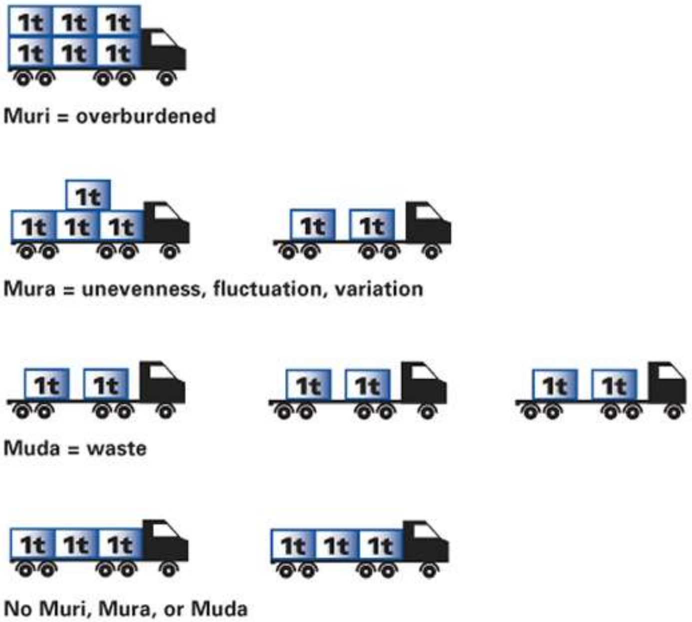
1-4 PRODUCTION MANAGEMENT

- Production leveling, also known as production smoothing or – by its Japanese original term – heijunka is a technique for reducing the Mura (Unevenness) which in turn reduces muda (waste).
- It was vital to the development of production efficiency in the Toyota Production System and lean manufacturing. The goal is to produce intermediate goods at a constant rate so that further processing may also be carried out at a constant and predictable rate.



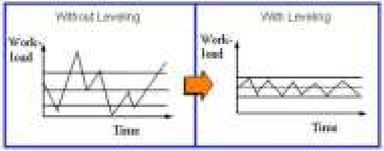

The 7 Wastes
Over-production
1
2
Inventory
3
Motion
4
Waiting
5
Transportation
6
Rework
7
Over-processing


Muda
Waste
Mura
Unevenness
Muri
Overburden


1t 1t 1t
1t 1t 1t
Muri = overburdened
1t
1t 1t 1t
1t 1t
Mura = unevenness, fluctuation, variation
1t 1t
1t 1t
1t 1t
Muda = waste
1t 1t 1t
1t 1t 1t
No Muri, Mura, or Muda

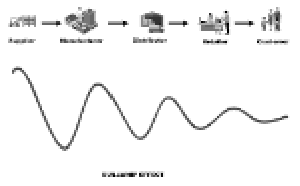
1-4 PRODUCTION MANAGEMENT

- On a production line, as in any process, fluctuations in performance increase waste. This is because equipment, workers, inventory and all other elements required for production must always be prepared for peak production.
- This is a cost of flexibility. If a later process varies its withdrawal of parts in terms of timing and quality, the range of these fluctuations will increase as they move up the line towards the earlier processes. This is known as demand amplification.



1-4 PRODUCTION MANAGEMENT

- The bullwhip effect is a distribution channel phenomenon in which forecasts yield supply chain inefficiencies.
- It refers to increasing swings in inventory in response to shifts in customer demand as one moves further up the supply chain.



1-4 PRODUCTION MANAGEMENT

- The bullwhip effect can be caused by a huge number of contributing factors, but some of the most common causes of the bullwhip effect include:
  - Forecast errors – Decisions in every link of the supply chain are made based on demand forecasts for businesses. Errors in forecasting lead to miscalculations that are magnified as they move up the supply chain.
  - Order batching – Placing frequent orders for small quantities creates less of a bullwhip effect than placing larger orders less frequently. With order batching, the retailer places orders with its supplier once per month (rather than several times throughout the month), which creates inconsistent demand for the supplier over time.

1-4 PRODUCTION MANAGEMENT

- Lead time – Lead time is the span of time between when an order is placed and when it's received. Failing to consider lead time when managing inventory can lead to an overstocking of products, which in turn results in a change in supplier demand over time i.e. the bullwhip effect.
- Sales and price discounts – Sales and discounts create a boom-and-bust cycle. Lots of product moves during the promotional period, which is followed by lower levels of sales. This cycle ripples through the supply chain, resulting in the bullwhip effect.

The bullwhip effect exists in all supply chains and is the root of the boom-and-bust cycles in many operations. Left unchecked, it can have detrimental effects on a business, which is why it's so important to manage it proactively, as we'll see below.

1-4 PRODUCTION MANAGEMENT

Taking the bullwhip by its handle

1. Streamline your supply chain – Reducing the number of suppliers and the number of tiers in your supply chain can facilitate better communication across teams and decrease the swing that creates the bullwhip effect. Utilizing supply chain automation technology helps link together all aspects of the supply chain and consolidate communication channels.

2. Optimize inventory management – Keeping track of stock levels, orders, and demand with inventory management software leads to more accurate ordering from suppliers, decreasing the bullwhip effect.

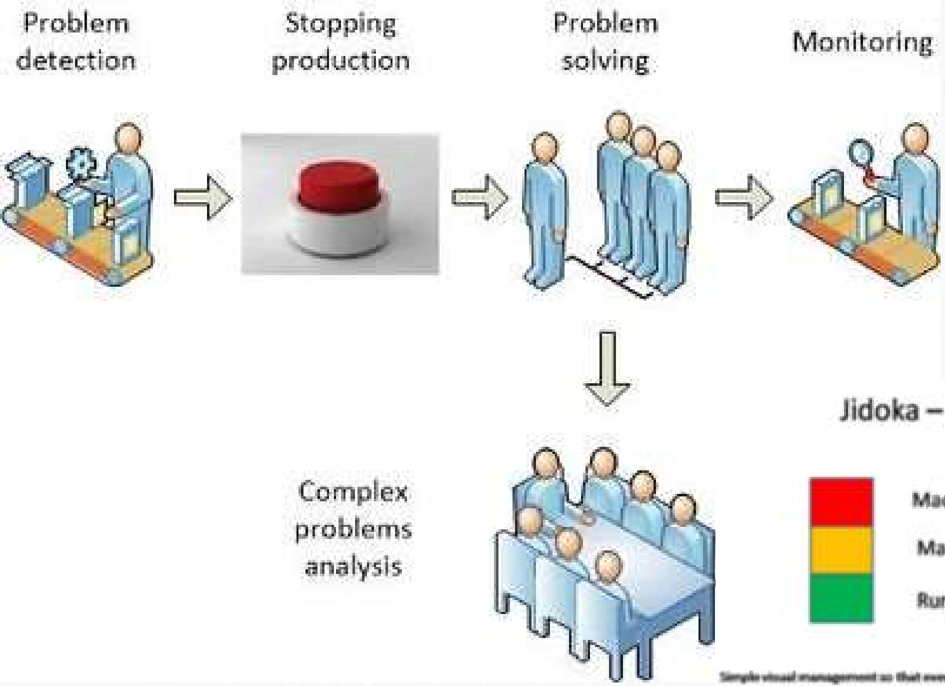
1-4 PRODUCTION MANAGEMENT

3. Minimize sales and discounts – Maintaining a steady price point even during market fluctuations decreases the bullwhip effect by encouraging a regular stream of customer demand. Clothing and accessories business Ever lane reduces the bullwhip effect by rarely holding sales or giving discounts, instead opting to keep prices low year-round with a smart direct-to-consumer model.

4. Maintain consistent, smaller order sizes – Offering bulk discounts may attract customers but it also unnecessarily increases inventory levels and magnifies the bullwhip effect. Encouraging orders according to customer need instead of bulk discounts helps mitigate the bullwhip effect.

1-4 PRODUCTION MANAGEMENT

- Jidoka is one of the two pillars of the Toyota Production System along with just-in-time.
- Jidoka highlights the causes of problems because work stops immediately when a problem first occurs. This leads to improvements in the processes that build in quality by eliminating the root causes of defects.

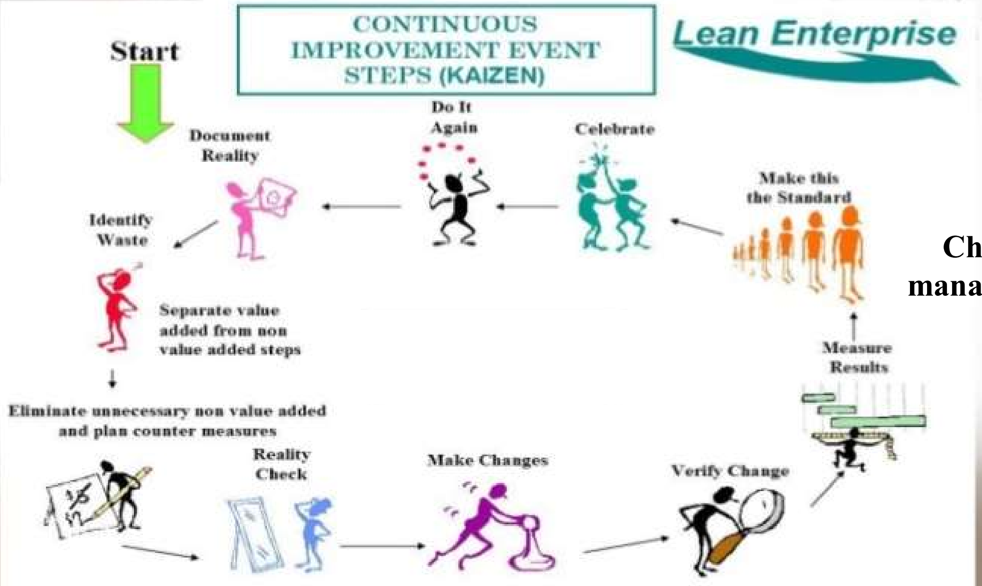

Problem detection
Stopping production
Problem solving
Monitoring
Complex problems analysis


Jidoka – Andon Light
Machine is Stopped
Machine Has Problems
Running OK

1-4 PRODUCTION MANAGEMENT

- Kaizen, Japanese for "improvement." When used in the business sense and applied to the workplace, kaizen refers to activities that continuously improve all functions and involve all employees from the CEO to the assembly line workers.
- It also applies to processes, such as purchasing and logistics, that cross organizational boundaries into the supply chain. By improving standardized activities and processes, kaizen aims to eliminate waste

PROCESS OF KAIZEN



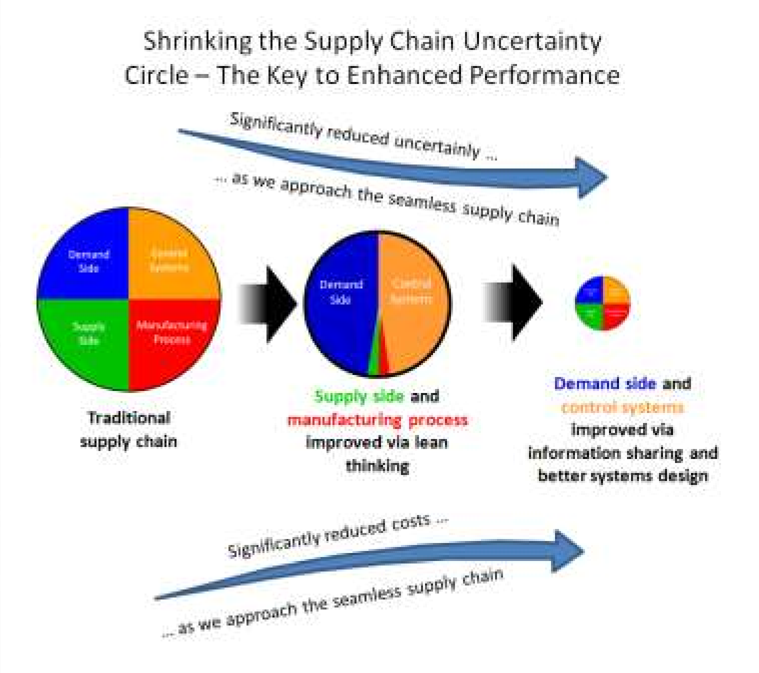
Change management

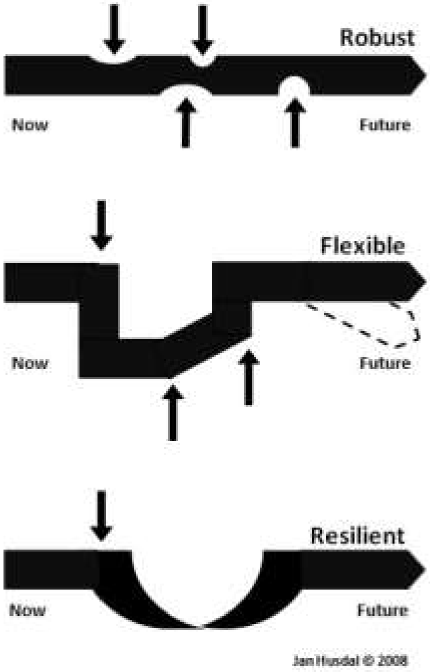
1-3 CONCEPT OF PRODUCTION

Strategies to deal with uncertainty:

- Adapter
- Shaper

Uncertainty: The lack of certainty, a state of limited knowledge where it is impossible to exactly describe the existing state, a future outcome, or more than one possible outcome


Shrinking the Supply Chain Uncertainty Circle – The Key to Enhanced Performance
Significantly reduced uncertainly ...
... as we approach the seamless supply chain
Demand Side
Control Systems
Supply Side
Manufacturing Process
Demand Side
Control Systems
Traditional supply chain
Supply side and manufacturing process improved via lean thinking
Demand side and control systems improved via information sharing and better systems design
Significantly reduced costs ...
... as we approach the seamless supply chain



1. Robustness is the ability to accommodate any uncertain future events or unexpected developments such that the initially desired future state can still be reached.
2. Flexibility is the ability to defer, abandon, expand, or contract any investment towards the desired goal.
3. Resilience is the ability of a system to return to its original state or move to a new desirable state after being disturbed.

1-3 CONCEPT OF PRODUCTION

- Risk management
    - Inactive
    - Reactive
    - Proactive
- In risk, you can predict the possibility of a future outcome while in uncertainty you cannot predict the possibility of a future outcome.
- Risk can be managed while uncertainty is uncontrollable.
- Risks can be measured and quantified while uncertainty cannot.

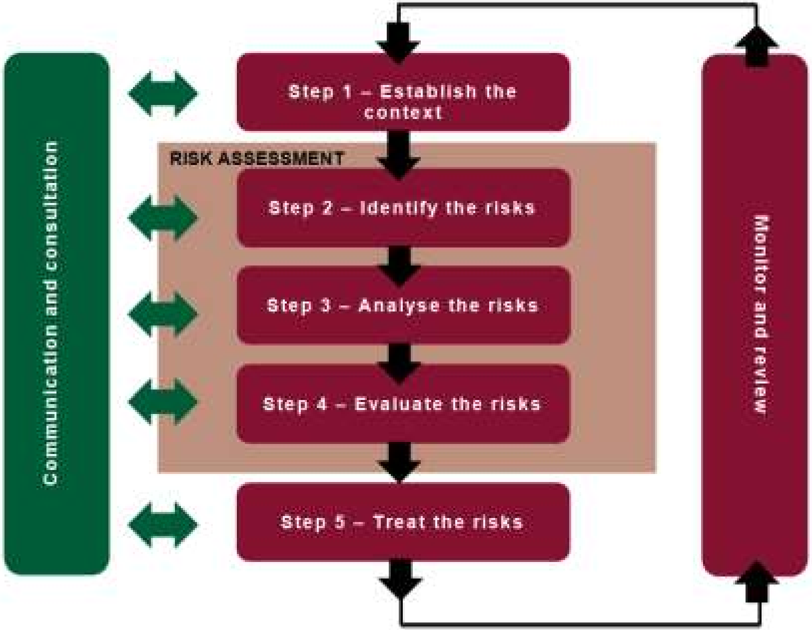
1-3 CONCEPT OF PRODUCTION

- Disruption

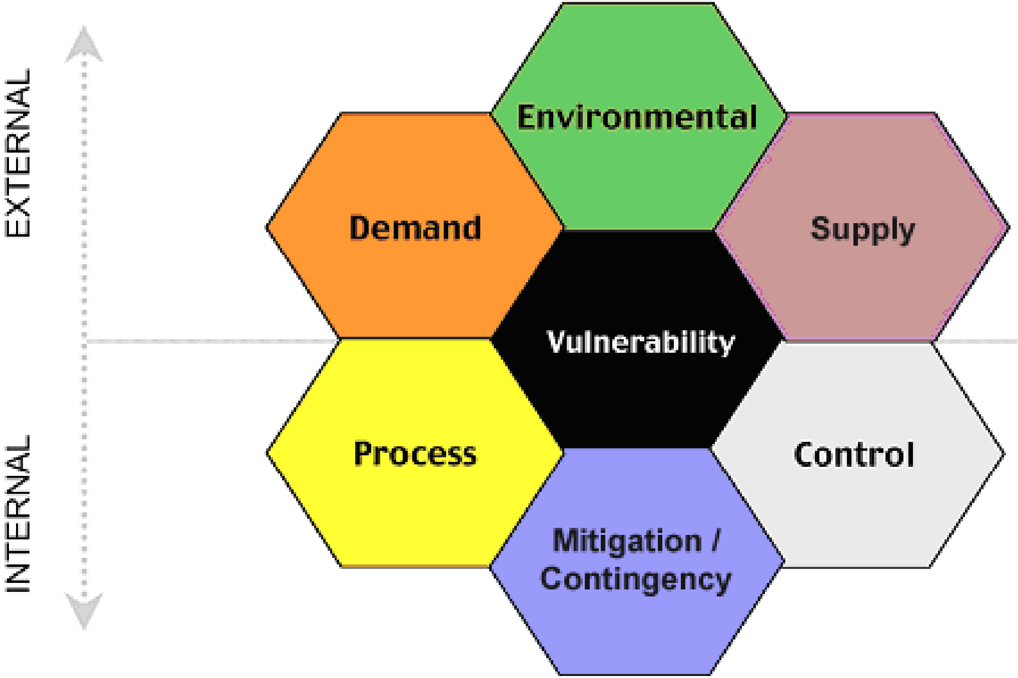
The act or process of disrupting something : a break or interruption in the normal course or continuation of some activity, process, etc.

- Disaster

A disaster is a serious disruption occurring over a relatively short period of time that causes widespread human, material, economic or environmental loss which exceeds the ability of the affected community or society to cope on a timely basis using its own resources.



Communication and consultation
Step 1 – Establish the context
RISK ASSESSMENT
Step 2 – Identify the risks
Step 3 – Analyse the risks
Step 4 – Evaluate the risks
Step 5 – Treat the risks
Monitor and review


EXTERNAL
INTERNAL
Environmental
Demand
Supply
Vulnerability
Process
Control
Mitigation / Contingency

External Drivers

- Demand risk

Demand risk relates to potential or actual disturbances to flow of product, information, and cash, emanating from within the network, between the focal company and the market. This demand risk can be a failure on either the high or low side to accurately accommodate the level of demand.

- Supply risk

Supply risk is the upstream equivalent of demand risk, it relates to potential or actual disturbances to the flow of product or information emanating within the network, upstream of the focal company. Therefore, it is risk associated with a company's suppliers, or supplier's suppliers being unable to deliver the materials the company needs to effectively meet its production requirements/demand forecasts.

- Environmental

Environmental risk is the risk associated with external and, from the company's perspective, uncontrollable events. Examples would include port and depot blockades, closure of an entire industrial area due to fire or chemical spillage, events such as earthquake, cyclone, volcanic or terrorist activity.

Internal Drivers

- Process risk

Processes are the sequences of value-adding and managerial activities undertaken by the company. Process risk relates to disruptions to these processes.

- Control risk

Controls are the assumptions, rules, systems and procedures that govern how an organization exerts control over the processes. In terms of the supply chain they may be order quantities, batch sizes, safety stock policies etc. Control risk is therefore the risk arising from the application or misapplication of these rules.

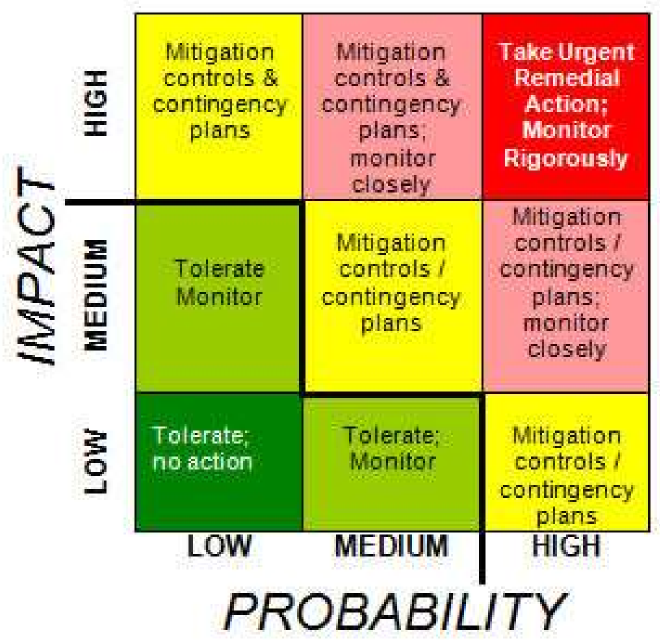
- Mitigation and contingency

Mitigation is a hedge against risk built into the operations themselves and, therefore, the lack of mitigating tactics is a risk in itself.

Contingency is the existence of a prepared plan and the identification of resources that can be mobilized in the event of a risk being identified.

The classic mitigations in supply chain management are:

  - Inventory
  - Capacity
  - Dual sourcing
  - Distribution and logistics alternatives
  - Back up arrangements



IMPACT
HIGH
MEDIUM
LOW
Mitigation controls & contingency plans
Mitigation controls & contingency plans; monitor closely
Take Urgent Remedial Action; Monitor Rigorously
Tolerate Monitor
Mitigation controls / contingency plans
Mitigation controls / contingency plans; monitor closely
Tolerate; no action
Tolerate; Monitor
Mitigation controls / contingency plans
LOW
MEDIUM
HIGH
PROBABILITY

1-3 CONCEPT OF PRODUCTION

Establish the external context

- The **external context is the environment** in which the firm operates and seeks to achieve its objectives.
- Consideration should be given to the following inputs as they relate to the business, social, regulatory, legislative, cultural, competitive, financial, and political environment, including:
- Strengths, weaknesses, opportunities and threats
- Relationships with, perceptions and values of, external stakeholders such as clients.

1-3 CONCEPT OF PRODUCTION

Establish the internal context

- **The internal context is the internal environment** in which the firm functions and seeks to achieve its objectives. Consideration should be given to factors such as:
- Objectives and strategies in place to achieve objectives
- Governance, structure, roles and accountabilities
- Capability of people, systems and processes
- Changes to processes or compliance obligations
- The risk tolerance and appetite of the firm.

1-4 PRODUCTION MANAGEMENT

Production management is a process of planning, organizing, directing and controlling the activities of the production function. It combines and transforms various resources used in the production subsystem of the organization into value added product in a controlled manner as per the policies of the organization.

E.S. Buffa defines production management as, "Production management deals with decision making related to production processes so that the resulting goods or services are produced according to specifications, in the amount and by the schedule demanded and out of minimum cost."

1-4 Objectives of Production Management

1. RIGHT QUALITY

The quality of product is established based upon the customers needs. The right quality is not necessarily best quality. It is determined by the cost of the product and the technical characteristics as suited to the specific requirements.

2. RIGHT QUANTITY

The manufacturing organization should produce the products in right number. If they are produced in excess of demand the capital will block up in the form of inven[illegible] quantity is produced in short of demand, leads to shortage of products.

1-4 Objectives of Production Management

3. RIGHT TIME

Timeliness of delivery is one of the important parameter to judge the effectiveness of production department. So, the production department has to make the optimal utilization of input resources to achieve its objective.

4. RIGHT MANUFACTURING COST

Manufacturing costs are established before the product is actually manufactured. Hence, all attempts should be made to produce the products at pre-established cost, so as to r variation between actual and the standard (pre-established) cost.

1-4 Competitive advantages

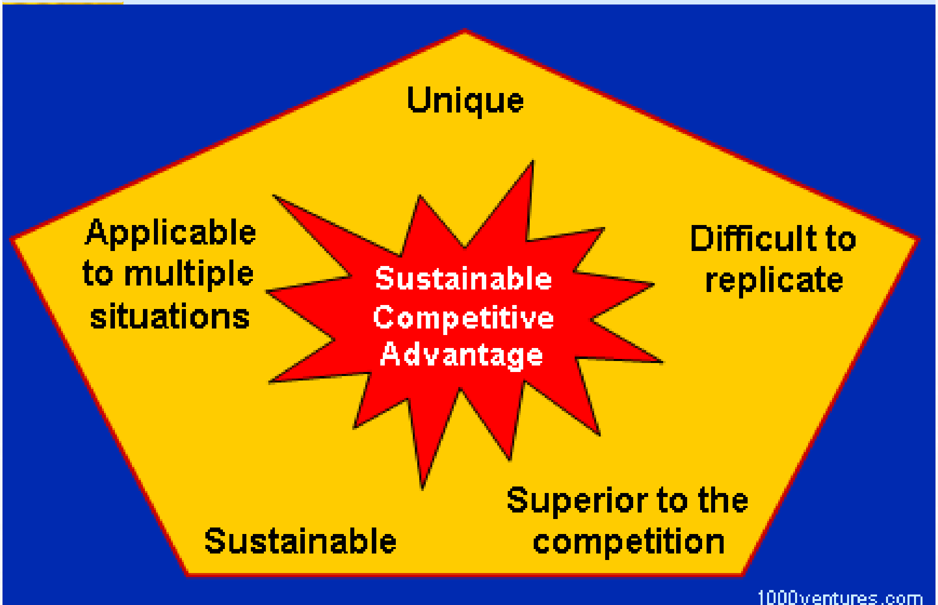
A **competitive advantage** is an **advantage** over **competitors** gained by offering consumers greater value, either by means of lower prices or by providing greater benefits and service that justifies higher prices.

Competitive advantage

		Competitive advantage	
		Lower costs	Differentiation
Competitive scope	Broad target	Cost leadership	Differentiation
	Narrow target	Cost focus	Differentiation focus

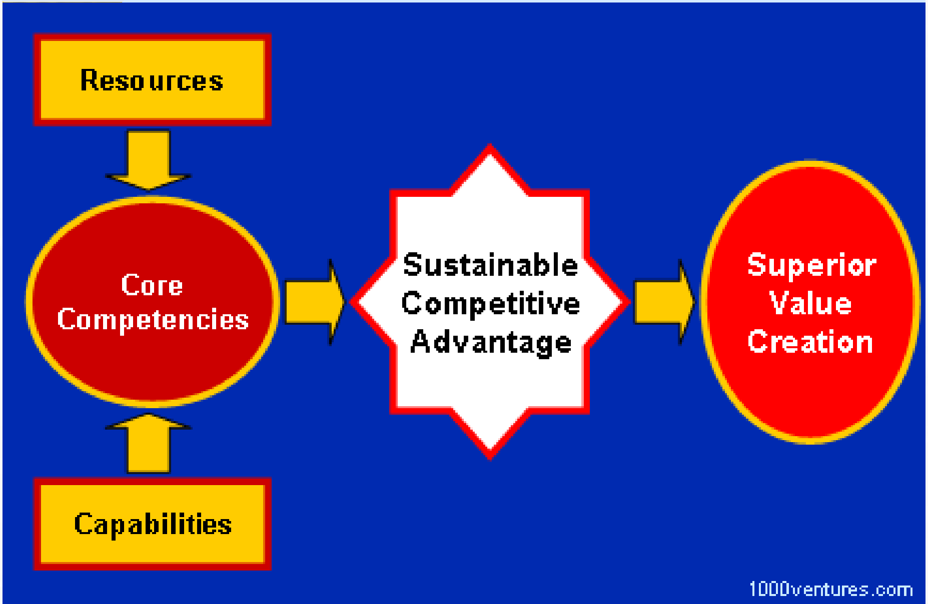
Sustainable Competitive Advantage

The Five Criteria

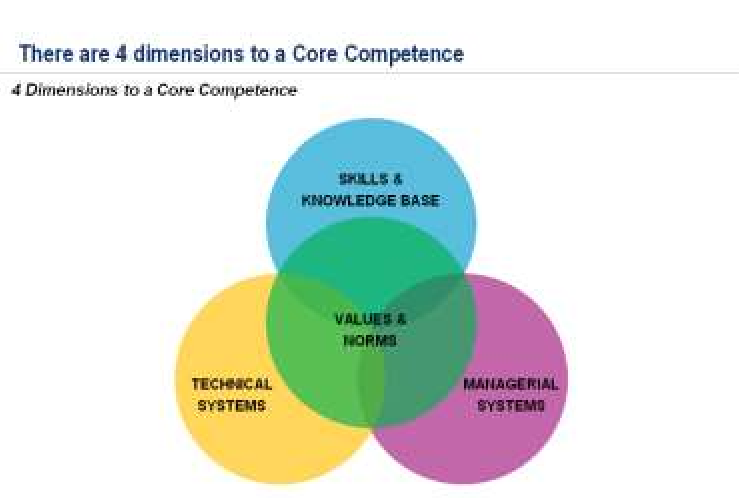


Sustainable Competitive Advantage

Resource-based View



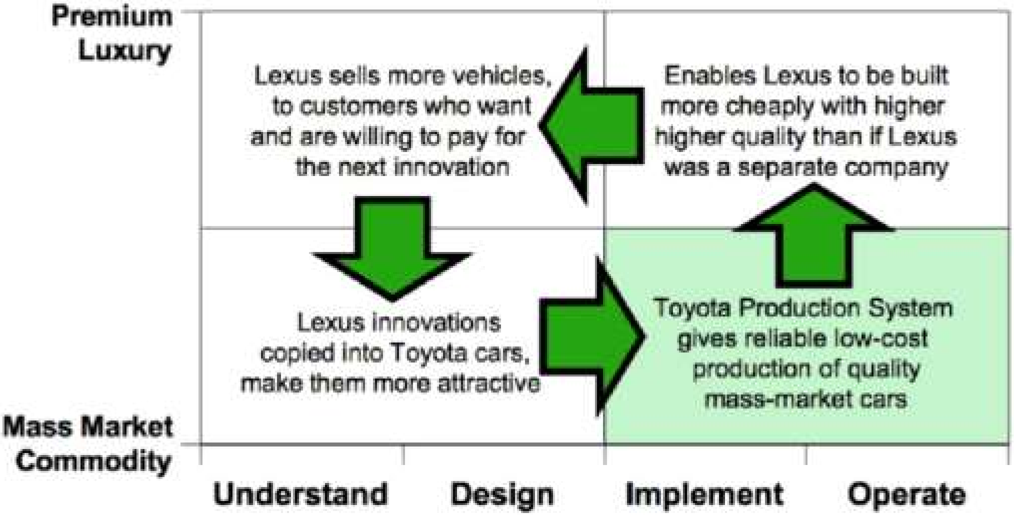
- A core competency is a concept in management theory introduced by C. K. Prahalad and Gary Hamel. It can be defined as "a harmonized combination of multiple resources and skills that distinguish a firm in the marketplace" and therefore are the foundation of companies' competitiveness

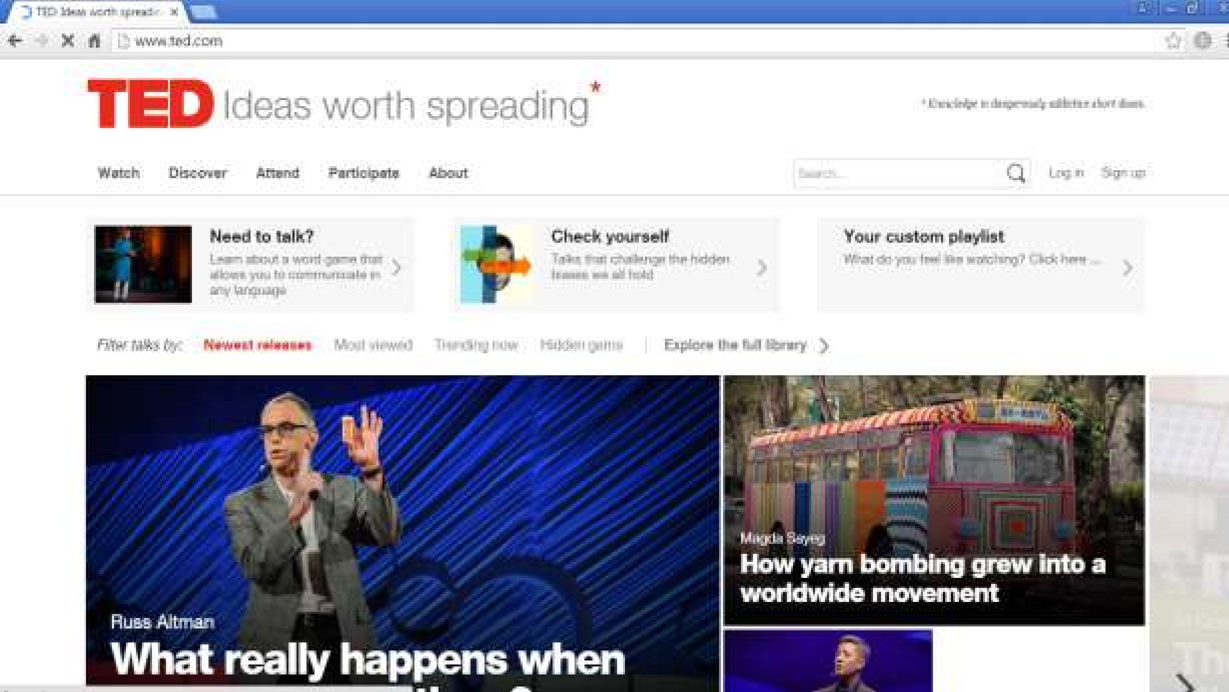


Will Toyota be able to sustain its competitive advantage in the future?

- Its difficult to say.
- There are a lot of factors that could come into play.
- Keeping environmental factors aside the founding family now owns a very small stake in the company.
- If the initial drive to keep moving forward is lost then the company may not be able to maintain its advantage.
- However if the company keeps moving forward and constantly seeks improvement then the company should be able to maintain its competitive advantage.

Toyota - Lexus

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Watch
Discover
Attend
Participate
About
Log in
Sign up
Need to talk?
Learn about a word game that allows you to communicate in any language
Check yourself
Talks that challenge the hidden biases we all hold
Your custom playlist
What do you feel like watching? Click here ...
Filter talks by:
Newest releases
Most viewed
Trending now
Hidden gems
Explore the full library
Russ Altman
What really happens when
Magda Sayeg
How yarn bombing grew into a worldwide movement

STRATEGIES for *e*-BUSINESS

Creating Value through Electronic and Mobile Commerce

CONCEPTS and CASES

FT Prentice Hall

TAWFIK JELASSI

ALBRECHT ENDERS

1-6 OPERATING SYSTEM

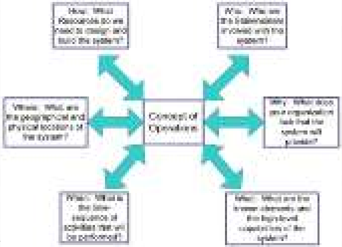
Operating system converts inputs in order to provide outputs which are required by a customer.

It converts physical resources into outputs, the function of which is to satisfy customer wants i.e., to provide some utility for the customer. In some of the organization the product is a physical good (hotels) while in others it is a service (hospitals). Bus and taxi services, tailors, hospital and builders are the examples of an operating system.

- Everett E. Adam & Ronald J. Ebertdefine operating system as, "**An operating system (function) of an organization is the part of an organization that produces the organization's physical goods and services**."
- Ray Wilddefines operating system as, "An operating system is a configuration of resources combined for the provision of goods or services."

1-6 OPERATING SYSTEM

An operation is defined in terms of the mission it serves for the organization, technology it employs and the human and managerial processes it involves. Operations in an organization can be categorized into manufacturing operations and service operations. Manufacturing operations is a conversion process that includes manufacturing yields a tangible output: a product, whereas, a conversion process that includes service yields an intangible output: a deed, a performance, an effort.



1-6 Distinction between Manufacturing Operations and Service Operations

Following characteristics can be considered for distinguishing manufacturing operations with service operations:

1. Tangible/Intangible nature of output
2. Consumption of output
3. Nature of work (job)
4. Degree of customer contact
5. Customer participation in conversion
6. Measurement of performance.

1-6 Distinction between Manufacturing Operations and Service Operations

Manufacturing is characterized by tangible outputs (products),

outputs that customers consume overtime,

jobs that use less labor and more equipment,

little customer contact, no customer participation in the conversion process (in production),

and sophisticated methods for measuring production activities and resource consumption as product are made.

1-6 Distinction between Manufacturing Operations and Service Operations

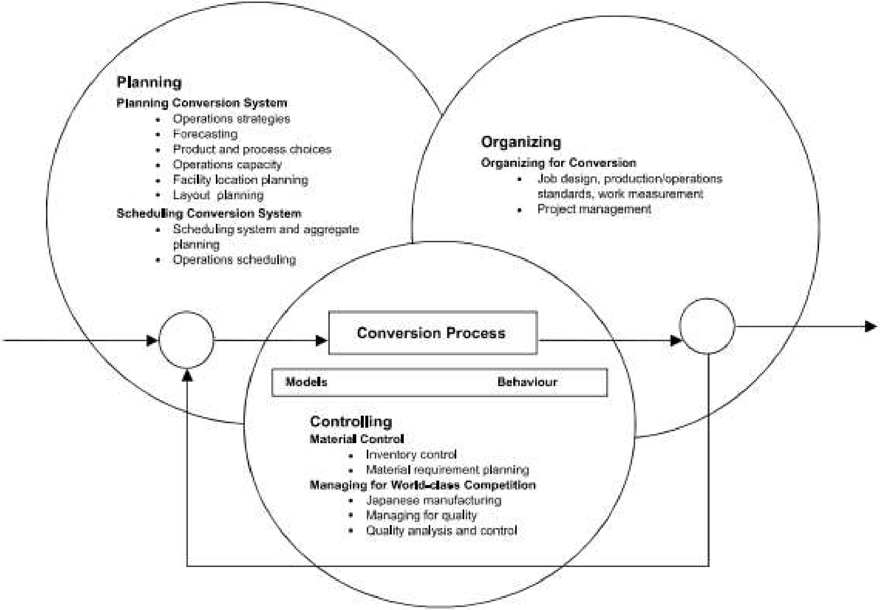
Service is characterized by intangible outputs, outputs that customers consumes immediately, jobs that use more labor and less equipment, direct consumer contact, frequent customer participation in the conversion process,

and elementary methods for measuring conversion activities and resource consumption.

Some services are equipment based namely rail-road services, telephone services and some are people based namely tax consultant services, hair styling.

1-7 OPERATIONS MANAGEMENT

- Managing operations can be enclosed in a frame of general management function as shown previously.
- Operation managers are concerned with planning, organizing, and controlling the activities which affect human behavior through models.



General model for managing operations

1-7 A Framework for Managing Operations

PLANNING Activities that establishes a course of action and guide future decision-making is planning.

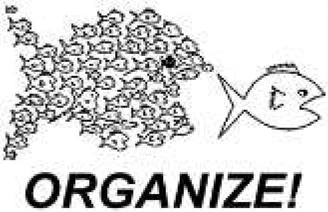
The operations manager defines the objectives for the operations subsystem of the organization, and the policies, and procedures for achieving the objectives. This stage includes clarifying the role and focus of operations in the organization's overall strategy.

It also involves product planning, facility designing and using the conversion pro

1-7 A Framework for Managing Operations

Activities that establishes a structure of tasks and authority.

Operation managers establish a structure of roles and the flow of information within the operations subsystem. They determine the activities required to achieve the goals and assign authority and responsibility for carrying them out.



1-7 A Framework for Managing Operations

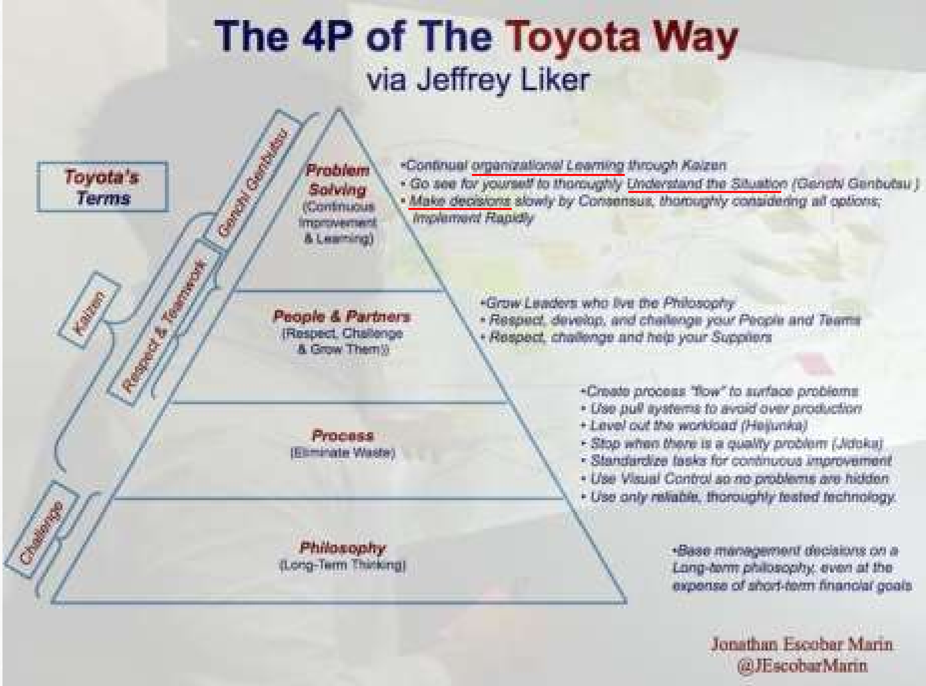
Activities that assure the actual performance in accordance with planned performance.

To ensure that the plans for the operations subsystems are accomplished, the operations manager must exercise control by measuring actual outputs and comparing them to planned operations management. Controlling costs, quality, and schedules are the important functions here.

1-7 BEHAVIOUR

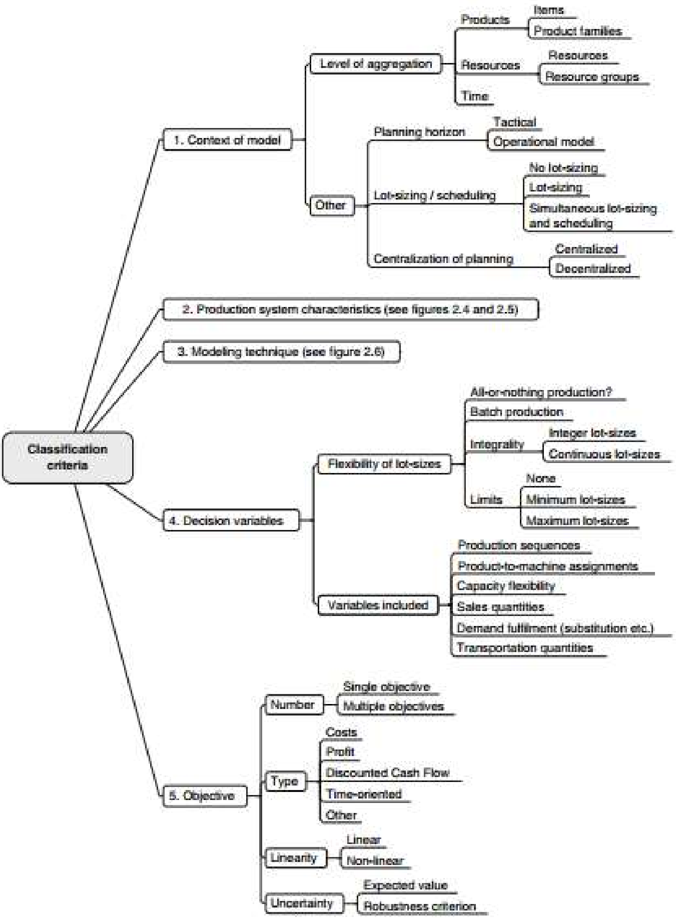
Operation managers are concerned with how their efforts to plan, organize, and control affect human behavior. They also want to know how the behavior of subordinates can affect management's planning, organizing, and controlling actions. Their interest lies in decision making behavior.

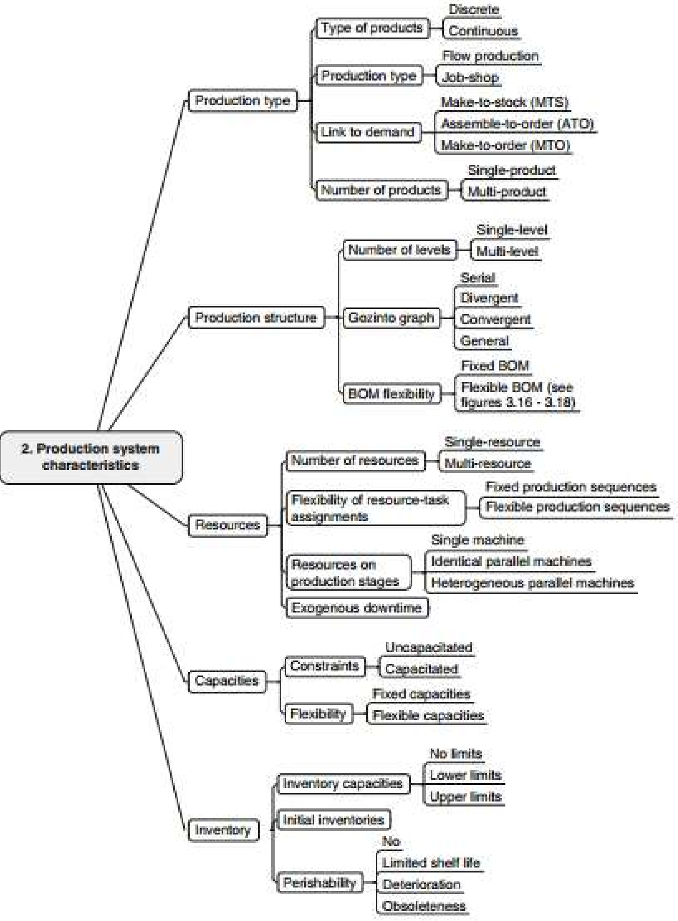
Professional Behaviours
Achieving results
Managing self and personal skills
Delivering excellent service
Finding innovative solutions
Embracing change
Using resources
Providing direction
Developing self and others
Working with people

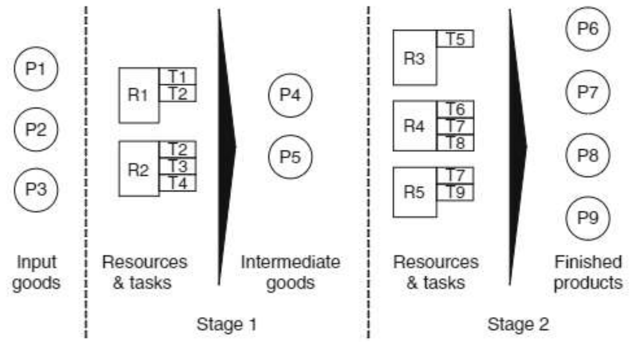

The 4P of The Toyota Way
via Jeffrey Liker
Toyota's Terms
Genchi Genbutsu
Kaizen
Respect & Teamwork
Challenge
Problem Solving
(Continuous Improvement & Learning)
•Continual organizational Learning through Kaizen
• Go see for yourself to thoroughly Understand the Situation (Genchi Genbutsu)
• Make decisions slowly by Consensus, thoroughly considering all options; Implement Rapidly
People & Partners
(Respect, Challenge & Grow Them)
•Grow Leaders who live the Philosophy
• Respect, develop, and challenge your People and Teams
• Respect, challenge and help your Suppliers
Process
(Eliminate Waste)
•Create process "flow" to surface problems
• Use pull systems to avoid over production
• Level out the workload (Heijunka)
• Stop when there is a quality problem (Jidoka)
• Standardize tasks for continuous improvement
• Use Visual Control so no problems are hidden
• Use only reliable, thoroughly tested technology
Philosophy
(Long-Term Thinking)
•Base management decisions on a Long-term philosophy, even at the expense of short-term financial goals
Jonathan Escobar Marin
@JEscobarMarin

1-7 MODELS

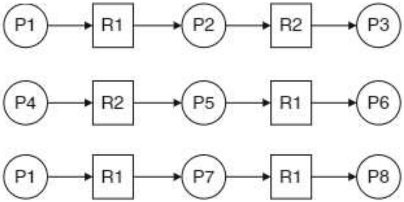
As operation managers plan, organize, and control the conversion process, they encounter many problems and must make many decisions. They can simplify their difficulties using models like aggregate planning models for examining how best to use existing capacity in short-term, break even analysis to identify break even volumes, linear programming and computer simulation for capacity utilization, decision tree analysis for long-term capacity problem of facility expansion, simple median model for determining best locations of facilities etc.


Classification criteria
1. Context of model
Level of aggregation
Products
Items
Product families
Resources
Resources
Resource groups
Time
Other
Planning horizon
Tactical
Operational model
Lot-sizing / scheduling
No lot-sizing
Lot-sizing
Simultaneous lot-sizing and scheduling
Centralization of planning
Centralized
Decentralized
2. Production system characteristics (see figures 2.4 and 2.5)
3. Modeling technique (see figure 2.6)
4. Decision variables
Flexibility of lot-sizes
All-or-nothing production?
Batch production
Integrality
Integer lot-sizes
Continuous lot-sizes
Limits
None
Minimum lot-sizes
Maximum lot-sizes
Variables included
Production sequences
Product-to-machine assignments
Capacity flexibility
Sales quantities
Demand fulfilment (substitution etc.)
Transportation quantities
5. Objective
Number
Single objective
Multiple objectives
Type
Costs
Profit
Discounted Cash Flow
Time-oriented
Other
Linearity
Linear
Non-linear
Uncertainty
Expected value
Robustness criterion


2. Production system characteristics
Production type
Type of products
Discrete
Continuous
Production type
Flow production
Job-shop
Link to demand
Make-to-stock (MTS)
Assemble-to-order (ATO)
Make-to-order (MTO)
Number of products
Single-product
Multi-product
Production structure
Number of levels
Single-level
Multi-level
Gozinto graph
Serial
Divergent
Convergent
General
BOM flexibility
Fixed BOM
Flexible BOM (see figures 3.16 - 3.18)
Resources
Number of resources
Single-resource
Multi-resource
Flexibility of resource-task assignments
Fixed production sequences
Flexible production sequences
Resources on production stages
Single machine
Identical parallel machines
Heterogeneous parallel machines
Exogenous downtime
Capacities
Constraints
Uncapacitated
Capacitated
Flexibility
Fixed capacities
Flexible capacities
Inventory
Inventory capacities
No limits
Lower limits
Upper limits
Initial inventories
Perishability
No
Limited shelf life
Deterioration
Obsoleteness



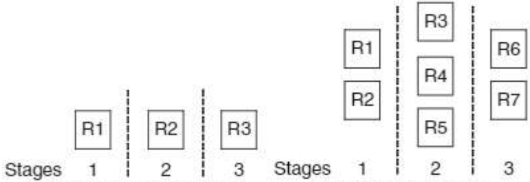
Example – stages, resources, tasks, and products in a flow production system



Example – resource sequences in a job-shop production environment

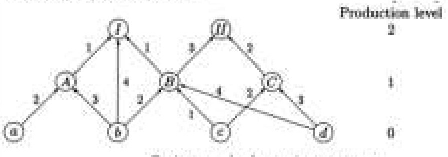
		production sequences	
		fixed	flexible
bill of materials / recipe	fixed	standard fixed production structure	flexible production sequences, fixed BOM
	flexible	flexible BOM, resource assignments fixed	flexible production sequences and flexible BOM

Interrelation of flexible BOMs and flexible production sequences



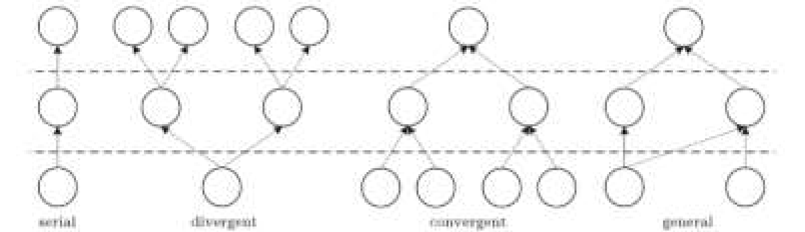
(a) Serial resource structure (b) Parallel machines

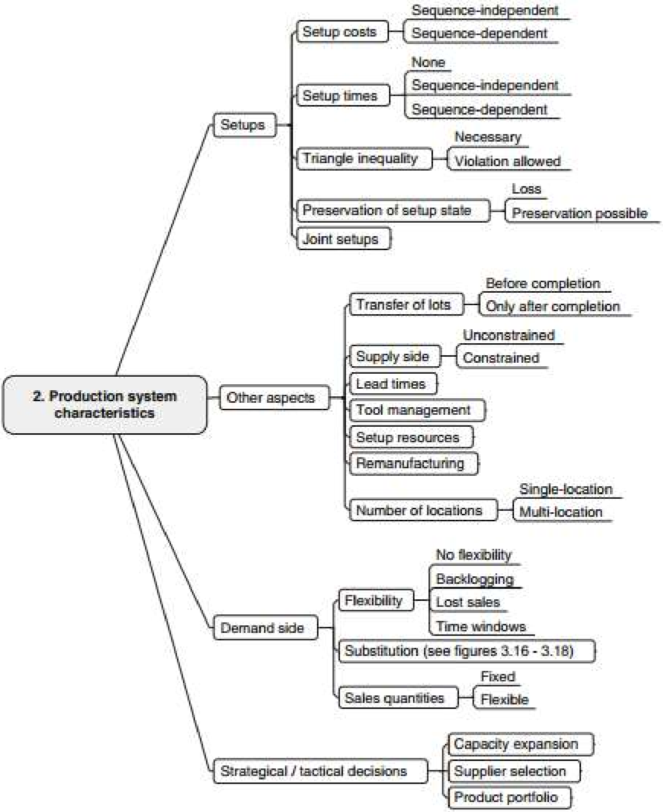
The *product structure* of a firm can be represented by a so–called *gozinto graph* (the name is a parody of “the part that goes into”). A gozinto graph is a weighted directed graph whose nodes correspond to the products. The final products correspond to the sinks of the gozinto graph at the highest production level, and the raw materials correspond to the sources at the lowest level zero.



Gozinto graph of a product structure

$$\sigma(x, y_1, y_2, \ldots, y_S) = \sum_{s\in S} p_s \xi_s + \lambda \sum_{s\in S} p_s \Big(\xi_s - \sum_{s'\in S} p_{s'} \xi_{s'} \Big)^2.$$



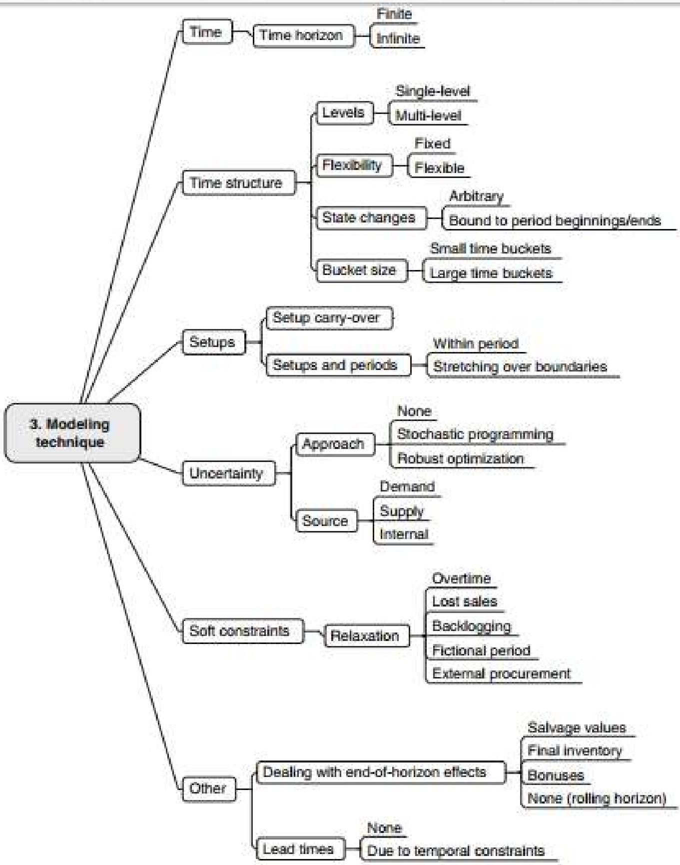

2. Production system characteristics
Setups
Setup costs
Sequence-independent
Sequence-dependent
Setup times
None
Sequence-independent
Sequence-dependent
Triangle inequality
Necessary
Violation allowed
Preservation of setup state
Loss
Preservation possible
Joint setups
Other aspects
Transfer of lots
Before completion
Only after completion
Supply side
Unconstrained
Constrained
Lead times
Tool management
Setup resources
Remanufacturing
Number of locations
Single-location
Multi-location
Demand side
Flexibility
No flexibility
Backlogging
Lost sales
Time windows
Substitution (see figures 3.16 - 3.18)
Sales quantities
Fixed
Flexible
Strategical / tactical decisions
Capacity expansion
Supplier selection
Product portfolio

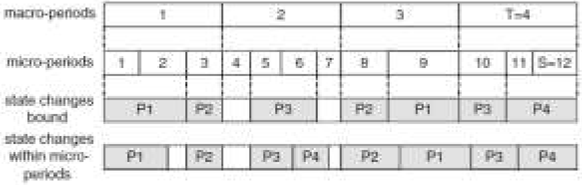
Aggregation

In tactical/strategic models, it is often necessary to **aggregate** certain entities (e.g., products or machines) of the production system

Aggregation means, e.g., that the model plans production quantities for product types instead of individual products and considers constrained capacities of entire production lines or groups of machines instead of individual machines. One important reason for aggregation is that demand forecasts in medium- or long-term models on the level of individual products could involve too much uncertainty, whereas forecasts on the level of groups of products will presumably have smaller errors. Also, detailed and accurate data on products and resources might not be available and expensive to obtain, especially in large companies with complex product portfolios and manufacturing systems. Thus, it often makes sense to consider products and resources on an aggregated level. Another reason is that the model size would explode when considering the manufacturing system on the finest, most disaggregated level. Such a large model is difficult to solve, it might take a prohibitively long time to be solved and require more memory than available even on high-end computers.

Another dimension of aggregation – in addition to products and resources – is time: The longer the periods considered in a production model (e.g., days, weeks, or months), the higher the level of aggregation of time. Also, one could use a fine time grid in the earlier part of the model's planning horizon (e.g., hours or days) and a coarser time grid (e.g., weeks) in the later part of the time horizon, as data regarding this part is very uncertain anyway.


3. Modeling technique
Time
Time horizon
Finite
Infinite
Time structure
Levels
Single-level
Multi-level
Flexibility
Fixed
Flexible
State changes
Arbitrary
Bound to period beginnings/ends
Bucket size
Small time buckets
Large time buckets
Setups
Setup carry-over
Setups and periods
Within period
Stretching over boundaries
Uncertainty
Approach
None
Stochastic programming
Robust optimization
Source
Demand
Supply
Internal
Soft constraints
Relaxation
Overtime
Lost sales
Backlogging
Fictional period
External procurement
Other
Dealing with end-of-horizon effects
Salvage values
Final inventory
Bonuses
None (rolling horizon)
Lead times
None
Due to temporal constraints



Example of a two-level time structure

If models have time buckets with rather short durations (e.g., hours), these are called *small time bucket (STB)* models. Models with time buckets that have a longer duration (e.g., weeks or months) are called *large time bucket (LTB)* models. Note that this classification criterion refers to the macro-periods when considering models with a multi-level time structure.

However, some newer lot-sizing and scheduling models distinguish an exogenous from an endogenous time structure, e.g., the Discrete Lot-sizing and Scheduling Problem (DLSP) with sequence-dependent setup costs (Fleischmann, 1994) and the General Lot-sizing and Scheduling Problem (GLSP) (Fleischmann and Meyr, 1997). So-called *macro-periods* map the exogenous time structure, *micro-periods* the endogenous time structure. In contrast to other models with a *single-level time structure*, these models thus have a *multi-level time structure*. Each macro-period contains one or more micro-periods. Thus, the lengths of micro-periods are assumed to be shorter than the lengths of macro-periods. The underlying assumption is that endogenous state changes are required more frequently than occurring exogenous state changes. Both exogenous and endogenous *time structure* are either *fixed* (i.e., state changes can only occur at certain fixed points in time) or *flexible* (i.e., state changes can happen at arbitrary points in time). Here, "fixed points in time" refers to beginnings or ends of time periods that are predetermined. The lengths of periods might be non-identical. Arbitrary points in time for state changes can be modeled by treating period lengths and beginnings or ends of periods as decision variables instead of parameters, and by allowing state changes that are not bound to beginnings and ends of periods.

1-7 Objectives of Operations Management

Objectives of operations management can be categorized into:

- Customer service and
- Resource utilization.

1-7 Objectives of Operations Management

CUSTOMER SERVICE

- The first objective of operating systems is the customer service to the satisfaction of customer wants. Therefore, customer service is a key objective of operations management.
- The operating system must provide something to a specification which can satisfy the customer in terms of cost and timing. Thus, primary objective can be satisfied by providing the 'right thing at a right price at the right time'.

1-7 Objectives of Operations Management

CUSTOMER SERVICE

- These aspects of customer service—specification, cost and timing—are described for four functions in the following table.
- They are the principal sources of customer satisfaction and must, therefore, be the principal dimension of the customer service objective for operations managers.

1-7 Objectives of Operations Management

Aspects of customer service

Principal function	*Principal customer wants*	
	Primary considerations	*Other considerations*
Manufacture	Goods of a given, requested or acceptable specification	*Cost, i.e.*, purchase price or cost of obtaining goods. *Timing, i.e.*, delivery delay from order or request to receipt of goods.
Transport	Management of a given, requested or acceptable specification	*Cost, i.e.*, cost of movements. *Timing, i.e.*, 1. Duration or time to move. 2. Wait or delay from requesting to its commencement.
Supply	Goods of a given, requested or acceptable specification	*Cost, i.e.*, purchase price or cost of obtaining goods. *Timing, i.e.*, delivery delay from order or request to receipt of goods.
Service	Treatment of a given, requested or acceptable specification	*Cost, i.e.*, cost of movements. *Timing, i.e.*, 1. Duration or time required for treatment. 2. Wait or delay from requesting treatment to its commencement.

1-7 Objectives of Operations Management

RESOURCE UTILISATION

- Another major objective of operating systems is to utilize resources for the satisfaction of customer wants effectively, i.e., customer service must be provided with the achievement of effective operations through efficient use of resources.
- Inefficient use of resources or inadequate customer service leads to commercial failure of an operating system. Operations management is concerned essentially with the utilization of resources, i.e., obtaining maximum effect from resources or minimizing their loss, under utilization or waste.

1-7 Objectives of Operations Management

RESOURCE UTILISATION

The extent of the utilization of the resources' potential might be expressed in terms of :

- The proportion of available time used or occupied,
- Space utilization,
- Levels of activity, etc.

Each measure indicates the extent to which the potential or capacity of such resources is utilized. This is referred as the objective of resource utilization.

1-7 Objectives of Operations Management

- Operations management is also concerned with the achievement of both satisfactory customer service and resource utilization.
- An improvement in one will often give rise to deterioration in the other. Often both cannot be maximized, and hence a satisfactory performance must be achieved on both objectives.
- All the activities of operations management must be tackled with these two objectives in mind, and many of the problems will be faced by operations managers because of this conflict. Hence, operations managers must attempt to balance these basic objectives.

1-7 Objectives of Operations Management

- Pareto front solutions

- For a nontrivial multi-objective optimization problem, there does not exist a single solution that simultaneously optimizes each objective. In that case, the objective functions are said to be conflicting, and there exists a (possibly infinite) number of Pareto optimal solutions.

1-7 Objectives of Operations Management

- Pareto front solutions

- A solution is called non-dominated, Pareto optimal, Pareto efficient or non-inferior, if none of the objective functions can be improved in value without degrading some of the other objective values.
- Without additional subjective preference information, all Pareto optimal solutions are considered equally good (as vectors cannot be ordered completely).

1-7 Objectives of Operations Management

- The proposed table summarizes the twin objectives of operations management.
- The type of balance established both between and within these basic objectives will be influenced by market considerations, competitions, the strengths and weaknesses of the organization, etc.
- The operations managers should make a contribution when these objectives are set.

The twin objectives of operations management

The customer service objective. To provide agreed/adequate levels of customer service (and hence customer satisfaction) by providing goods or services with the right specification, at the right cost and at the right time.	**The resource utilisation objective.** To achieve adequate levels of resource utilisation (or productivity) e.g., to achieve agreed levels of utilisation of materials, machines and labour.

1-8 MANAGING GLOBAL OPERATIONS

- The term 'globalization' describes businesses' deployment of facilities and operations around the world. Globalization can be defined as a process in which geographic distance becomes a factor of diminishing importance in the establishment and maintenance of cross border economic, political and socio-cultural relations. It can also be defined as worldwide drive toward a globalized economic system dominated by supranational corporate trade and banking institutions that are not accountable to democratic processes or national governments.
- There are four developments, which have spurred the trend toward globalization:

1. Improved transportation and communication technologies
2. Opened financial systems
3. Reduced import quotas and other trade barriers.
4. Increased demand for imports

1-8 MANAGING GLOBAL OPERATIONS

- When a firm sets up facilities abroad it involve some added complexities in its operation.
  - Global markets impose new standards on quality and time.
  - Managers should not think about domestic markets first and then global markets later, rather it could be think globally and act locally. Also, they must have a good understanding of their competitors.
  - Some other important challenges of managing multinational operations include other languages and customs, different management style, unfamiliar laws and regulations, and different costs.

1-8 MANAGING GLOBAL OPERATIONS

- Managing global operations would focus on the following key issues:
  - To acquire and properly utilize the following concepts and those related to global operations, supply chain, logistics, etc.
  - To associate global historical events to key drivers in global operations from different perspectives.
  - To develop criteria for conceptualization and evaluation of different global operations.
  - To associate success and failure cases of global operations to political, social, economical and technological environments.
  - To envision trends in global operations.
  - To develop an understanding of the world vision regardless of their country of origin, residence or studies in a respectful way of perspectives of people from different races, studies, preferences, religion, politic affiliation, place of origin, etc.

1-8 MANAGING GLOBAL OPERATIONS

- Supply chain management has been defined as the "design, planning, execution, control, and monitoring of supply chain activities with the objective of:
  - creating net value,
  - building a competitive infrastructure,
  - leveraging worldwide logistics,
  - synchronizing supply with demand and
  - measuring performance globally."

1-9 SCOPE OF PRODUCTION AND OPERATIONS MANAGEMENT

Demand management

CHAPTER OUTLINE

1.1 Demand management in MPC systems
1.2 Demand management and MPC environment
1.3 communicating with other MPC modules and customers
1.4 Information use in demand management
1.5 Managing demand
1.6 Collaborative planning, forecasting and replenishment

2 Introduction

- Demand management concerned with
  - how a firm integrates information from and about its customers, internal and external to the firm, into the manufacturing planning and control (MPC) system.

2 Introduction

- It is in this module that all potential demands on manufacturing capacity are collected and coordinated.
- Demand management includes activities that range from *determining or estimating the demand from customers, through converting specific customer orders into promised delivery dates, to helping balance demand with supply.*

2 Introduction

- A well-developed demand management system within the MPC system brings significant benefits to the firm.
- Proper planning of all externally and internally generated demands means capacity (ultimately, supply) can be better managed and controlled.
- Information that helps to integrate the needs of the customers with the capabilities of the firm can be developed. Timely and honest customer order promises are possible. Physical distribution activities can be improved significantly.

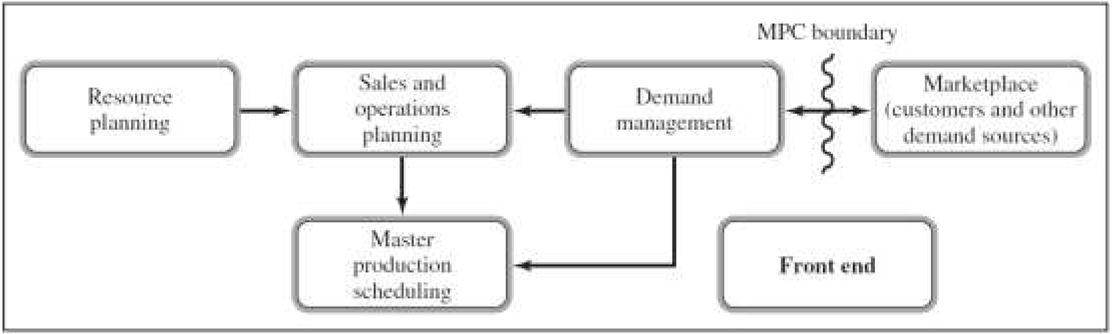
2 Introduction

- Demand management in MPC systems: What role does demand management play in the manufacturing planning and control system?
- Demand management and the MPC environment: How do the different manufacturing environments shape the demand management activities?
- Communicating with other MPC modules and customers: What are the communication linkages between demand management, other MPC modules and customers?

2 Introduction

- Information use in demand management: How can the information collected be used to <u>enhance</u> the current and future <u>performance</u> of the firm?
- Managing demand: What day-to-day management activities are required to manage demand?

2 Demand management in MPC system



2 Types of Demand

- **Negative Demand**
  - Negative demand is a type of demand which is created if the product is disliked in general. The product might be beneficial but the customer does not want it.
  - For example – Dental work where people don't want problems with their teeth and use preventive measures to avoid the same. Insurance, which people should have but they delay buying an insurance policy. Similarly, people would like to avoid heart attacks and hence may pay for a full body check up where the results might be negative, but still the customer has to pay.
  - The marketer has to solve the issue of no demand by analyzing why the market dislikes the product and then counter acting with the right marketing tactics.

2 Types of Demand

- **Unwholesome demand**
  - Unwholesome demand is the other side of Negative demand.
  - In negative type of demands, customer does not want the product even though product might be necessary for the customer. But in unwholesome demand, the customer should not desire the product, yet the customer wants the product badly.
  - Best example of unwholesome demand are cigarettes, alcohol, guns etc.

2 Types of Demand

- **No demands**
    - Certain products face the challenge of no demand.
    - The best example for the same can be education courses where there is very low demand or no demand at all. Such cases are very hard to counter.

2 Types of Demand

- **Latent Demand**
  - Latent demand is, as the name suggests, a demand which the customer realizes later. Thus, while buying the product, he might not desire some features. But later on, he might think about those features and buy the product.
  - The best example of latent demand are normal phones vs smart phones. People nowadays want more and more features in the smartphone. They might settle for a normal phone, but then later on they get the itch to buy a smart phone.
  - A marketing managers job is to find out the features which people might be looking for later and market them to the customer in such a manner that he immediately wants them.

2 Types of Demand

- **Declining demand**
  - Declining demand is when demand for a product is declining.
  - For example, when CD players were introduced and IPOD came in the market, the demand for Walkman went down. Although there was still a demand for the product, the demand was a declining demand.
  - A marketers job in such a case to think ways to revive the product so that the demand is not declining.

2 Types of Demand

- **Irregular demand**
  - Irregular demand – Irregular demand can be demand which is not consistent.
  - The best example of irregular demand is seasonal products like umbrellas, air conditioners or resorts. These products sell irregularly and sell more during peak season whereas their demand is very low during non seasons.
  - The best way to counter irregular demand is to introduce incentives for the customer to buy the product.

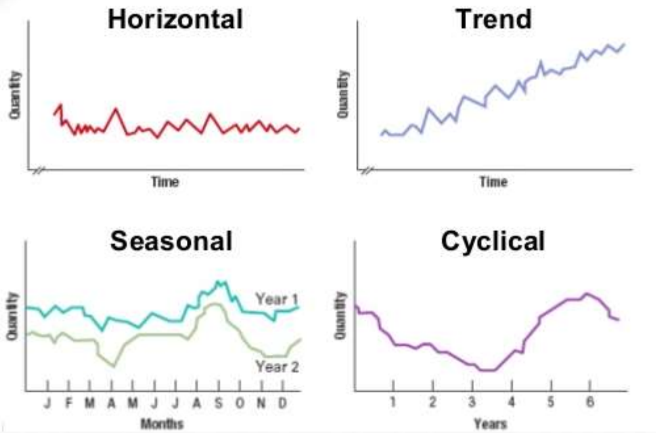
2 Types of Demand

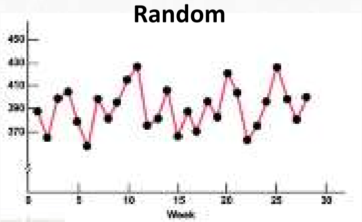
- **Full demand**
  - In an ideal environment, a company should always have full demand. Full demand means that the demand is meeting the supply potential of the company.
  - It also means that the markets are happy with the products of the company and that people want to buy from the same company.
  - The marketing challenge in this type of demand is to maintain the same level of interest in the product and the company.

2 Types of Demand

- **Overfull demand**
  - Overfull demands happen when the companies manufacturing capacity is limited but the demand is more than the supply.
  - This can be observed in the cement industry occasionally. Generally, most cement industries have limited manufacturing capacity. And hence, brand switching in cement industry is high.
  - Many companies use de marketing techniques to counter act overfull demands. This is because if the company keeps marketing, but it is not able to supply the material, then the company might suffer badly in brand equity.

Demand Patterns





2 Demand management in MPC system

- A master production schedule (MPS) is a plan for individual commodities to be produced in each time period such as production, staffing, inventory, etc.
- It is usually linked to manufacturing where the plan indicates when and how much of each product will be demanded.

Demand Management	12/7	12/8	12/9	12/10	12/11
Monthly Demand for Product A	4000	4000	4000	4000	4000
Working Days in Month	23	23	23	23	23
MPS Daily Demand for Product A	174	174	174	174	174

2 Demand management in MPC environment

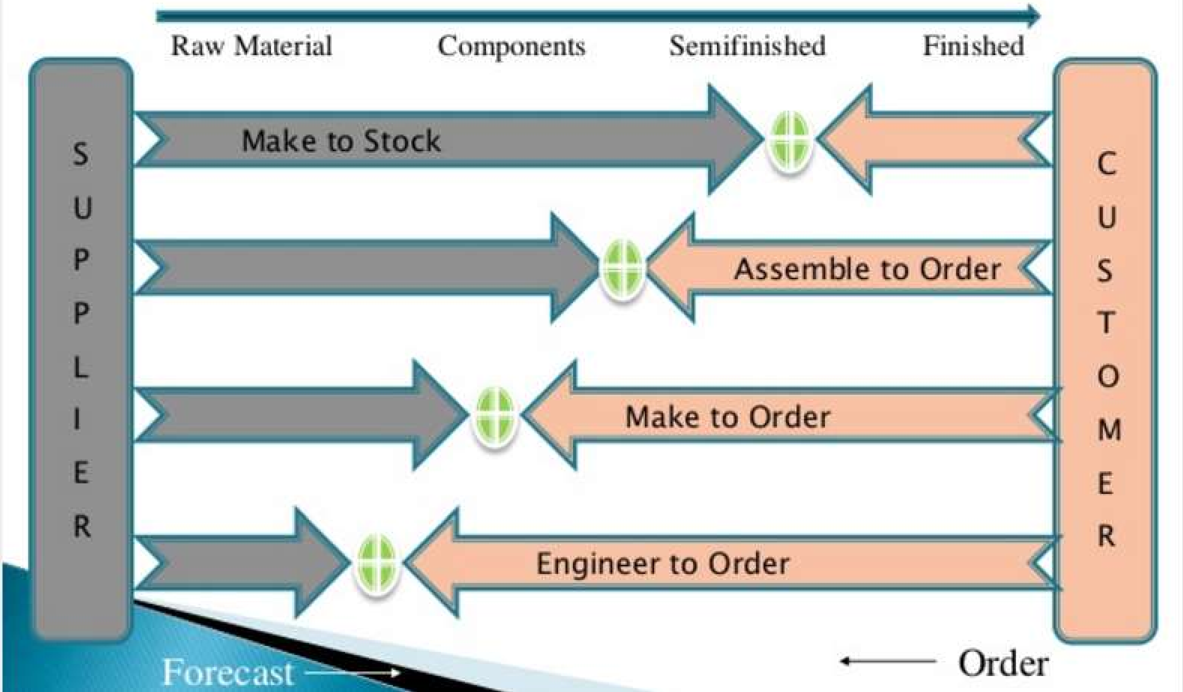
- Demand management in …

2 Demand management in MPC environment

- Demand management in tailor shop

2 Demand management in MPC environment

Inventory location	Suppliers	Raw materials	Work-in-process (WIP) parts and components	Finished goods
Customer order decoupling point	△	△	△	△
Environment	Engineer-to-order (ETO)	Make-to-order (MTO)	Assemble-to-order (ATO)	Make-to-stock (MTS)


Raw Material
Components
Semifinished
Finished
SUPPLIER
Make to Stock
Assemble to Order
Make to Order
Engineer to Order
CUSTOMER
Forecast
Order

2 Demand management in MPC environment

- Firms that serve their customers from finished goods inventory are known as *make-to-stock* firms.
- Those that combine a number of options together to meet a customer's specifications are called assemble-to order firms.
- Those that make the customer's product from raw materials, parts, and components are make-to-order firms.

2 Demand management in MPC environment

- An engineer-to-order firm will work with the customer to design the product, then make it from purchased materials, parts, and components.

Many firms will serve a combination of these environments, and a few will have all simultaneously.

2 Demand management in MPC environment

Inventory location	Suppliers	Raw materials	Work-in-process (WIP) parts and components	Finished goods
Customer order decoupling point	△	△	△	△
Environment	Engineer-to-order (ETO)	Make-to-order (MTO)	Assemble-to-order (ATO)	Make-to-stock (MTS)

2 The Make-to-Stock (MTS) Environment

- In the MTS environment, the key focus of the demand management activities is on the maintenance of finished goods inventories.
- The customers buy directly from the available inventory, so customer service is determined by whether their item is in stock or not.

Service level is the expected probability of not hitting a stock-out during the next replenishment cycle, and thus, it is also the probability of not losing sales.

2 The Make-to-Stock (MTS) Environment

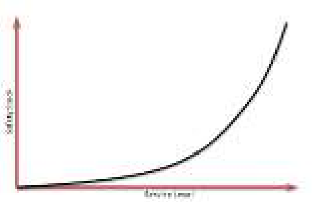
- It is at this point that the independent demand of the customer for suits becomes the dependent demand for fabric to support the tailor's plans for making suits.
- There may be several locations from which the customers buy their goods. This means that there is both a geographical and temporal dimension to the maintenance of finished goods inventory. Thus, tracking of demand by location throughout the supply chain is an important activity in the MTS environment.

2 The Make-to-Stock (MTS) Environment

- Tracking of demand by Radio Frequency Identification (RFID) in supply chain

2 The Make-to-Stock (MTS) Environment

- The essential issue in satisfying customers in the make-to-stock environment is to balance the level of inventory against the level of service to the customer.
- Providing more inventory increases costs, so a trade-off between the costs of the inventory and the level of customer service must be made.



2 The Make-to-Stock (MTS) Environment

- The trade-off can be improved by better estimates (or knowledge) of customer demand, by more rapid transportation alternatives, by speedier production, and by more flexible manufacturing.
- Many MTS firms are investing in such lean manufacturing programs in order to shift the trade-off, that is, to achieve higher service levels for a given inventory investment.

2 The Assemble-to-Order (ATO) Environment

- You may have experienced this yourself when you ordered a personal computer.
- You decided what components you wanted, and the company assembled the components to complete your order.
- Many people buy their cars this way, and some industrial products are assembled to meet the users' specifications.

2 The Assemble-to-Order (ATO) Environment

- In the assemble-to-order environment, the primary task of demand management is to define the customer's order in terms of alternative components and options, for example, a two-door versus four-door car, with or without antilock brakes.
- It is also important to assure that they can be combined into a viable product in a process known as configuration management.

2 The Assemble-to-Order (ATO) Environment

- Configuration management is a critical step, because it might not be possible to assemble certain combinations.

2 The Assemble-to-Order (ATO) Environment

- One of the capabilities required for success in the assemble-to order environment is engineering design that enables as much flexibility in combining components, options, and modules into finished products as possible.
- Modular design, or "modularity in design", is a design approach that subdivides a system into smaller parts called modules or skids, that can be independently created and then used in different systems.

2 The Assemble-to-Order (ATO) Environment

- The assemble-to-order environment clearly illustrates the two-way nature of the communication between customers and demand management.
- Customers need to be informed of the allowable combinations, and the combinations should support marketplace desires, such as sports trim for cars.

2 The Assemble-to-Order (ATO) Environment

- Moreover, customers' orders must be configured, and the customers must be informed of the delivery date of the finished product. In this environment, the independent demand for the assembled items is transformed into dependent demand for the parts required to produce the components needed.
- The inventory that defines customer service is the inventory of components, not the inventory of finished product.

2 The Assemble-to-Order (ATO) Environment

- Some ATO firms have applied lean manufacturing principles to dramatically decrease the time required to assemble finished goods.
- Via using lean manufacturing principles, they are delivering customers' orders so quickly that they appear to be MTS firms from the perspective of the customer.

2 The Assemble-to-Order (ATO) Environment

- There are some significant advantages from moving the customer order decoupling point from finished goods to components.
- The number of finished products is usually substantially greater than the number of components that are combined to produce the finished product.

2 The Make (Engineer)-to-Order (MTO) Environment

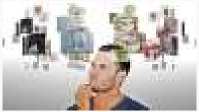
- It is much easier to manage and forecast the demand for components than for finished products.
- The focus of demand management in the MTS and ATO environments was largely on satisfying customers from the appropriate inventory—finished goods or components.
- In the make-to-order and engineer-to-order environments, there is another resource that needs to be taken into account—engineering.

2 The Make (Engineer)-to-Order (MTO) Environment

- Moving the customer order decoupling point to raw materials or even suppliers puts independent demand information further into the firm and reduces the scope of dependent demand information.

2 The Make (Engineer)-to-Order (MTO) Environment

- Moreover, the nature of the information needed from customers changes.
- We knew what the customers could buy in the MTS and ATO environments, but not if, when, or how many; in the make (engineer)-to-order environment, on the other hand, we are not sure what they are going to buy.



2 The Make (Engineer)-to-Order (MTO) Environment

- We need, therefore, to get the product specifications from the customers and translate these into manufacturing terms in the company.
- This means that a task of demand management in this environment is to coordinate information on customers' product needs with engineering.

Sector	Market Type	CODP	Comment
Automobile	ATO	Semi finished	Multiple levels of supplier. Accessories & assemblies as per product.
	ATO	Semi finished	
Aircraft	MTO	Components, Raw Material	Heavy finished product, with complex assembly
	MTO	Components, Raw Material	
Food (Packaged)	MTS	Finished	Standard sizes of end product & forecast driven
	MTS	Finished	
Pharmaceuticals	MTS	Finished	The demand is sporadic & with intense standards, regulations.
	MTS	Finished	

Customer Order Decoupling Point (CODP)

Sector	Market Type	CODP	Comment
FMCG	MTS	Finished	Standard sizes of end product & forecast driven
	MTS	Finished	
Cement	MTS	Finished	No variation in end product, high demand.
	MTS	Finished	
Construction	MTO, ATO	Raw Material	Many OEMs used with engineered approach
	MTO, ATO	Raw Material	
Textile	MTS	Finishes	Demand is high & driven by Brands. Very less customer part.
	MTS	Finished	

- Fast-moving consumer goods (FMCG) or consumer packaged goods (CPG) are products that are sold quickly and at relatively low cost.

2 Demand management in MPC environment

Key Demand Management Tasks for Each Environment

Tasks	MTS	ATO	MTO
Information	Provide forecast	Configuration management	Product specifications
Planning	Project inventory levels	Determine delivery dates	Provide engineering capacity
Control	Assure customer service levels	Meet delivery dates	Adjust capacity to customer needs

2 Communicating with Other MPC Modules and Customers

- Regardless of the environment, demand management has important internal and external communication tasks.
- Forecast information must be provided to sales and operations planning (SOP).

2 Communicating with Other MPC Modules and Customers

- Detailed demand information must be communicated to master production scheduling (MPS), and information on product availability must be made available to customers both for planning purposes and to manage the day-to-day customer order activities.

2 Communicating with Other MPC Modules and Customers

Demand Management Communication Activities for Each Environment

Connection	MTS	ATO	MTO
SOP	Demand forecasts	Demand forecasts, product family mix	Demand forecasts, engineering detail
MPS	Actual demands	Mix forecasts, actual demands	Final configuration
Customer(s)	Next inventory replenishment	Configuration issues, delivery date	Design status, delivery date

2 Communicating with Other MPC Modules and Customers

Demand Management Communication Activities for Each Environment

Connection	MTS	ATO	MTO
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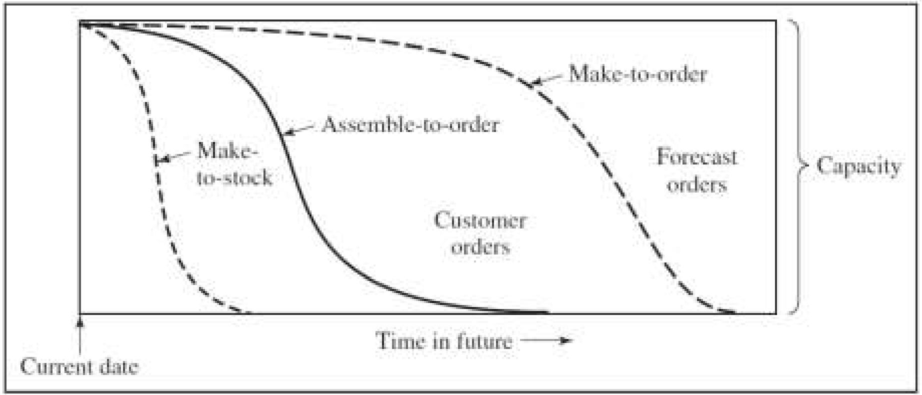
Customer(s)	Next inventory replenishment	Configuration issues, delivery date	Design status, delivery date

2 Communicating with Other MPC Modules and Customers



Forecasts Consumed by Orders

2 Communicating with Other MPC Modules and Customers

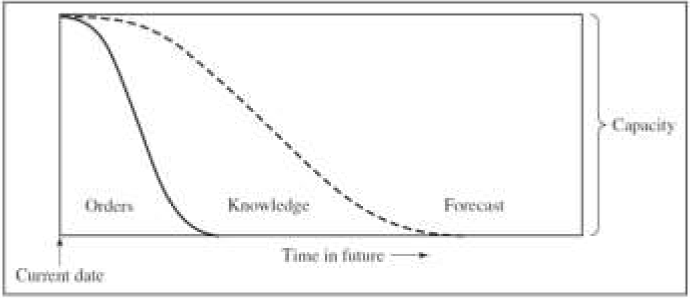
- The types of uncertainty also differ between these environments.
- In the make-to stock case, uncertainty is largely in the demand variations around the forecast at each of the inventory locations. In this case, additional levels of inventory (safety stock) are held in order to provide the service levels required.
- In the assemble-to-order case, the uncertainty involves not only the quantity and timing of customer orders but product mix as well.

2 Communicating with Other MPC Modules and Customers

- For the make-to-order environment, the uncertainty is often not the timing or quantity of the customer order but, rather, what level of company resources will be required to complete the engineering and produce the product once the exact requirements are determined.
- One aspect of the communications between master production scheduling and demand management is to facilitate buffering against the uncertainties that exist.

2 Communicating with Other MPC Modules and Customers

- Deal with uncertainty via using adapter or shaper strategies.



Replacing Forecasts with Knowledge

2 Communicating with Other MPC Modules and Customers

- The knowledge comes from a natural evolution in the use of electronic data interchange (EDI) and Internet-based systems.
- Application of data mining in Advanced production and operation management and understanding customer behavior

Forecasting

CHAPTER OUTLINE

1.1 Providing appropriate forecast information
1.2 regression analysis and cyclic decomposition technique
1.3 Short term forecasting techniques
1.4 Using the forecasts

2 A Framework for Forecasting

A Framework for Forecasting

Nature of the Decision	Strategic Business Planning	Sales and Operations Planning	Master Production Scheduling and Control
Level of aggregation	Total sales or output volume	Product family units	Individual finished goods or components
Top management involvement	Intensive	When reconciling functional plans	Very little
Forecast frequency	Annual or less	Monthly or quarterly	Constantly
Length of forecast	Years by years or quarters	Several months to a year by months	A few days to weeks
Management investment in the forecast(s)	Very large	Moderate	Very little
Cost of data processing and acquisition	High	Moderate	Minimal
Useful techniques	Management judgment, economic growth models, regression	Aggregation of detailed forecasts, customer plans, regression	Projection techniques (moving averages, exponential smoothing)

2 Regression Analysis and Cyclic Decomposition Techniques

- Regression can be defined as a functional relationship between two or more correlated variables.
- It is used to predict one variable given the other.
- The relationship is usually developed from observed data.
- The data should be plotted first to see if they appear linear or if at least parts of the data are linear.

2 Regression Analysis and Cyclic Decomposition Techniques

- Linear regression refers to the special class of regression where the relationship between variables forms a straight line.
- The linear regression line is of the form Y a bX, where Y is the value of the dependent variable that we are solving for, a is the Y-intercept, b is the slope, and X is the independent variable (In time series analysis, X is units of time).

2 Regression Analysis and Cyclic Decomposition Techniques

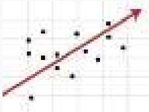
- Linear regression is useful for long-term forecasting of major occurrences and aggregate planning.
- For example, linear regression would be very useful to forecast demands for product families. Even though demand for individual products within a family may vary widely during a time period, demand for the total product family is surprisingly smooth.

2 Regression Analysis and Cyclic Decomposition Techniques

- The major restriction in using linear regression forecasting is, as the name implies, that past data and future projections are assumed to fall about a straight line.
- Although this does limit its application, sometimes, if we use a shorter period of time, linear regression analysis can still be used.
- For example, there may be short segments of the longer period that are approximately linear.

2 Regression Analysis and Cyclic Decomposition Techniques

- Linear regression is used both for time series forecasting and for causal relationship forecasting.
- When the dependent variable (usually the vertical axis on a graph) changes as a result of time (plotted as the horizontal axis), it is time series analysis.
- If one variable changes because of the change in another variable, this is a causal relationship (such as the number of deaths from lung cancer increasing with the number of people who smoke).



Least Squares Method

A firm's sales for a product line during the 12 quarters of the past three years were as follows:

Quarter	Sales	Quarter	Sales
1	600	7	2,600
2	1,550	8	2,900
3	1,500	9	3,800
4	1,500	10	4,500
5	2,400	11	4,000
6	3,100	12	4,900

The firm wants to forecast each quarter of the fourth year—that is, quarters 13, 14, 15, and 16.

2 Regression Analysis and Cyclic Decomposition Techniques

Solution

The least squares equation for linear regression is

$$Y = a + bx$$

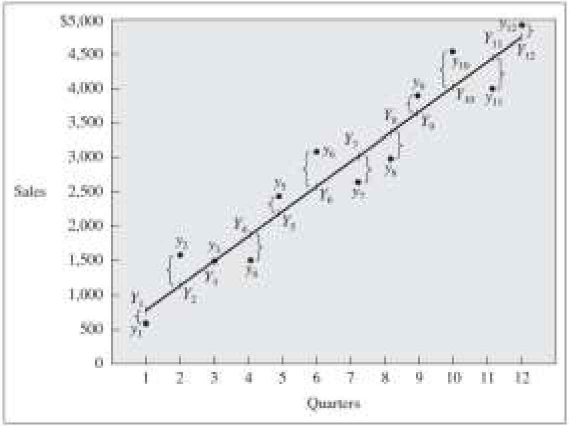
where

Y = dependent variable computed by the equation
y = the actual dependent variable data point (used below)
a = Y-intercept
b = slope of the line
x = time period

2 Regression Analysis and Cyclic Decomposition Techniques

- The least squares method tries to fit the line to the data that minimizes the sum of the squares of the vertical distance between each data point and its corresponding point on the line.
- If a straight line is drawn through the general area of the points, the difference between the point and the line Y is y.

2 Regression Analysis and Cyclic Decomposition Techniques



Least Squares Regression Line

2 Regression Analysis and Cyclic Decomposition Techniques

- The sum of the squares of the differences between the plotted data points and the line points is

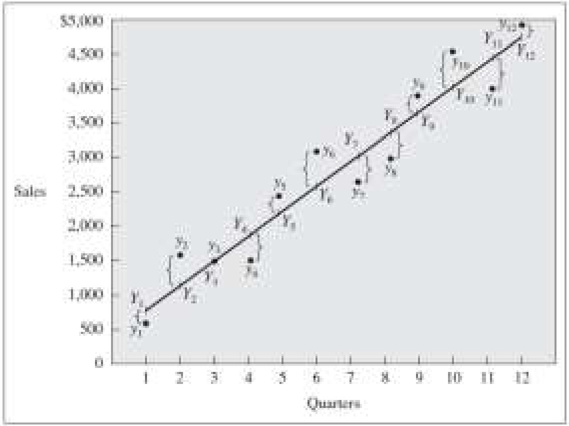
$$(y_1 - Y_1)^2 + (y_2 - Y_2)^2 + \cdots + (y_{12} - Y_{12})^2$$

The best line to use is the one that minimizes this total.

As before, the straight line equation is

$$Y = a + bx$$

2 Regression Analysis and Cyclic Decomposition Techniques



Least Squares Regression Line

2 Regression Analysis and Cyclic Decomposition Techniques

Previously we determined a and b from the graph. In the least squares method, the equations for a and b are

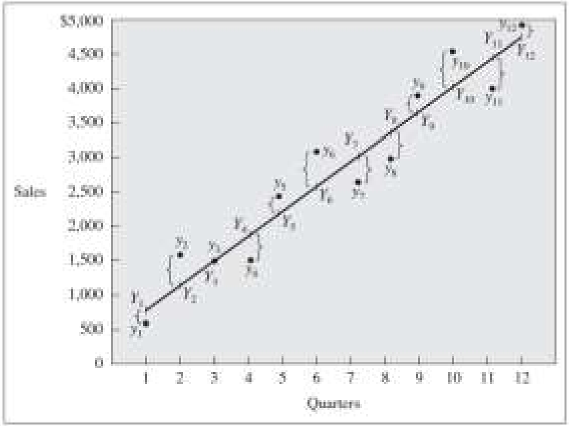
$$a = \bar{y} - b\bar{x}$$

$$b = \frac{\sum xy - n\bar{x}\cdot\bar{y}}{\sum x^2 - n\bar{x}^2}$$

where

a = Y-intercept
b = slope of the line
$\bar{y}$ = average of all y's
$\bar{x}$ = average of all x's
x = x value at each data point
y = y value at each data point
n = number of data points
Y = value of the dependent variable computed with the regression equation

2 Regression Analysis and Cyclic Decomposition Techniques



Least Squares Regression Line

2 Regression Analysis and Cyclic Decomposition Techniques

Strictly based on the equation, forecasts for periods 13 through 16 would be

$$Y_{13} = 441.6 + 359.6(13) = 5{,}116.4$$

$$Y_{14} = 441.6 + 359.6(14) = 5{,}476.0$$

$$Y_{15} = 441.6 + 359.6(15) = 5{,}835.6$$

$$Y_{16} = 441.6 + 359.6(16) = 6{,}195.2$$

The standard error of estimate, or how well the line fits the data, is

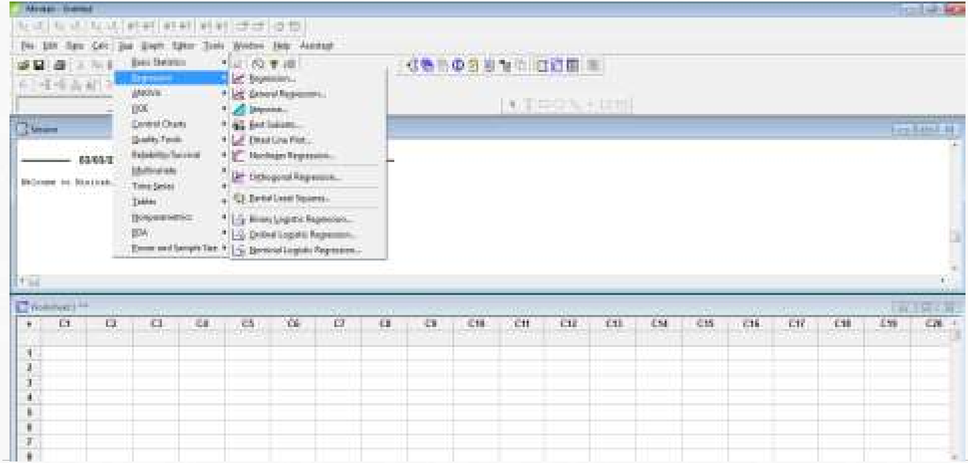
$$S_{yx} = \sqrt{\frac{\sum_{i=1}^{n} (y_i - Y_i)^2}{n - 2}}$$

The standard error of estimate is computed from the second and last columns of Figure

$$S_{yx} = \sqrt{\frac{(600 - 801.3)^2 + (1{,}550 - 1{,}160.9)^2 + (1{,}500 - 1{,}520.5)^2 + \cdots + (4{,}900 - 4{,}757.1)^2}{10}}$$

$$= 363.9$$

2 Regression Analysis and Cyclic Decomposition Techniques



2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Regression
- You can use Regression to perform simple and multiple regression using least squares.
- Use this procedure for fitting general least squares models, storing regression statistics, examining residual diagnostics, generating point estimates, generating prediction and confidence intervals, and performing lack-of-fit tests .

2 Regression Analysis and Cyclic Decomposition Techniques

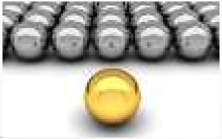
- Stat > Regression > General Regression
- Use General Regression to perform least squares regression when you have continuous and categorical predictors or a polynomial model .

2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Stepwise
- Stepwise regression removes and adds variables to the regression model for the purpose of identifying a useful subset of the predictors .
- Minitab provides three commonly used procedures: standard stepwise regression (adds and removes variables), forward selection (adds variables), and backward elimination (removes variables).

2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Best Subsets
- Best subsets regression identifies the subset models that produce the highest R values from full set of the predictor variables that you specify.
- Best subsets regression is an efficient way to identify models that achieve your goals with as few predictors as possible.
- Subset models may actually estimate the regression coefficients and predict future responses with smaller variance than the full model using all predictors



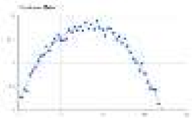
2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Fitted Line Plot
- This procedure performs regression with <u>linear and polynomial (second or third order)</u> terms, if requested, of a single predictor variable and plots a regression line through the data, on the actual or log10 scale.

2x	Monomial	Monomials consist of 1 term
2x + 3y • • 1 2	Binomial	Binomials consist of 2 terms
$2x^2$ + 3x + 5 • • • 1 2 3	Trinomial	Trinomials consist of 3 terms.
$3x^3$ + $2x^2$ - 6x + 2 • • • • 1 2 3 4	Polynomial	If there are more than 3 terms, use the term polynomial

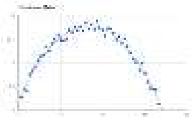
2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Nonlinear Regression
  - Use Nonlinear Regression to mathematically describe the nonlinear relationship between a response variable and one or more predictor variables.
  - Specifically, use nonlinear regression instead of ordinary least squares regression when you cannot adequately model the relationship with linear parameters.



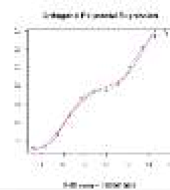
2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Nonlinear Regression
- Parameters are linear when each term in the model is additive and contains only one parameter that multiplies the term. Use this procedure for fitting models that are nonlinear in the parameters, storing regression statistics, examining residual diagnostics, generating point estimates, and generating prediction and confidence intervals.



2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Orthogonal Regression
- Use orthogonal regression (Deming regression) to test whether two instruments or methods provide comparable measurements.
- This analysis is commonly used to test the equivalence of instruments used in clinical chemistry or measurements made by two different laboratories.
- Use orthogonal regression instead of ordinary least squares regression when both the response and predictor contain measurement error.



2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Partial Least Squares
- Use partial least squares (PLS) to perform biased, non-least squares regression with one or more responses.
- PLS is particularly useful when your predictors are highly collinear or you have more predictors than observations and ordinary least squares regression either fails or produces coefficients with high standard errors.

$$\operatorname{Bias}[\hat{\theta}] = \operatorname{E}[\hat{\theta}] - \theta = \operatorname{E}[\hat{\theta} - \theta] \qquad \lambda_0 + \lambda_1 X_{1i} + \lambda_2 X_{2i} + \cdots + \lambda_k X_{ki} = 0$$

2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Partial Least Squares

- PLS reduces the number of predictors to a set of uncorrelated components and performs least squares regression on these components. You can use partial least squares when you have continuous or categorical predictors or a polynomial model.

$$\rho_{X,Y} = \mathrm{corr}(X,Y) = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Binary Logistic Regression
- Use binary logistic regression to perform logistic regression on a binary response variable.
- A binary variable only has two possible values, such as presence or absence of a particular disease. A model with one or more predictors is fit using an iterative reweighted least squares algorithm to obtain maximum likelihood estimates of the parameters.

2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Ordinal Logistic Regression
- Use ordinal logistic regression to perform logistic regression on an ordinal response variable.
- Ordinal variables are categorical variables that have three or more possible levels with a natural ordering, such as strongly disagree, disagree, neutral, agree, and strongly agree.

2 Regression Analysis and Cyclic Decomposition Techniques

- Stat > Regression > Nominal Logistic Regression
- Use nominal logistic regression performs logistic regression on a nominal response variable using an iterative-reweighted least squares algorithm to obtain maximum likelihood estimates of the parameters.
- Nominal variables are categorical variables that have three or more possible levels with no natural ordering. For example, the levels in a food tasting study.

2 Decomposition of a Time Series

- A time series can be defined as chronologically ordered data that may contain one or more components of demand: trend, seasonal, cyclical, autocorrelation, and random.
- Decomposition of a time series means identifying and separating the time series data into these components.

2 Decomposition of a Time Series

- In practice, it is relatively easy to identify the trend (even without mathematical analysis, it is usually easy to plot and see the direction of movement) and the seasonal component (by comparing the same period year to year).
- It is considerably more difficult to identify the cycles (these may be many months or years long), autocorrelation, and random components.

2 Decomposition of a Time Series

- The forecaster usually calls random anything left over that cannot be identified as another component.
- When demand contains both seasonal and trend effects at the same time, the question is how they relate to each other.
- In this description, we examine two types of seasonal variation: additive and multiplicative

2 Decomposition of a Time Series

- Additive Seasonal Variation

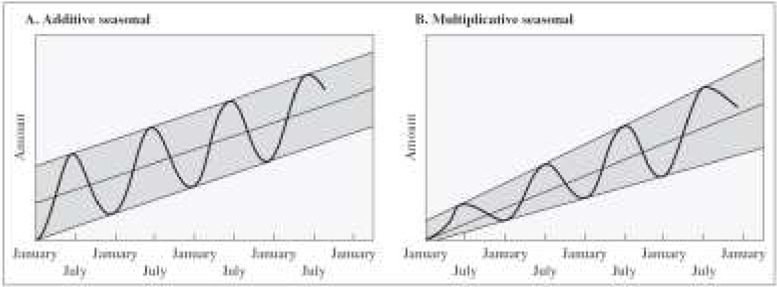
Additive seasonal variation simply assumes that the seasonal amount is a constant no matter what the trend or average amount is.

- Multiplicative Seasonal Variation

In multiplicative seasonal variation, the trend is multiplied by the seasonal factors.

$$\text{Forecast including trend and seasonal} = \text{Trend} \times \text{Seasonal factor}$$

2 Decomposition of a Time Series



Additive and Multiplicative Seasonal Variation Superimposed on Changing Trend

- Figure A shows an example of increasing trend with constant seasonal amounts.
- Figure B shows the seasonal variation increasing as the trend increases because its size depends on the trend.

2 Decomposition of a Time Series

- The multiplicative seasonal variation is the usual experience.
- Essentially, this says that the larger the basic amount projected, the larger the variation around this that we can expect.

2 Decomposition of a Time Series

Basic Structures

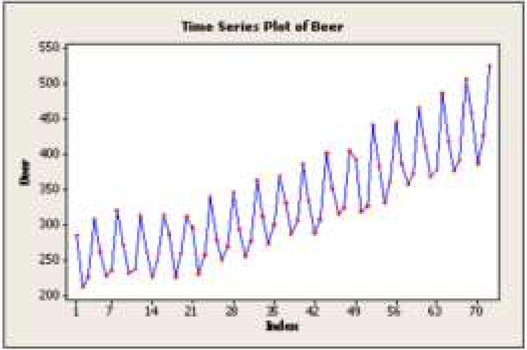
- The following two structures are considered for basic decomposition models:

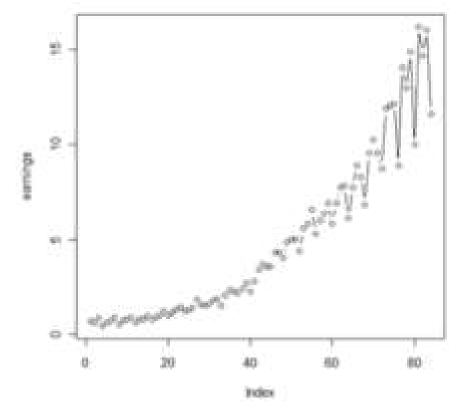
  1. Additive: x_t = Trend + Seasonal + Random
  2. Multiplicative: x_t = Trend * Seasonal * Random

  The "Random" term is often called "Irregular" in software for decompositions.

- How to Choose Between Additive and Multiplicative Decompositions
  - The additive model is useful when the seasonal variation is relatively constant over time.
  - The multiplicative model is useful when the seasonal variation increases over time.

2 Decomposition of a Time Series





2 Decomposition of a Time Series

- Short-Term Forecasting Techniques
  - In this section, we'll introduce two very common short-term forecasting techniques: moving averages and exponential smoothing.
  - We choose these procedures since they are commonly available in commercial software and meet the criteria of low cost and little management involvement.
  - The techniques are simple mathematical means for converting past information into forecasts.

2 Decomposition of a Time Series

Projection

- The easiest time series method simply projects future demand based on the last period's demand.
- The forecast for the next period t+1, F_{t+1}, is simply a projection of this period t demand, D_t

$$F_{t+1} = D_t$$

2 Decomposition of a Time Series

- This method, although easy to use, doesn't make use of data that is easily available to most managers; thus, using more of the historical data should improve the forecast. Averages of past demand might be more useful and are discussed next.

t	d	f
1	380	-
2	372	380
3	397	372
4	416	397
5	515	416

2 Decomposition of a Time Series

Simple Moving Average (MA)

- The simple moving average forecast makes use of more of the historical demand data than just the last period's demand. An n-period moving average uses the last *n* periods of demand as a forecast for next periods demand:

$$F_{t+1} = \frac{D_t + D_{t-1} + D_{t-2} + \ldots + D_{t-n+1}}{n}$$

2 Decomposition of a Time Series

Simple Moving Average (MA)

- This forecast model is most useful where the demand level is fairly constant over time.
- The model then makes simple adjustments to this average level rather than assuming that the level is forever constant.
- Its advantage over the projection model is that by averaging, the forecast won't tend to fluctuate as much.

2 Decomposition of a Time Series

MONTH	Demand	Month	Demand
January	89	July	223
February	57	August	286
March	144	September	212
April	221	October	275
May	177	November	188
June	280	December	312

- 3 month MA: (Oct+nov+dec)/3=258.33
- 6 month MA: (Jul+aug+…+dec)/6=249.33
- 12 month MA: (Jan+feb+…+dec)/12=205.33

2 Decomposition of a Time Series

- The average of the previous n periods can be viewed as the estimate of the average "level" of demand as of period t. Thus, one could define the level, Lt, as

$$L_t = \frac{D_t + D_{t-1} + D_{t-2} + \ldots + D_{t-n+1}}{n}$$

and thus the forecast, F_{t+1}, is just the last estimate of the level of demand.

$$F_{t+1} = L_t$$

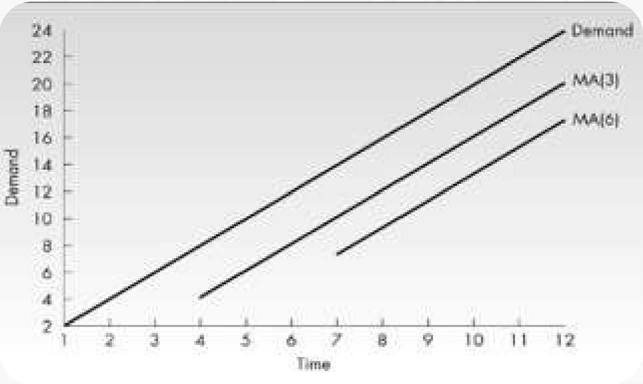
This forecast is no different than the direct forecast given above in equation, but the interpretation allows for an easier presentation of the more advanced forecasting models to come.

2 Decomposition of a Time Series

- *Advantages of Moving Average Method*
  - Easily understood
  - Easily computed
  - Provides stable forecasts
- *Disadvantages of Moving Average Method*
  - Requires saving lots of past data points: at least the N periods used in the moving average computation
  - Lags behind a trend
  - Ignores complex relationships in data

2 Decomposition of a Time Series

Moving Average Lags a Trend



2 Decomposition of a Time Series

Weighted Moving Average (WMA)

- One shortcoming of the simple moving average is the equal weighting of data.
- For instance, a 5-period moving average weights each of the past 5 demand observations the same – each has a 20% impact on the forecast.
- This runs counter to ones intuition that the most recent data is the most relevant. Thus, the weighted moving average allows for more emphasis to be placed on the most recent data.

2 Decomposition of a Time Series

Weighted Moving Average (WMA)

- This forecast is:

$$F_{t+1} = L_t = \frac{w_t D_t + w_{t-1} D_{t-1} + w_{t-2} D_{t-2} + \dots + w_{t-n+1} D_{t-n+1}}{w_t + w_{t-1} + w_{t-2} + \dots + w_{t-n+1}}$$

where w_t is the weight applied to the demand incurred in period t, w_{t-1} is the weight given to that of period t-1, and so on.

Intuitively, the expectation would be that the more recent demand data should be weighted more heavily than older data; so, generally, one would expect the weights to follow the relationship $w_t \geq w_{t-1} \geq w_{t-2} \geq \dots$.

2 Decomposition of a Time Series

Basic Exponential Smoothing (BES)

- Nice properties of a weighted moving average would be one where the weights not only decrease as older and older data are used, but one where the differences between the weights are "smooth".
- Obviously the desire would be for the weight on the most recent data to be the largest. The weights should then get progressively smaller the more periods one considers into the past. The exponentially decreasing weights of the basic exponential smoothing forecast fit this bill nicely.

2 Decomposition of a Time Series

Basic Exponential Smoothing (BES)

- The forecast equation is given by:

$$F_{t+1} = L_t = \alpha D_t + (1 - \alpha)F_t$$

- where α is a smoothing parameter between 0 and 1. To show that this forecast is in fact a weighted average forecast, it is instructive to look at the algebraic expansion of this model.

Since

$$F_t = \alpha D_{t-1} + (1-\alpha)F_{t-1}$$

$$F_{t+1} = \alpha D_t + (1-\alpha)[\alpha D_{t-1} + (1-\alpha)F_{t-1}]$$

$$F_{t+1} = \alpha D_t + \alpha (1-\alpha)D_{t-1} + (1-\alpha)^2 F_{t-1}$$

Basic Exponential Smoothing (BES)

Continuing this expansion, the model can be written as:

$$F_{t+1} = \alpha D_t + \alpha (1-\alpha) D_{t-1} + \alpha (1-\alpha)^2 D_{t-2} + \alpha (1-\alpha)^3 D_{t-3} + \dots$$

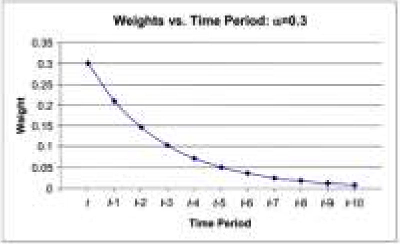
Thus, the exponential smoothing model is actually a weighted moving average model with special weights. These weights get continuously smaller as they are applied to periods farther away from the current period. With some algebra, it can be shown that these weights sum to one.

$$\alpha + \alpha(1-\alpha) + \alpha(1-\alpha)^2 + \alpha(1-\alpha)^3 + \dots = 1$$

2 Decomposition of a Time Series

Basic Exponential Smoothing (BES)

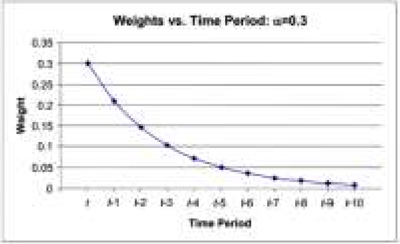
Even though these weights have nice properties, it is not necessary to keep track of each of the weights. In addition, a system running the model does not need to store the historical data or does it need to compute anything based on old data.



2 Decomposition of a Time Series

Basic Exponential Smoothing (BES)

- The only thing that is needed is the smoothing factor α, last period's demand, and last period's forecast.
- The nice thing about the model is that all past demand data is effectively "stored" in the last period's forecast.



2 Decomposition of a Time Series

Basic Exponential Smoothing (BES)

		Alpha=0.15	Alpha=0.5	Alpha=0.95
t	D	F	F	F
1	100	100	100	100
2	105	100	100	100
3	110	100.75	102.5	104.5
4	120	102.1375	106.25	109.45
5	129	104.816875	113.125	118.945

2 Decomposition of a Time Series

Basic Exponential Smoothing (BES)

- Small values of α means that the forecasted value will be stable (show low variability)
- Low α increases the lag of the forecast to the actual data if a trend is present
- Large values of α mean that the forecast will more closely track the actual time series
- $\alpha = 2/(N + 1)$

2 Decomposition of a Time Series

- Seasonal Factor (or Index)
  - A seasonal factor is the amount of correction needed in a time series to adjust for the season of the year.
  - We usually associate seasonal with a period of the year characterized by some particular activity.
  - We use the word cyclical to indicate other than annual recurrent periods of repetitive activity.

2 Decomposition of a Time Series

- Seasonal Factor (or Index)
  - The following examples show how seasonal indexes are determined and used to forecast:

    (1) a simple calculation based on past seasonal data and

    (2) the trend and seasonal index from a hand-fit regression line.

We follow this with a more formal procedure for the decomposition of data and forecasting using least squares regression.

2 Decomposition of a Time Series

- Seasonal Variation
  - We mentioned that seasonal variation is another of the components of a time series.
  - Business series, such as automobile sales, shipments of soft-drink bottles, and residential construction, have periods of above-average and below-average activity each year.

2 Decomposition of a Time Series

- Seasonal Variation
  - In the area of production, one of the **reasons** for analyzing seasonal fluctuations is to have a sufficient supply of raw materials on hand to meet the varying seasonal demand.
  - An analysis of seasonal fluctuations over a period of years can also help in evaluating current sales.

2 Decomposition of a Time Series

- Determining a Seasonal Index
    - A typical set of monthly indexes consists of 12 indexes that are representative of the data for a 12-month period. Logically, there are four typical seasonal indexes for data reported quarterly.
    - Each index is a percent, with the average for the year equal to 100.0; that is, each monthly index indicates the level of sales, production, or another variable in relation to the annual average of 100.0.

2 Decomposition of a Time Series

- Determining a Seasonal Index
  - A typical index of 96.0 for January indicates that sales (or whatever the variable is) are usually 4 percent below the average for the year.
  - An index of 107.2 for October means that the variable is typically 7.2 percent above the annual average.

2 Decomposition of a Time Series

- Determining a Seasonal Index
  - Several methods have been developed to measure the typical seasonal fluctuation in a time series.
  - The method most commonly used to compute the typical seasonal pattern is called the ratio-to-moving-average method. It eliminates the trend, cyclical, and irregular components from the original data (Y).
  - In the following discussion, T refers to trend, C to cyclical, S to seasonal, and I to irregular variation. The numbers that result are called the typical seasonal index.

2 Decomposition of a Time Series

- Example

Quarterly Sales of Toys International ($ millions)

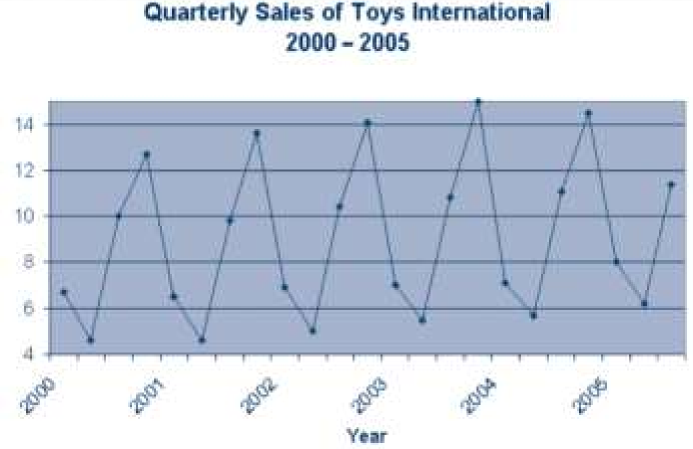
Year	Winter	Spring	Summer	Fall
2000	6.7	4.6	10.0	12.7
2001	6.5	4.6	9.8	13.6
2002	6.9	5.0	10.4	14.1
2003	7.0	5.5	10.8	15.0
2004	7.1	5.7	11.1	14.5
2005	8.0	6.2	11.4	14.9

2 Decomposition of a Time Series

- Example
  - Notice the seasonal nature of the sales.
  - For each year, the fourth-quarter sales are the largest and the second-quarter sales are the smallest. Also, there is a moderate increase in the sales from one year to the next.
  - To observe this feature, look only at the six fourth-quarter sales values. Over the six-year period, the sales in the fourth quarter increased. If you connect these points in your mind, you can visualize fourth-quarter sales increasing for 2006.

2 Decomposition of a Time Series

- Example



2 Decomposition of a Time Series

- Example

Year	Quarter	(1) Sales ($ millions)	(2) Four-Quarter Total	(3) Four-Quarter Moving Average	(4) Centred Moving Average	(5) Specific Seasonal
2000	Winter	6.7				
	Spring	4.6				
			34.0	8.500		
	Summer	10.0			8.475	1.180
			33.8	8.450		
	Fall	12.7			8.450	1.503
			33.8	8.450		
2001	Winter	6.5			8.425	0.772
			33.6	8.400		
	Spring	4.6			8.513	0.540
			34.5	8.625		
	Summer	9.8			8.675	1.130
			34.9	8.725		
	Fall	13.6			8.775	1.550
			35.3	8.825		
2002	Winter	6.9			8.900	0.775
			35.9	8.975		

Sum → Average → Average →

(10/8.475)=1.180

2 Decomposition of a Time Series

- Example

Year	Quarter	(1) Sales ($ millions)	(2) Four-Quarter Total	(3) Four-Quarter Moving Average	(4) Centered Moving Average	(5) Specific Seasonal
	Spring	5.0			9.038	0.553
			36.4	9.100		
	Summer	10.4			9.113	1.141
			36.5	9.125		
	Fall	14.1			9.188	1.535
			37.0	9.250		
2003	Winter	7.0			9.300	0.753
			37.4	9.350		
	Spring	5.5			9.463	0.581
			38.3	9.575		
	Summer	10.8			9.588	1.126
			38.4	9.600		
	Fall	15.0			9.625	1.558
			38.6	9.650		
2004	Winter	7.1			9.688	0.733
			38.9	9.725		
	Spring	5.7			9.663	0.590
			38.4	9.600		
	Summer	11.1			9.713	1.143
			39.3	9.825		
	Fall	14.5			9.888	1.466
			39.8	9.950		
2005	Winter	8.0			9.988	0.801
			40.1	10.025		
	Spring	6.2			10.075	0.615
			40.5	10.125		
	Summer	11.4				
	Fall	14.9				

2 Decomposition of a Time Series

- Example

Calculations Needed for Typical Quarterly Indexes

Year	Winter	Spring	Summer	Fall	
2000			1.180	1.503	
2001	0.772	0.540	1.130	1.550	
2002	0.775	0.553	1.141	1.535	
2003	0.753	0.581	1.126	1.558	
2004	0.733	0.590	1.143	1.466	
2005	0.801	0.615			
Total	3.834	2.879	5.720	7.612	
Mean	0.767	0.576	1.144	1.522	4.009
Adjusted	0.765	0.575	1.141	1.519	4.000
Index	76.5	57.5	114.1	151.9	

2 Decomposition of a Time Series

- Example
  - The four quarterly means (0.767, 0.576, 1.144, and 1.522) should theoretically total 4.00 because the average is set at 1.0. The total of the four quarterly means may not exactly equal 4.00 due to rounding. In this problem the total of the means is 4.009.
  - A correction factor is therefore applied to each of the four means to force them to total 4.00.

2 Decomposition of a Time Series

- Example

CORRECTION FACTOR FOR ADJUSTING QUARTERLY MEANS

$$\text{Correction factor} = \frac{4.00}{\text{Total of four means}}$$

In this example,

$$\text{Correction factor} = \frac{4.00}{4.009} = 0.997755$$

2 Decomposition of a Time Series

- Example
  - The adjusted winter quarterly index is, therefore, .767(.997755)=.765. Each of the means is adjusted downward so that the total of the four quarterly means is 4.00.
  - Usually indexes are reported as percentages, so each value in the last row of the previous table has been multiplied by 100. So the index for the winter quarter is 76.5 and for the fall it is 151.9.

2 Decomposition of a Time Series

- Example

Calculations Needed for Typical Quarterly Indexes

Year	Winter	Spring	Summer	Fall	
2000			1.180	1.503	
2001	0.772	0.540	1.130	1.550	
2002	0.775	0.553	1.141	1.535	
2003	0.753	0.581	1.126	1.558	
2004	0.733	0.590	1.143	1.466	
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Adjusted	0.765	0.575	1.141	1.519	4.000
Index	76.5	57.5	114.1	151.9	

2 Decomposition of a Time Series

- Example
  - How are these values interpreted?
  - Sales for the fall quarter are 51.9 percent above the typical quarter, and for winter they are 23.5 below the typical quarter (100.0-76.5).
  - These findings should not surprise you. The period prior to Christmas (the fall quarter) is when toy sales are brisk. After Christmas (the winter quarter) sales of the toys decline drastically.

2 Decomposition of a Time Series

- Example
  - Now we briefly summarize the reasoning underlying the preceding calculations. The original data in column 1 of the previous table contain trend (T), cyclic (C), seasonal (S), and irregular (I) components. The ultimate objective is to remove seasonal (S) from the original sales valuation.

2 Decomposition of a Time Series

- Example
  - Columns 2 and 3 in Table 16–8 are concerned with deriving the centered moving average given in column 4. Basically, we "average out" the seasonal and irregular fluctuations from the original data in column 1. Thus, in column 4 we have only trend and cyclic (TC).
  - Next, we divide the sales data in column 1 (TCSI) by the centered fourth-quarter moving average in column 4 (TC) to arrive at the specific seasonals in column 5 (SI). In terms of letters, TCSI/TC=SI. We multiply SI by 100.0 to express the typical seasonal in index form.

Year	Quarter	(1) Sales ($ millions)	(2) Four-Quarter Total	(3) Four-Quarter Moving Average	(4) Centred Moving Average	(5) Specific Seasonal

2 Decomposition of a Time Series

- Example

Year	Quarter	(1) Sales ($ millions)	(2) Four-Quarter Total	(3) Four-Quarter Moving Average	(4) Centred Moving Average	(5) Specific Seasonal
2000	Winter	6.7				
	Spring	4.6				
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	Spring	4.6			8.513	0.540
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	Summer	9.8			8.675	1.130
			34.9	8.725		
	Fall	13.6			8.775	1.550
			35.3	8.825		
2002	Winter	6.9			8.900	0.775
			35.9	8.975		

Sum

Average

Average

(10/8.475)=1.180

2 Decomposition of a Time Series

- Example

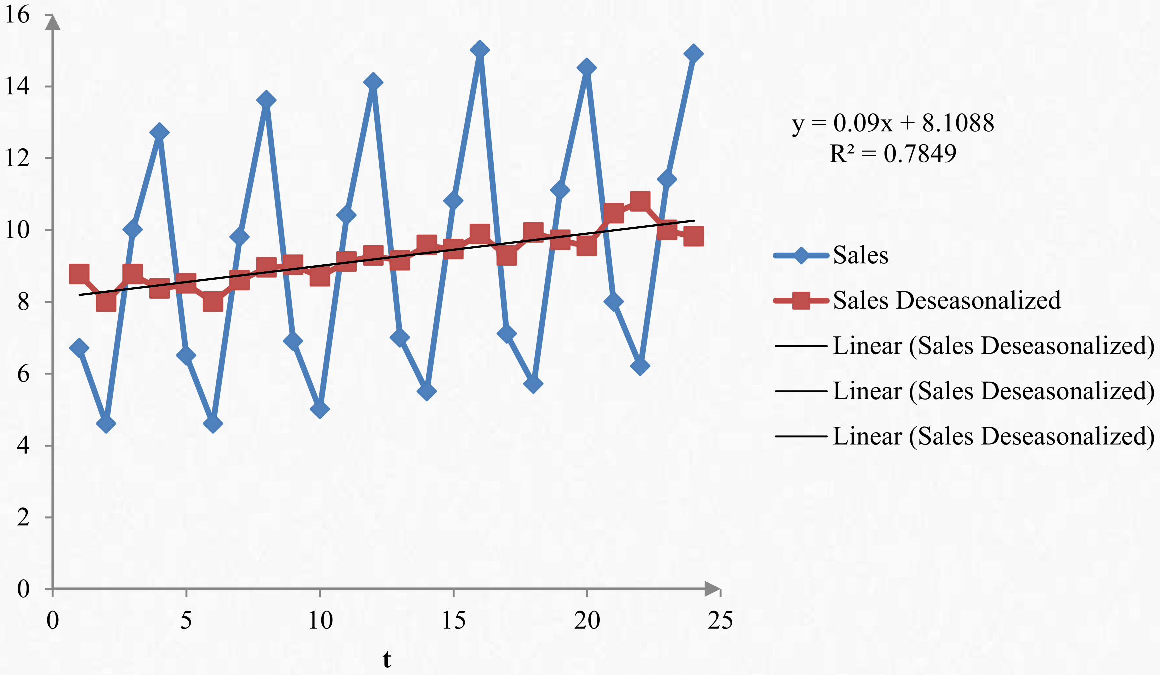
Calculations Needed for Typical Quarterly Indexes

Year	Winter	Spring	Summer	Fall	
2000			1.180	1.503	
2001	0.772	0.540	1.130	1.550	
2002	0.775	0.553	1.141	1.535	
2003	0.753	0.581	1.126	1.558	
2004	0.733	0.590	1.143	1.466	
2005	0.801	0.615			
Total	3.834	2.879	5.720	7.612	
Mean	0.767	0.576	1.144	1.522	4.009
Adjusted	0.765	0.575	1.141	1.519	4.000
Index	76.5	57.5	114.1	151.9	

2 Decomposition of a Time Series

- Example
  - Finally, we take the mean of all the winter typical indexes, all the spring indexes, and so on.
  - This averaging eliminates most of the irregular fluctuations from the seasonals, and the resulting four indexes indicate the typical seasonal sales pattern.

t	Year	Quarter	Sales	Centered Moving Average	Ratio to CMA	Seasonal Indexes	Sales Deseasonalized
1	1	1	6.7			0.765	8.76 = 6.7 / 0.765
2	1	2	4.6			0.575	8.00
3	1	3	10.0	8.475	1.180	1.141	8.76
4	1	4	12.7	8.450	1.503	1.519	8.36
5	2	1	6.5	8.425	0.772	0.765	8.50
6	2	2	4.6	8.513	0.540	0.575	8.00
7	2	3	9.8	8.675	1.130	1.141	8.59
8	2	4	13.6	8.775	1.550	1.519	8.95
9	3	1	6.9	8.900	0.775	0.765	9.02
10	3	2	5.0	9.038	0.553	0.575	8.70
11	3	3	10.4	9.113	1.141	1.141	9.11
12	3	4	14.1	9.188	1.535	1.519	9.28
13	4	1	7.0	9.300	0.753	0.765	9.15
14	4	2	5.5	9.463	0.581	0.575	9.57
15	4	3	10.8	9.588	1.126	1.141	9.46
16	4	4	15.0	9.625	1.558	1.519	9.88
17	5	1	7.1	9.688	0.733	0.765	9.28
18	5	2	5.7	9.663	0.590	0.575	9.92
19	5	3	11.1	9.713	1.143	1.141	9.72
20	5	4	14.5	9.888	1.466	1.519	9.55
21	6	1	8.0	9.988	0.801	0.765	10.46
22	6	2	6.2	10.075	0.615	0.575	10.79
23	6	3	11.4			1.141	9.99
24	6	4	14.9			1.519	9.81



y = 0.09x + 8.1088
R² = 0.7849
Sales
Sales Deseasonalized
Linear (Sales Deseasonalized)
Linear (Sales Deseasonalized)
Linear (Sales Deseasonalized)
t
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25

2 Decomposition of a Time Series

- Example

Simple Proportion Assume that in past years, a firm sold an average of 1,000 units of a particular product line each year. On the average, 200 units were sold in the spring, 350 in the summer, 300 in the fall, and 150 in the winter. The seasonal factor (or index) is the ratio of the amount sold during each season divided by the average for all seasons.

2 Decomposition of a Time Series

- Example

	Past Sales		Expected Demand for Next Year
Spring	200	Spring	
Summer	350	Summer	
Fall	300	Fall	
Winter	150	Winter	
Total	1,000	Total	1,100

?

2 Decomposition of a Time Series

- Solution

In this example, the yearly amount divided equally over all seasons is 1,000 /4=250. The seasonal factors therefore are

	Past Sales	Average Sales for Each Season (1,000/4)	Seasonal Factor
Spring	200	250	200/250 = 0.8
Summer	350	250	350/250 = 1.4
Fall	300	250	300/250 = 1.2
Winter	150	250	150/250 = 0.6
Total	1,000		

2 Decomposition of a Time Series

- Using these factors, if we expect demand for next year to be 1,100 units, we would forecast the demand to occur as

	Expected Demand for Next Year	Average Sales for Each Season (1,100/4)		Seasonal Factor		Next Year's Seasonal Forecast
Spring		275	×	0.8	=	220
Summer		275	×	1.4	=	385
Fall		275	×	1.2	=	330
Winter		275	×	0.6	=	165
Total	1,100					

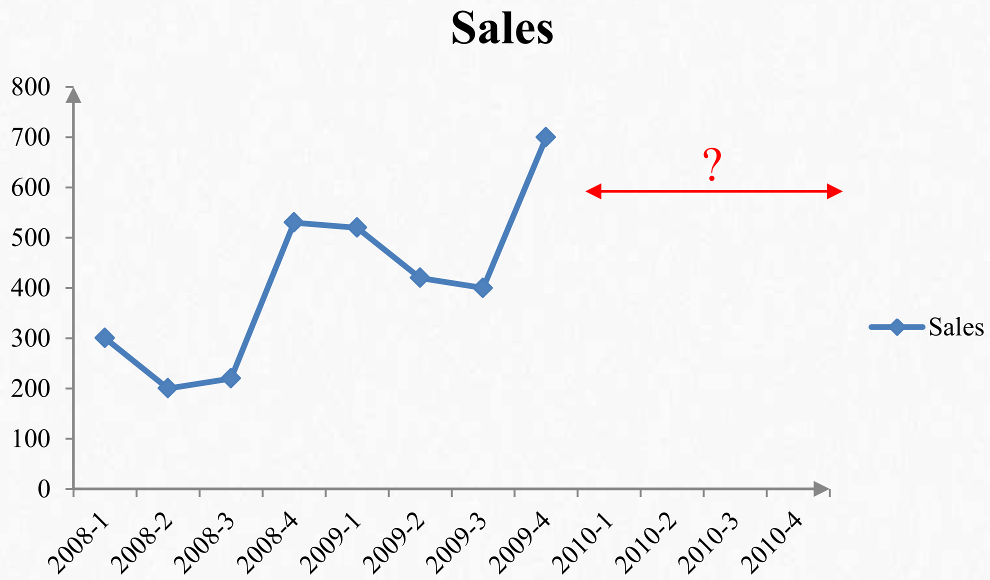
- The seasonal factor may be periodically updated as new data are available. The following example shows the seasonal factor and multiplicative seasonal variation.

2 Decomposition of a Time Series

- Example

Computing Trend and Seasonal Factor from a Hand-Fit Straight Line Here we must compute the trend as well as the seasonal factors.

Quarter	Amount	Quarter	Amount
I—2008	300	I—2009	520
II—2008	200	II—2009	420
III—2008	220	III—2009	400
IV—2008	530	IV—2009	700



Sales
800
700
600
500
400
300
200
100
0
2008-1
2008-2
2008-3
2008-4
2009-1
2009-2
2009-3
2009-4
2010-1
2010-2
2010-3
2010-4
?
Sales

2 Decomposition of a Time Series

- Solution

We solve this problem by simply hand fitting a straight line through the data points and measuring the trend and intercept from the graph. Assume the history of data is

Quarter	Amount	Quarter	Amount
I—2008	300	I—2009	520
II—2008	200	II—2009	420
III—2008	220	III—2009	400
IV—2008	530	IV—2009	700

2 Decomposition of a Time Series

First, we plot as in the below figure and then visually fit a straight line through the data (Naturally, this line and the resulting equation are subject to variation.).

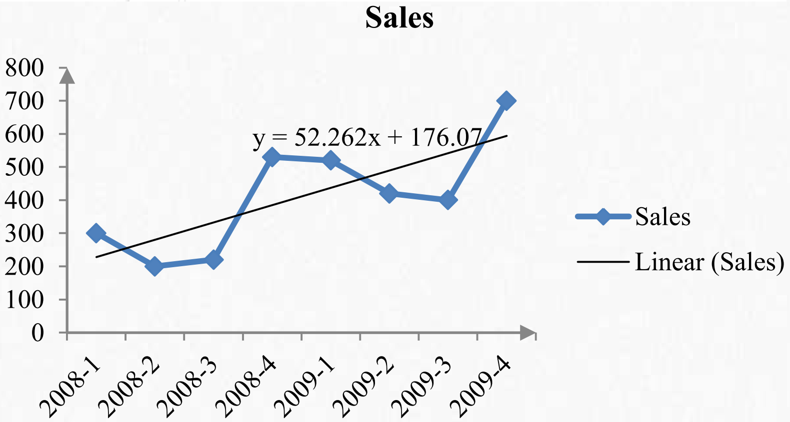
The equation for the line is $\text{Trend}_t = 170 + 55t$

Next we can derive a seasonal index by comparing the actual data with the trend line as in the following figure.

The seasonal factor was developed by averaging the same quarters in each year.

2 Decomposition of a Time Series

Computing a Seasonal Factor from the Actual Data and Trend Line



2 Decomposition of a Time Series

Quarter	Actual Amount	From Trend Equation $T_t = 170 + 55t$	Ratio of Actual ÷ Trend	Seasonal Factor (Average of Same Quarters in Both Years)
2008				
I	300	225	1.33	
II	200	280	0.71	
III	220	335	0.66	I—1.25
IV	530	390	1.36	II—0.78
2009				III—0.69
I	520	445	1.17	IV—1.25
II	420	500	0.84	
III	400	555	0.72	
IV	700	610	1.15	

2 Decomposition of a Time Series

We can compute the 2010 forecast including trend and seasonal factors (FITS) as follows:

$$\text{FITS}_t = \text{Trend} \times \text{Seasonal}$$

2010-I	$\text{FITS}_9 = [170 + 55(9)]1.25 = 831$
2010-II	$\text{FITS}_{10} = [170 + 55(10)]0.78 = 562$
2010-III	$\text{FITS}_{11} = [170 + 55(11)]0.69 = 535$
2010-IV	$\text{FITS}_{12} = [170 + 55(12)]1.25 = 1{,}038$

2 Decomposition of a Time Series

Quarter	Actual Amount	From Trend Equation $T_t = 170 + 55t$	Ratio of Actual ÷ Trend	Seasonal Factor (Average of Same Quarters in Both Years)
2008				
I	300	225	1.33	
II	200	280	0.71	
III	220	335	0.66	I—1.25
IV	530	390	1.36	II—0.78
2009				III—0.69
I	520	445	1.17	IV—1.25
II	420	500	0.84	
III	400	555	0.72	
IV	700	610	1.15	

2 Decomposition of a Time Series

- Decomposition Using Least Squares Regression
  - Decomposition of a time series means finding the series' basic components of trend, seasonal, and cyclical. Indexes are calculated for seasons and cycles.
  - The forecasting procedure then reverses the process by projecting the trend and adjusting it by the seasonal and cyclical indexes, which were determined in the decomposition process.

2 Decomposition of a Time Series

- Decomposition Using Least Squares Regression

More formally, the process is decompose the time series into its components.

a. Find seasonal component.

b. Deseasonalize the demand.

c. Find trend component.

4.7 Deseasonalized Demand

(1) Period (x)	(2) Quarter	(3) Actual Demand (y)	(4) Average of the Same Quarters of Each Year	(5) Seasonal Factor	(6) Deseasonalized Demand (y_d) Col. (3) ÷ Col. (5)
1	I	600	(600 + 2,400 + 3,800)/3 = 2,266.7	0.82	735.7
2	II	1,550	(1,550 + 3,100 + 4,500)/3 = 3,050	1.10	1,412.4
3	III	1,500	(1,500 + 2,600 + 4,000)/3 = 2,700	0.97	1,544.0
4	IV	1,500	(1,500 + 2,900 + 4,900)/3 = 3,100	1.12	1,344.8
5	I	2,400		0.82	2,942.6
6	II	3,100		1.10	2,824.7
7	III	2,600		0.97	2,676.2
8	IV	2,900		1.12	2,599.9
9	I	3,800		0.82	4,659.2
10	II	4,500		1.10	4,100.4
11	III	4,000		0.97	4,117.3
12	IV	4,900		1.12	4,392.9
78		33,350		12.03	33,350.1*

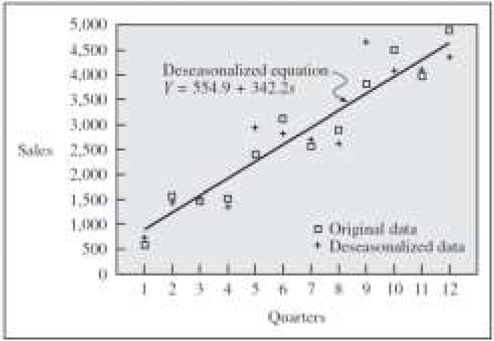
(33350 / 12) = 2779.16
2266.7 / 2779.16 = 0.82

2 Decomposition of a Time Series

- 2. Forecast future values of each component.
  - a. Project trend component into the future.
  - b. Multiply trend component by seasonal component.
- Note that the random component is not included in this list. We implicitly remove the random component from the time series when we average as in step 1. It is pointless to attempt a projection of the random component in step 2 unless we have information about some unusual event, such as a major labor dispute, that could adversely affect product demand (and this would not really be random).

2 Decomposition of a Time Series

- The following Figure shows the decomposition of a time series using least squares regression and the same basic data we used in our earlier examples. Each data point corresponds to using a single three-month quarter of the three-year (12-quarter) period. Our objective is to forecast demand for the four quarters of the fourth year.



Straight Line Graph of Deseasonalized Equation

2 Decomposition of a Time Series

- Step 1. Determine the seasonal factor (or index).

The previous Table summarizes the calculations needed. Column 4 develops an average for the same quarters in the three year period. For example, the first quarters of the three years are added together and divided by three. A seasonal factor is then derived by dividing that average by the general average for all 12 quarters (33350/12, or 2779). These are entered in column 5. Note that the seasonal factors are identical for similar quarters in each year.

Deseasonalized Demand

(1) Period (x)	(2) Quarter	(3) Actual Demand (y)	(4) Average of the Same Quarters of Each Year	(5) Seasonal Factor	(6) Deseasonalized Demand (y_d) Col. (3) ÷ Col. (5)	(7) x^2 (Col. 1)^2	(8) $x \times y_d$ Col. (1) × Col. (6)
1	I	600	(600 + 2,400 + 3,800)/3 = 2,266.7	0.82	735.7	1	735.7
2	II	1,550	(1,550 + 3,100 + 4,500)/3 = 3,050	1.10	1,412.4	4	2,824.7
3	III	1,500	(1,500 + 2,600 + 4,000)/3 = 2,700	0.97	1,544.0	9	4,631.9
4	IV	1,500	(1,500 + 2,900 + 4,900)/3 = 3,100	1.12	1,344.8	16	5,379.0
5	I	2,400		0.82	2,942.6	25	14,713.2
6	II	3,100		1.10	2,824.7	36	16,948.4
7	III	2,600		0.97	2,676.2	49	18,733.6
8	IV	2,900		1.12	2,599.9	64	20,798.9
9	I	3,800		0.82	4,659.2	81	41,932.7
10	II	4,500		1.10	4,100.4	100	41,004.1
11	III	4,000		0.97	4,117.3	121	45,290.1
12	IV	4,900		1.12	4,392.9	144	52,714.5
78		33,350		12.03	33,350.1*	650	265,706.9

$$\bar{x} = \frac{78}{12} = 6.5 \qquad b = \frac{\Sigma x y_d - n\bar{x}\bar{y}_d}{\Sigma x^2 - n\bar{x}^2} = \frac{265{,}706.9 - 12(6.5)2{,}779.2}{650 - 12(6.5)^2} = 342.2$$

$$\bar{y}_d = 33{,}350/12 = 2{,}779.2 \qquad a = \bar{y}_d - b\bar{x} = 2{,}779.2 - 342.2(6.5) = 554.9$$

Therefore, $Y = a + bx = 554.9 + 342.2x$

*Column 3 and column 6 totals should be equal at 33,350. Differences are due to rounding. Column 5 was rounded to two decimal places.

2 Decomposition of a Time Series

- Step 2. Deseasonalize the original data.

To remove the seasonal effect on the data, we divide the original data by the seasonal factor. This step is called the deseasonalization of demand and is shown in column 6 of the previous table.

- Step 3. Develop a least squares regression line for the deseasonalized data.

The purpose here is to develop an equation for the trend line Y, which we then modify with the seasonal factor. The procedure is the same as we used before:

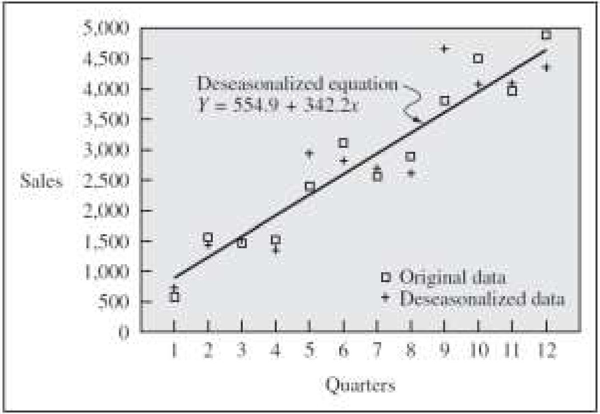
2 Decomposition of a Time Series

$$Y = a + bx$$

where

y_d = deseasonalized demand
x = quarter
Y = demand computed using the regression equation $Y = a + bx$
a = Y-intercept
b = slope of the line

2 Decomposition of a Time Series



Straight Line Graph of Deseasonalized Equation

2 Decomposition of a Time Series

The least squares calculations using columns 1, 7, and 8 of previous figure are shown in the lower section of the exhibit.

The final deseasonalized equation for our data is $Y = 554.9+342.2x$. This straight line is shown in following Figure.

- Step 4. Project the regression line through the period to be forecast.

Our purpose is to forecast periods 13 through 16. We start by solving the equation for Y at each of these periods (shown in step 5, column 3).

2 Decomposition of a Time Series

- Step 5. Create the final forecast by adjusting the regression line by the seasonal factor.

Recall that the Y equation has been deseasonalized. We now reverse the procedure by multiplying the quarterly data we derived by the seasonal factor for that quarter:

2 Decomposition of a Time Series

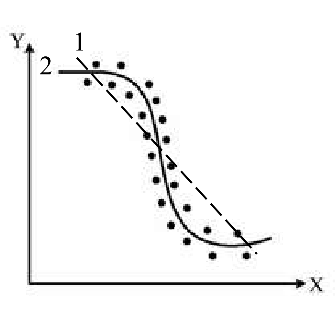
Period	Quarter	Y from Regression Line	Seasonal Factor	Forecast (Y × Seasonal Factor)
13	1	5,003.5	0.82	4,102.87
14	2	5,345.7	1.10	5,880.27
15	3	5,687.9	0.97	5,517.26
16	4	6,030.1	1.12	6,753.71

Our forecast is now complete. The procedure is generally the same as what we did in the hand-fit previous example. In the present example, however, we followed a more formal procedure and computed the least squares regression line as well.

2 Decomposition of a Time Series

- Error Range

When a straight line is fitted through data points and then used for forecasting, errors can come from two sources.



2 Decomposition of a Time Series

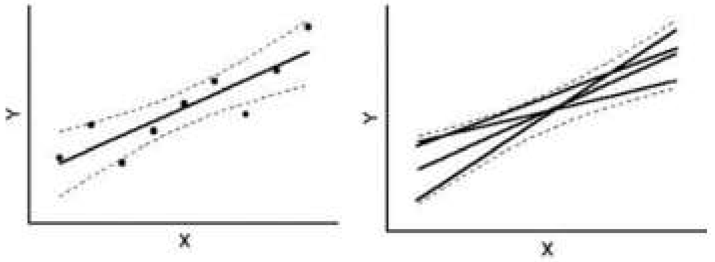
- Error Range

When a straight line is fitted through data points and then used for forecasting, errors can come from two sources.

- First, there are the usual errors similar to the standard deviation of any set of data.
- Second, there are errors that arise because the line is wrong. The following figure shows this error range. We develop the statistic later in the chapter; here, we will briefly show why the range broadens.

2 Decomposition of a Time Series

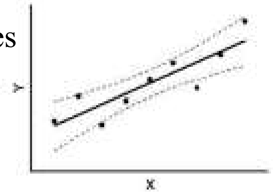
- Error Range



Confidence vs. prediction intervals

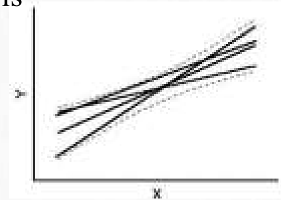
2 Decomposition of a Time Series

- Error Range
  - In this graph, a linear regression line is calculated to fit the sample data points. The confidence interval consists of the space between the two curves (dotted lines).
  - Thus there is a 95% probability that the true best-fit line for the population lies within the confidence interval (e.g. any of the lines in the figure on the right above).



2 Decomposition of a Time Series

- Error Range
  - There is also a concept called prediction interval. Here we look at any specific value of x, x_0, and find an interval around the predicted value $\hat{y}_0$ for x_0 such that there is a 95% probability that the real value of y (in the population) corresponding to x_0 is within this interval



2 Decomposition of a Time Series

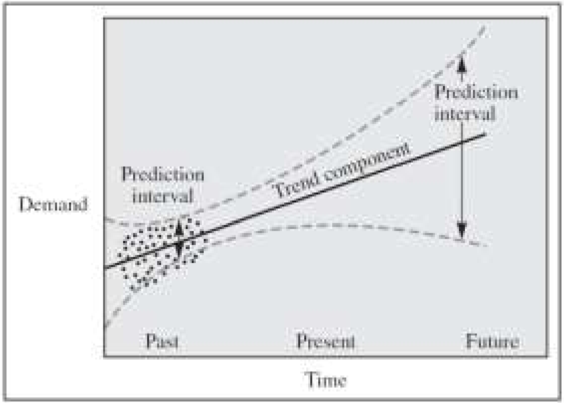
- Error Range

First, visualize that one line is drawn that has some error such that it slants too steeply upward. Standard errors are then calculated for this line.

Now visualize another line that slants too steeply downward. It also has a standard error.

The total error range, for this analysis, consists of errors resulting from both lines as well as all other possible lines. We included this exhibit to show how the error range widens as we go further into the future.

2 Decomposition of a Time Series



Prediction Intervals for Linear Trend

New Observation at x

Want to **predict** $y^{new}(x^*) = \alpha + \beta x^* + \epsilon^{new}$

new draw of y from subpopulation given $x = x^*$

Point prediction: $\hat{y}(x^*) = a + bx^*$

Sources of uncertainty : a, b estimated.

random error ϵ of new observ.

$$SE^2_{\hat{y}(x^*)} = s^2_{Y|x} + SE^2_{\hat{\mu}_{Y|x^*}} = s_{yx}\sqrt{1 + \frac{1}{n} + \frac{(x_0 - \bar{x})^2}{SS_x}}$$

Prediction Interval : level $(1-\alpha)\%$ n-2 df

$$\hat{y}(x^*) \pm t_{1-\alpha/2, n-2} SE_{\hat{y}(x^*)}$$

Claim: 95% of the time , Pred. Interv. covers $y^{new}(x^*)$

2 Decomposition of a Time Series

- Evaluating Forecasts
  - Ultimately, of course, the quality of any forecast is reflected in the quality of the decisions based on the forecast.
  - This leads to suggesting the ideal comparison of forecasting procedures would be based on the costs of producing the forecast and the value of the forecast for the decision.

2 Decomposition of a Time Series

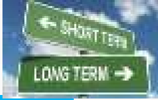
- Evaluating Forecasts
  - From these data, the appropriate trade-off between the cost of developing and the cost of making decisions with forecasts of varying quality could be made.

2 Decomposition of a Time Series

- Evaluating Forecasts
    - Unfortunately, neither cost is easily measured. In addition, such a scheme suggests that a different forecasting procedure might be required for each decision, an undesirably complex possibility. As a result of these complications, we rely on some direct measures of forecast quality.

2 Decomposition of a Time Series

- Evaluating Forecasts
  - For any forecasting procedure we develop, an important criterion is honesty, or lack of bias; that is, the procedure should produce forecasts that are neither consistently high nor consistently low.
  - Forecasts shouldn't be overly optimistic or pessimistic, but rather should "tell it like it is." Because we're dealing with projecting past data, lack of bias means smoothing out past data's randomness so that forecasts that are too high are offset by forecasts that are too low.



2 Decomposition of a Time Series

- Evaluating Forecasts
  - Optimistic or pessimistic?

			Daily supply			
	40 salads	0.10				
	60 salads	0.40				

2 Decomposition of a Time Series

- Evaluating Forecasts
    - To measure bias, we'll use the mean error as defined by the below equation. In this equation, the forecast error in each period is actual demand in each period minus forecast demand for that period.

$$\text{Mean error (bias)} = \frac{\sum_{i=1}^{n}(\text{Actual demand}_i - \text{Forecast demand}_i)}{n}$$

where:

i = period number
n = number of periods of data

2 Decomposition of a Time Series

- Evaluating Forecasts

The following figure shows an example calculation of bias.

Example Bias Calculation

	Period (i)			
	1	2	3	4
(1) Actual demand	1,500	1,400	1,700	1,200
(2) Forecast demand	1,600	1,600	1,400	1,300
Error (1) − (2)	−100	−200	300	−100

$$\text{Bias} = \sum_{i=1}^{4} \text{error}_i/4 = (-100 - 200 + 300 - 100)/4$$

$$= -100/4 = -25$$

2 Decomposition of a Time Series

- Evaluating Forecasts
  - As following figure shows, when forecast errors tend to cancel one another out, the measure of bias tends to be low. Positive errors in some periods are offset by negative errors in others, which tends to produce an average error, or bias near zero.
  - In the following figure there's a bias and the demand was over forecast by an average of 25 units per period for the four periods.

Figure 4.16 Sample MA

	Period (*i*)			
	1	2	3	4
(1) Actual demand	1,500	1,400	1,700	1,200
(2) Forecast demand	1,600	1,600	1,400	1,300
Error (1) − (2)	−100	−200	300	−100

$$\text{MAD} = \sum_{i=1}^{4} |\text{error}_i|/4$$
$$= (|-100| + |-200| + |300| + |-100|)/4 = 175$$

$$\text{Bias} = \sum_{i=1}^{4} \text{error}_i/4 = (-100 - 200 + 300 - 100)/4$$
$$= -100/4 = -25$$

	Period (*i*)			
	1	2	3	4
(1) Actual demand	100	100	5,500	100
(2) Forecast demand	1,600	1,600	1,400	1,300
Error (1) − (2)	−1,500	−1,500	4,100	−1,200

$$\text{Bias} = \sum_{i=1}^{4} |\text{error}_i|/4 = (-1{,}500 - 1{,}500 + 4{,}100 - 1{,}200)/4$$
$$= -100/4 = -25$$

$$\text{MAD} = \sum_{i=1}^{4} |\text{error}_i|/4$$
$$= (|-1{,}500| + |-1{,}500| + |4{,}100| + |-1{,}200|)/4$$
$$= 8{,}300/4 = 2{,}075$$

2 Decomposition of a Time Series

- Having an unbiased forecast is important in manufacturing planning and control, since the unbiased estimates, on average, are about right. But that's not enough. We still need to be concerned with the errors' magnitude.
- Note, for the example in the previous figure, we obtain the identical measure of bias if actual demand for the four periods had been 100, 100, 5,500, and 100, respectively. (This is shown as part of the calculations in the following figure)

2 Decomposition of a Time Series

- However, the individual errors are much larger, and this difference would have to be reflected in extra inventory if we were to maintain a consistent level of customer service.
- Let's now turn to a widely used measure of forecast error magnitude, the mean absolute deviation (MAD).
- The equation for calculating MAD is provided in Equation (4), while the following figure shows example calculations.

$$\text{Mean absolute deviation (MAD)} = \frac{\sum_{i=1}^{n} |\text{Actual demand}_i - \text{Forecast demand}_i|}{n} \qquad (4)$$

Sample MAD Calculations

	Period (i)			
	1	2	3	4
(1) Actual demand	1,500	1,400	1,700	1,200
(2) Forecast demand	1,600	1,600	1,400	1,300
Error (1) − (2)	−100	−200	300	−100

$$\text{MAD} = \sum_{i=1} |\text{error}_i|/4$$

$$= (|-100| + |-200| + |300| + |-100|)/4 = 175$$

	Period (i)			
	1	2	3	4
(1) Actual demand	100	100	5,500	100
(2) Forecast demand	1,600	1,600	1,400	1,300
Error (1) − (2)	−1,500	−1,500	4,100	−1,200

$$\text{Bias} = \sum_{i=1}^{4} |\text{error}_i|/4 = (-1{,}500 - 1{,}500 + 4{,}100 - 1{,}200)/4$$

$$= -100/4 = -25$$

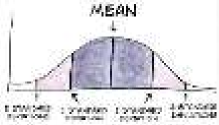
$$\text{MAD} = \sum_{i=1}^{4} |\text{error}_i|/4$$

$$= (|-1{,}500| + |-1{,}500| + |4{,}100| + |-1{,}200|)/4$$

$$= 8{,}300/4 = 2{,}075$$

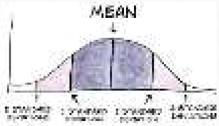
2 Decomposition of a Time Series

- The mean absolute deviation expresses the size of the average error irrespective of whether it's positive or negative. It's the combination of bias and MAD that allows us to evaluate forecasting results.
- Bias is perhaps the most critical, since we can compensate for forecast errors through inventory, expediting, faster delivery means, and other kinds of responses.



2 Decomposition of a Time Series

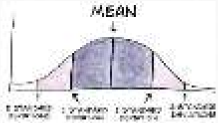
- MAD indicates the expected compensation's size (e.g., required speed).
- However, if a forecast is consistently lower than demand, the entire material-flow pipeline will run dry; it will be necessary to start over again with raw materials. Inventory buildups can arise with a consistently high forecast.



2 Decomposition of a Time Series

- Before turning to some managerial issues concerning forecasting, we would like to provide one other relationship that is quite useful.
- The most widely used measure of deviation or dispersion in statistics is the standard deviation. MAD also measures deviation (error) from an expected result (the forecast).
- The Standard Deviation is a measure of how spread out numbers are. Its symbol is σ. σ is the square root of the Variance. The Variance is defined as:

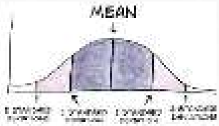
"The average of the squared differences from the Mean."



2 Decomposition of a Time Series

- When the forecast errors are distributed normally, there is a direct relationship between the two measures that can be used to develop statistical insights and conclusions. The standard deviation of the errors is arithmetically related to MAD by Equation (4):

$$\text{Standard deviation of forecast errors} = 1.25 \text{ MAD} \qquad (4)$$



2 Decomposition of a Time Series

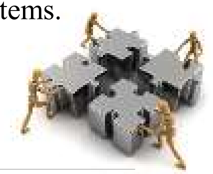
- In the demand management module we are interested in providing the appropriate level of detail and frequency of the forecast to the other modules in the front end of the MPC system. This may require modification of the forecasts or reconciliation with other forecast sources before they can be used for decision making.

2 Decomposition of a Time Series

- Using the Forecasts
  - Using the forecasts requires a heavy dose of common sense, as well as application of techniques. In this section, we'll look at some technical reasons for aggregating forecasts and some of the methods for readying the forecasts for use in sales and operations planning.
  - We'll also review some means for incorporating management information into the forecasts.

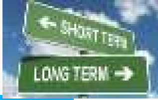
2 Decomposition of a Time Series

- Considerations for Aggregating Forecasts
    - There are several reasons for aggregating product items in both time and level of detail for forecasting purposes. We must do it with caution, however. Aggregating individual products into product lines, geographical areas, or customer types, for example, must be done in ways that are compatible with the planning systems.



2 Decomposition of a Time Series

- Considerations for Aggregating Forecasts
  - Product groupings must also be developed, so that the forecast unit is sensible to forecasters. Provided we follow these guidelines, we can use product groupings to facilitate the forecasting task.



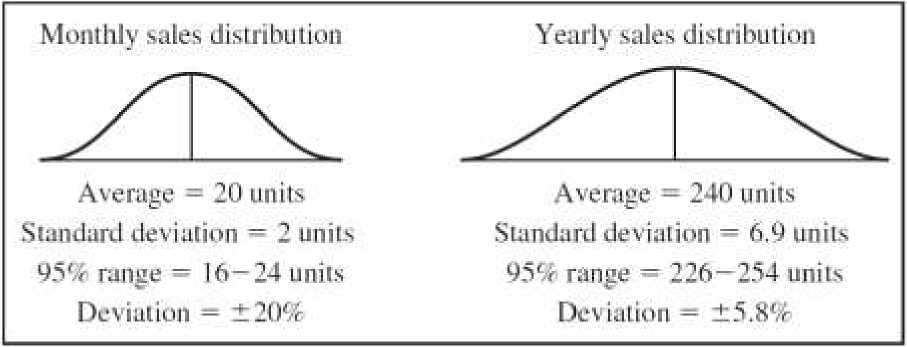
2 Decomposition of a Time Series

- Considerations for Aggregating Forecasts
  - It's a well-known phenomenon that long-term or product-line forecasts are more accurate than short-term and/or detailed forecasts.

2 Decomposition of a Time Series

- Considerations for Aggregating Forecasts
  - Consider the example in the following figure. Monthly sales average 20 units but vary randomly with a standard deviation of two units. This means 95 percent of the monthly demands lie between 16 and 24 units when demand is normally distributed. This corresponds to a forecast error of plus or minus 20 percent around the forecast of 20 units per month.

2 Decomposition of a Time Series



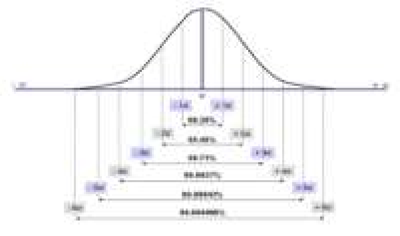
Effect of Aggregating on Forecast Accuracy

2 Decomposition of a Time Series

- Now suppose, instead of forecasting demand on a monthly basis, we prepare an annual forecast of demand—in this case, 240 (12 months×20 units/month) units for the year.
- If monthly sales are independent, the resulting standard deviation is 6.9 units. This is found by noting that the variance of the monthly distribution is 4 units (2^2). The variance of the yearly distribution is 48 (12 months×4), so the standard deviation is 6.9 ($\sqrt{48}$). This corresponds to a 95 percent range of 226 to 254 units or a $\pm$5.8 percent deviation.

2 Decomposition of a Time Series

- The reduction from ±20 percent to ±5.8 percent is due to using a much longer time period.
- The same effect can be seen in forecasting demand for product lines instead of for individual items.



2 Decomposition of a Time Series

- In the assemble-to-order environment, the following equation shows the number of items that need to be forecast when finished products are used instead of the components.
- This is often a substantial increase in the number and, because of the detail, often results in very poor forecasting performance. For example, what is the forecast for red, two-door, small engine, antilock-brake cars with sport stripes.

2 Decomposition of a Time Series

- It is much easier to forecast demand for the components than the detailed component combinations.
- Many of the same advantages of error reduction that accrue to aggregating are possible here as well.

$$\text{Total number of combinations} = N_1 * N_2 * \cdots * N_n$$

2 Decomposition of a Time Series

- An issue arises whenever aggregations of products, regions, or time periods are used to develop strategic or sales and operations plans.
- The total forecast must be consistent with the individual product forecasts. The whole must be equal to the sum of the parts.
- Very often an individual product's share of the aggregate product line totals remains fairly constant. That is, there is more uncertainty in the day-to-day demand for the item than for its share in the demand for the total line.

2 Decomposition of a Time Series

- We can use this knowledge to disaggregate the aggregate forecasts and thereby maintain the consistency between the detail and the totals.
- We may even be able to show improvements in the accuracy of the detail forecasts by doing it this way. One formal method for achieving consistency is described next.

2 Decomposition of a Time Series

- Pyramid Forecasting
  - In addition, there may be budget restrictions, income goals, or other company considerations that shape the aggregate forecasts that need to be taken into account in developing the final forecasts at the item level.
  - One procedure for doing this is pyramid forecasting. It provides a means of coordinating, integrating, and assuring consistency between the various sources of forecasts and any company constraints or goals.

2 Decomposition of a Time Series

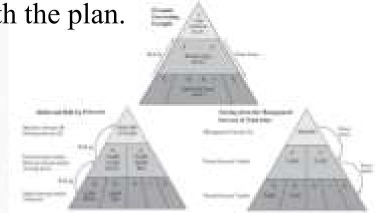
- Pyramid Forecasting

The following figure provides the basic framework for pyramid forecasting. The procedure used in implementing the approach often begins with individual product item forecasts at level 3, which are rolled up into forecasts for product lines shown as level 2. We then aggregate forecasts for product lines into a total business forecast (in dollars) at level 1 in the considered figure.

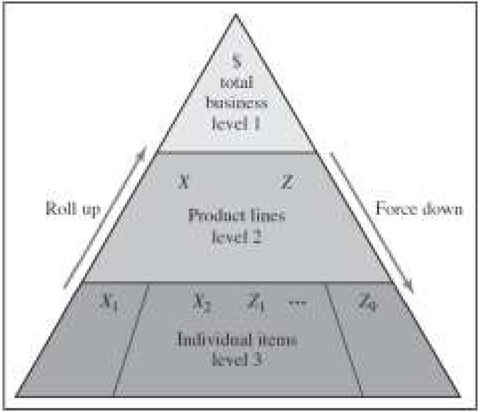
2 Decomposition of a Time Series

- Pyramid Forecasting

Once the individual item and product line forecasts have been rolled up and considered in finalizing the top management forecast (plan), the next step is to force down (constrain) the product line and individual item forecasts, so they're consistent with the plan.



2 Decomposition of a Time Series

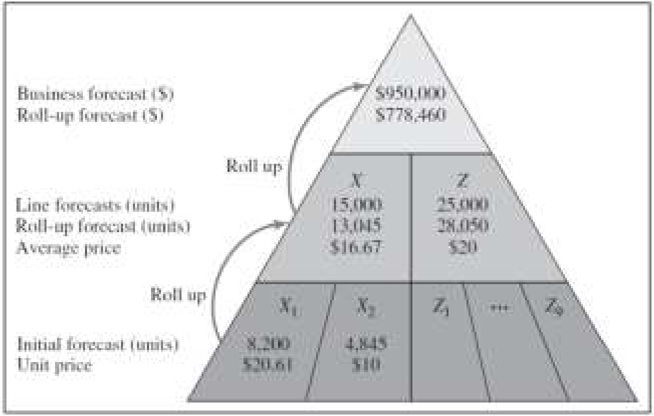


Pyramid Forecasting Example

2 Decomposition of a Time Series

- Pyramid Forecasting
  - In the example shown in the following figure, the 11 individual product items are divided into two product lines. Two of these items, X1 and X2, form product line X (which we'll study in detail), while the remaining products, Z1 through Z9, are included in product line Z. These two product lines, X and Z, represent the firm's entire range of products. The following figure shows unit prices and initial forecasts for each level.

2 Decomposition of a Time Series



Initial and Roll-Up Forecasts

2 Decomposition of a Time Series

- Pyramid Forecasting

The roll-up process starts by summing the individual item forecasts (level 3) to provide a total for each line (level 2). For the X line, the roll-up forecast is 13,045 units (8,200+4,845). The sum of the individual Z line items gives a forecast of 28,050 units. Note that the X line rollup doesn't correspond to the forecast of 15,000 units for the line.

2 Decomposition of a Time Series

- Pyramid Forecasting

If there’s substantial disagreement at this stage, reconciliation could occur or an error might be discovered. If there’s to be no reconciliation at this level, we needn’t prepare independent forecasts for the lines. If dollar forecasts are required at level 2, prices at level 3 can be used to calculate an average price.

2 Decomposition of a Time Series

- Pyramid Forecasting

To roll up to the level 1 dollar forecasts, the average prices at the line level are combined with the line roll-up forecasts. The total of \$778,460:

$$\$778{,}460 = (13{,}045 \times 16.67) + (28{,}050 \times 20.00)$$

is less than the independent business forecast of \$950,000.

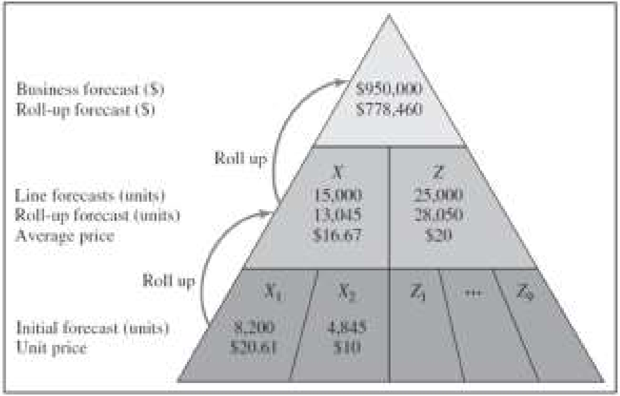
2 Decomposition of a Time Series

- For illustrative purposes, we'll assume management has evaluated the business forecast and the roll-up forecast and has decided to use $900,000 as the forecast at level 1. The next task is to make the line and individual item forecasts consistent with this amount.
- To bring about the consistencies, we use the forcing-down process. The ratio between the roll-up forecast at level 1 ($778,460) and the management total ($900,000) is used to make the adjustment.

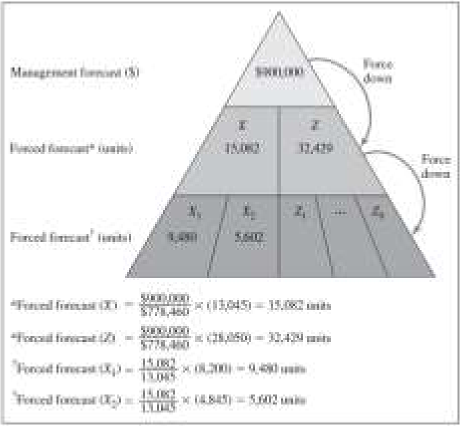
2 Decomposition of a Time Series

The forecasts at all levels appear in the following figure. The results are consistent forecasts throughout the organization, and the sum of the parts is forced to equal the whole. Note, however, the process of forcing the consistency needs to be approached with caution. In the example, forecasts at the lower level are now higher than they were originally and incorporate the plans at the higher levels. Even though the sum of the parts equals the whole, it's possible the people responsible for the forecast won't "own" the number. They mustn't be made to feel they're simply being given an allocation of someone else's wish list.

2 Decomposition of a Time Series



Initial and Roll-Up Forecasts



Forcing down the Management Forecast of Total Sales

2 Decomposition of a Time Series

Concluding Principles

- The forecasting models should not be any more complicated than necessary. Simple models often work better than more complicated ones.
- Input data and output forecasts should be routinely monitored for quality and appropriateness.
- Information on the sources of variation in sales, such as seasonality, market trends, and company policies, should be incorporated into the forecasting system.
- Forecasts from different sources must be reconciled and made consistent with company plans and constraints.

Advanced Sales and Operations Planning

- Mathematical Programming Approaches
  - Linear programming (LP)
  - Mixed Integer Programming

CHAPTER OUTLINE

3 Advanced Sales and Operations Planning

- This chapter deals with modeling procedures for establishing the overall, or aggregate, production and inventory portion of the sales and operations plan.
- Given a set of product demands stated in some common denominator, the basic issue is what levels of resources should be provided in each period.
- Today, powerful and easily accessible tools are available for solving these models.

3 Advanced Sales and Operations Planning

- This is important because as firms implement MPC systems, there's a natural evolution toward questions of overall production planning that provide direction to the other MPC system modules.
- This chapter provides a basic understanding of these models together with an introduction to how problems formulated with these models can be solved using a spreadsheet.

3 Advanced Sales and Operations Planning

- Linear Programming (LP)

There are many LP formulations for the aggregate production planning problem. The objective is typically to find the lowest-cost plan, considering when to hire and fire, how much inventory to hold, when to use overtime and under time, and so on, while always meeting the sales forecast. One formulation, based on measuring aggregate sales and inventories in terms of direct labor hours, follows:

3 Advanced Sales and Operations Planning

- Mixed Integer Linear Programming (ILP)
  - No shortage
  - No inventory at the first and final planning period
  - Product holding cost per month=1
  - Fixed and variable production costs are 4 and 10, respectively,
  - Maximum production and holding capacities are 4 and 3 per month, respectively.

Mathematical model
and
solution algorithm?

Month	March	April	May	June	July	August
Demand	1	2	5	3	2	1

3 Advanced Sales and Operations Planning

- Linear Programming (LP)

C_H = The cost of hiring an employee.

C_F = The cost of firing an employee.

C_R = The cost per labor-hour of regular time production.

C_O = The cost per labor-hour of overtime production.

C_I = The cost per month of carrying one labor-hour of work.

C_U = The cost per labor-hour of idle regular time production.

B_t = The minimum number of hours to be stored in inventory in month t.

A_{1t} = The maximum number of regular time hours to be worked per employee

3 Advanced Sales and Operations Planning

- Linear Programming (LP)

A_{2t} = The maximum number of overtime hours to be worked per employee per month.

A_3 = The initial employment level.

A_4 = The initial inventory level.

A_5 = The desired number of employees in month m (the last month in the planning horizon).

m = The number of months in the planning horizon.

3 Advanced Sales and Operations Planning

- Linear Programming (LP)

H_t = The number of employees hired in month t.

F_t = The number of employees fired in month t.

X_t = The regular time production hours scheduled in month t.

O_t = The overtime production hours scheduled in month t.

I_t = The hours stored in inventory at the end of month t.

U_t = The number of idle time regular production hours in month t.

D_t = The hours of production to be sold in month t.

3 Advanced Sales and Operations Planning

- Linear Programming (LP)

W_t = The number of people employed in month t.

S_t = The number of unused overtime hours per month per employee.

Minimize:

$$\sum_{t=1}^{m} (C_H H_t + C_F F_t + C_R X_t + C_O O_t + C_I I_t + C_U U_t)$$

subject to:

1. Inventory constraint:

$$I_{t-1} + X_t + O_t - I_t = D_t$$
$$I_t \geq B_t$$

2. Regular time production constraint:

$$X_t - A_{1t} W_t + U_t = 0$$

3. Overtime production constraint:

$$O_t - A_{2t} W_t + S_t = 0$$

4. Workforce level change constraints:

$$W_t - W_{t-1} - H_t + F_t = 0$$

5. Initializing constraints:

$$W_O = A_3$$
$$I_O = A_4$$
$$W_m = A_5$$

3 Advanced Sales and Operations Planning

- Mixed Integer Linear Programming (ILP)

D_{it} = The hours of product family i demanded in month t.

C_{si} = Setup cost of product family i.

C_{li} = Inventory carrying cost per month of one labor-hour of work for product family i.

C_{mi} = Materials cost per hour of production of family i.

C_H = Hiring cost per employee.

C_F = Firing cost per employee.

C_O = Overtime cost per employee hour.

3 Advanced Sales and Operations Planning

- Integer Linear Programming (ILP)

C_R = Regular time workforce cost per employee hour.

A_{1t} = The maximum number of regular time hours to be worked per employee in month t.

β_i = Setup time for product family i.

A_{2t} = Maximum number of overtime hours per employee in month t.

n = Number of product families.

m = Number of months in the planning horizon.

3 Advanced Sales and Operations Planning

- Integer Linear Programming (ILP)

X_{it} = Production in hours of product family i scheduled in month t.

I_{it} = The hours of product family i stored in inventory in month t.

H_t = The number of employees hired in month t.

F_t = The number of employees fired in month t.

O_t = Overtime production hours in month t.

W_t = Number of people employed on regular time in month t.

$\sigma(X_{it})$ = Binary setup variable for product family i in month t.

3 Advanced Sales and Operations Planning

- Integer Linear Programming (ILP)

Q_i = A large number used to ensure the effects of binary setup variables; that is,

$$Q_i \geq \sum_{t=1}^{m} D_{it}$$

Minimize:

$$\sum_{i=1}^{n}\sum_{t=1}^{m}(C_{si}\sigma(X_{it}) + C_{mi}X_{it} + C_{Ii}I_{it}) + \sum_{t=1}^{m}(C_H H_t + C_F F_t + C_O O_t + A_{1t}C_R W_t + A_{1t}C_R W_t)$$

subject to:

1. Inventory constraint:

$$I_{i,t-1} - I_{it} + X_{it} = D_{it} \quad (\text{for } I = 1, \ldots, n \text{ and } T = 1, \ldots, m)$$

2. Production and setup time constraint:

$$A_{it}W_t + O_t - \sum_{i=1}^{n} X_{it} - \sum_{i=1}^{n} \beta_i\sigma(X_{it}) \geq 0 \quad (\text{for } t = 1, \ldots, m)$$

3. Workforce level change constraint:

$$W_t - W_{t-1} - H_t + F_t = 0 \quad (\text{for } t = 1, \ldots, m)$$

4. Overtime constraint:

$$O_t - A_{2t}W_t \leq 0 \quad (\text{for } t = 1, \ldots, m)$$

5. Setup constraint:

$$-Q_i\sigma(X_{it}) + X_{it} \leq 0 \quad (\text{for } t = 1, \ldots, m \text{ and } I = 1, \ldots, n)$$

6. Binary constraint for setups:

$$\sum(X_{it}) = \begin{cases} 1 & \text{if } X_{it} > 0 \\ 0 & \text{if } X_{it} = 0 \end{cases}$$

7. Nonnegativity constraints:

$$X_{it}, I_{it}, H_t, F_t, O_t, W_t \geq 0$$

3 Advanced Sales and Operations Planning

- Integer Linear Programming (ILP)

The objective function and constraints in this model are similar to those in the linear programming model. The main difference is in the addition of product family setups in constraints 5 and 6. This model assumes all the setups for a product family occur in the month in which the end product is to be completed. Constraint 5 is a surrogate constraint for the binary variables used in constraint 6. This constraint forces $s(X_{it})$ to be nonzero when $X_{it} > 0$ because Q_i is defined as at least the total demand for a product family over the planning horizon.

3 Advanced Sales and Operations Planning

- Integer Linear Programming (ILP)

Additional constraints should be added to the model to specify the initial conditions at the start of the planning horizon; that is, constraints specifying beginning inventory for the product family, I_{io}, and workforce level in the previous month, W_o, are required. Likewise, constraints specifying workforce level at the end of the planning horizon, and minimum required closing inventory balance at the end of each month in the planning horizon, may be added.

Master Production Scheduling

CHAPTER OUTLINE

- The Master Production Scheduling (MPS) Activity
- Master Production Scheduling Techniques
- Planning in an Assemble-to-Order Environment
- Managing Using a Two-Level MPS

3 Advanced Sales and Operations Planning

- The MPS Is a Statement of Future Output
  - At the conceptual level, the master production schedule translates the sales and operations plan of the company into a plan for producing specific products in the future.
  - The MPS is a statement of the specific products that make up that output.
  - The MPS is the translation of the sales and operations plan into producible products with their quantities and timing determined.
  - As the statement of output ,the master production schedule forms the basic communication link between the market and manufacturing.

3 Advanced Sales and Operations Planning

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3 Advanced Sales and Operations Planning

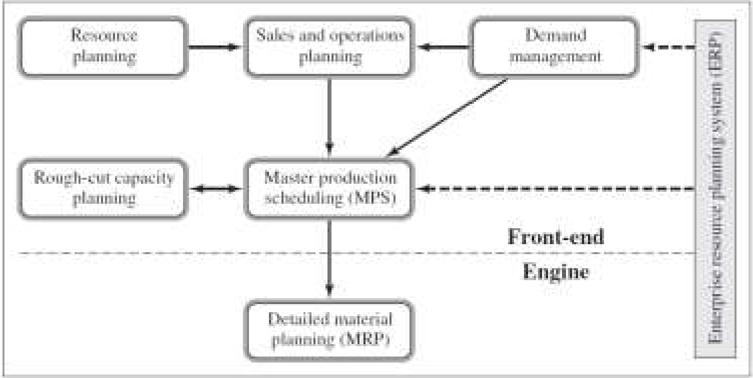
- The MPS Is a Statement of Future Output
  - The MPS is stated in product specifications in part numbers for which there are bills of materials (BOM), the language of product manufacturing.
  - Because the MPS is a build schedule, it must be stated in terms used to determine component-part needs and other requirements.

3 Advanced Sales and Operations Planning

- The Business Environment for the MPS
  - The business environment, as it relates to master production scheduling, encompasses the production approach used, the variety of products produced, and the markets served by the company.
  - Three basic production environments have been identified:
    - make-to-stock, make-to-order, and assemble-to-order.
  - Each of these environments affects the design of the MPS system, primarily through the choice of the unit used for stating the MPS that is whether the MPS is stated in end-item terms, some average end item, product modules or options, or specific customer orders.

3 Advanced Sales and Operations Planning

- Linkages to Other Company Activities



Master Production Scheduling in the MPC System

The MPS is the translation of the sales and operations plan into producible products with their quantities and timing determined

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques

- The following figure shows an example of an MPS involving an item with a beginning on-hand inventory of 20 units, a sales forecast that is increasing each period (typically weekly), and master a production schedule of 10 units per period.
- The master production schedule row states the timing for completion of units available to meet demand.
- As with the sales and operations plan, the projected available balance is governed by the following relationship:

Projected available balance = Beginning balance + Master production schedule - Forecast

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques

		Period				
	On hand	1	2	3	4	5
Forecast		5	5	8	10	15
Projected available balance	20	25	30	32	32	27
Master production schedule		10	10	10	10	10

MPS Example

Projected available balance = Beginning balance + Master production schedule - Forecast

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques

	On hand	Period 1	2	3	4	5
Forecast		5	5	8	10	15
Projected available balance	20			?		
Master production schedule				?		
Lot size = 30 Safety stock = 5 units						

Lot Sizing in the MPS

Projected available balance = Beginning balance + Master production schedule - Forecast

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques

	On hand	Period 1	2	3	4	5
Forecast		5	5	8	10	15
Projected available balance	20	15	10	32	22	7
Master production schedule				30		

Lot size = 30
Safety stock = 5 units

Lot Sizing in the MPS

Projected available balance = Beginning balance + Master production schedule - Forecast

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques
  - The MPS is a rolling schedule that requires updating the record to so the MPS reflects actual current conditions.
  - The updating captures the impact of actual transactions that have occurred from one period to the next on the MPS.
  - Actual sales were 10 units instead of 5 units, so now we see that on-hand inventory at the beginning of period 2 is 10 units rather than the 15 we expected last period.
  - Our forecast has also been updated, reflecting an anticipated surge in demand in periods 2, 3, and 4. A forecast for period 6 is added as part of rolling our plan forward one period.

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques

Actual sales were 10 units instead of 5 units

15-5=10

	On hand	Period 2	3	4	5	6
Forecast		20	20	20	15	20
Projected available balance	10	−10	0	−20	−35	−55
Master production schedule			30			

Lot size = 30
Safety stock = 5 units

Lot Sizing in the MPS

Projected available balance = Beginning balance + Master production schedule - Forecast

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques

	On hand	Period 2	3	4	5	6
Forecast		20	20	20	15	20
Projected available balance	10	20	30	10	25	5
Master production schedule		30	30		30	
Lot size = 30 Safety stock = 5 units						

Lot Sizing in the MPS

3 Advanced Sales and Operations Planning

- Master Production Scheduling Techniques
  - The revision shown in the previous figure solves the problem of projected negative available inventory but puts in clear focus the question of feasibility.
  - Does the company have the capacity to immediately produce a batch that was originally scheduled for period 3?
  - Can the company produce batches in two consecutive periods in the future?
  - Is material available to meet the requirements of this schedule?

3 Advanced Sales and Operations Planning

- Order Promising and Available-to-Promise (ATP)
  - For many products, customers do not expect immediate delivery, but place orders for future delivery. The delivery date (promise date) is negotiated through a cycle of order promising, where the customer either asks when the order can be shipped or specifies a desired shipment date.
  - If the company has a backlog of orders for future shipments, the order promising task is to determine when the shipment can be made.
  - Order promising can be coordinated with production schedules by using a concept known as available- to-promise (ATP).

3 Advanced Sales and Operations Planning

	On hand	Period 1	2	3	4	5
Forecast		5	5	8	10	15
Orders		5	3	2	0	0
Projected available balance	20	15	10	32	22	7
Available-to-promise		12		28		
Master production schedule				30		
Lot size = 30 Safety stock = 5						

20+0-max(5,5)=15

20+0-(5+3)=12

0+30-2=28

Available-to-Promise Order Promising Example: Week 1—Discrete ATP Logic

Between now and the beginning of period 3, we could deliver an additional 12 units. out of that second batch we could promise another 28 units for delivery in period 3 and out into the future.

3 Advanced Sales and Operations Planning

- The logic that we have just described is usually referred to as discrete ATP logic, where the first period, and every order after it, are considered independent from a planning view.
- We could take a cumulative ATP view and carry the units that we can promise from one batch forward to the next.

3 Advanced Sales and Operations Planning

The following is a step-by-step process for calculating the MPS including ATP calculations:

1. *Calculate projected available inventory.* Projected available inventory = Previous available inventory + Master production schedule − MAX (Forecast, Actual orders). Calculate for every period in the planning horizon.

2A. *ATP calculations (discrete logic).* For the first period, ATP = On hand + MPS − Sum of the orders until the next MPS. For each period when a subsequent MPS occurs, ATP = MPS − Sum of the orders until the next MPS.

2B. *ATP calculations (cumulative logic).* For the first period, ATP = On hand + MPS − Sum of the orders until the next MPS. For each period when a subsequent MPS occurs, ATP = Previous ATP + MPS − Sum of the order until the next MPS.

3 Advanced Sales and Operations Planning

7+30-max(8,17)=20

15+0-max(5,8)=7

		Period				
		2	3	4	5	6
Forecast		5	8	10	15	20
Orders		3 + 5 (new)	2 + 15	0	10	35
Projected available balance	15	7	20	10	25	20
Available-to-promise		7	13		20	−5
Master production schedule			30		30	30
Lot size = 30 Safety stock = 5						

15+0-8=7

0+30-(17+0)=13

0+30-10=20

0+30-35=5

ATP Order Promising Example: Week 2 after Update—Discrete ATP Logic

3 Advanced Sales and Operations Planning

		Period				
		2	3	4	5	6
Forecast		5	8	10	15	20
Orders		3 + 5 (new)	2 + 15	0	10	35
Projected available balance	15	7	20	10	25	20
Available-to-promise (cumulative)		7	20		40	35
Master production schedule			30		30	30
Lot size = 30 Safety stock = 5		7	13		20	−5

ATP Order Promising Example: Week 2 after Update—Cumulative ATP Logic

3 Advanced Sales and Operations Planning

- Cumulative approach looks attractive with this example, in practice it might overstate the real availability in the future due to the timing of how orders are booked.
- Within software packages, there are often options for how these calculations are performed and for the format of the schedules.

3 Advanced Sales and Operations Planning

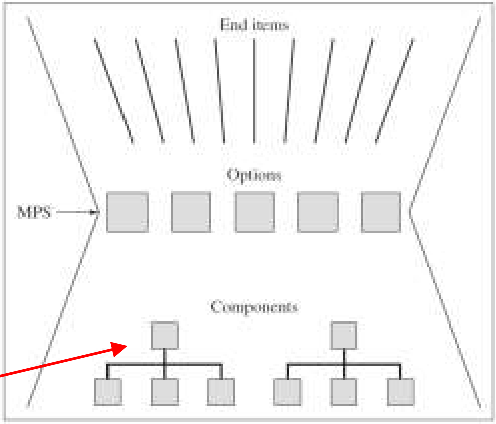
- The use of both the projected available balance and the available-to-promise row is the key to effective master production scheduling.
- Using ATP to book orders means that it is unlikely that a customer promise will be made that cannot be kept. Note, this may mean some orders must be booked at the end of a planning horizon concurrent with creating an additional MPS order. As actual orders are booked (and reflected in the order row), or anticipated (in the forecast row), or shipped (as reflected in the projected available balance), the available-to-promise row provides a signal for the creation of new MPS orders.

3 Advanced Sales and Operations Planning

- Planning in an Assemble-to-Order Environment
  - The assemble-to-order firm is typified by an almost limitless number of end-item possibilities due to the myriad combinations of basic components and subassemblies.
  - The bill of materials specifies the ingredients required to make each part number or assembly in our system. It is a listing of all the subassemblies, intermediates, parts, and raw materials that go into a parent assembly, showing the quantity of each required to make an assembly.

3 Advanced Sales and Operations Planning

Bill of Material (BOM)



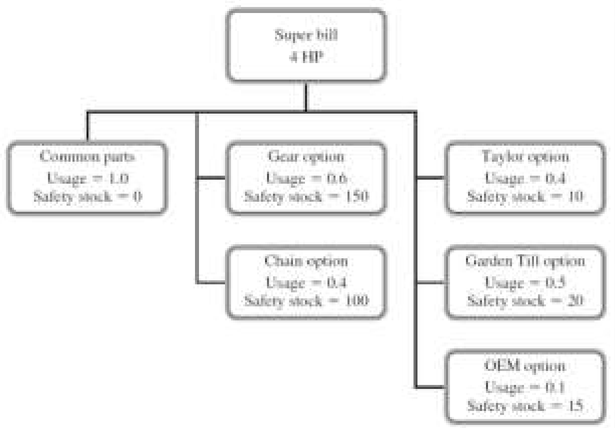
The MPS Hourglass

3 Advanced Sales and Operations Planning

- Another approach—one that would make customer response much quicker—would be to synchronize two parallel production systems.
- The first system is designed to efficiently produce the components and options that are needed in the final product.
- The second system is a final assembly process that is designed to put together a product from the options selected by each customer. For this approach to be successful, these two systems must be tightly integrated so that the desired options are available when the customer orders the product.
- The two-level MPS is designed to support this type of integration.

3 Advanced Sales and Operations Planning

- The super bill describes the related options or modules that make up the average end item.



- Use of safety stocks for the options to absorb variations in the mix.
- No safety stock is shown for the common parts. This means protection is provided for product mix variances but not for variances in the overall MPS quantity of 4-horsepower tillers.

3 Advanced Sales and Operations Planning

- Managing Using a Two-Level MPS
  - When a planning bill is used, the final assembly schedule (FAS) is often used to state the exact set of end products to be built over some time period.
  - It is the schedule that serves to plan and control final assembly and test operations, including the launching of final assembly orders, picking of component parts, subassembly, painting, or other finishing.

3 Advanced Sales and Operations Planning

- Many firms have found it useful to coordinate the final assembly schedule and component production by using a concept known as two-level master production schedules.
- This technique is most useful for an assemble-to-order firm, where it is critical that before an order is promised, key components are guaranteed to be available.
- The technique allows the use of available-to-promise logic at both the component level and at the final assembly level in the bill of materials.

4-Horsepower Tillers

		Period				
	On hand	1	2	3	4	5
Production plan		100	100	100	100	100
Orders		100	72	54	0	0
Projected available balance	0	0	0	0	0	0
Available-to-promise		0	28	46	100	100
Master production schedule		100	100	100	100	100
Safety stock = 0						

- Final assembly schedule (FAS) is often used to state the exact set of end products to be built over some time period

Taylor Brand 4-Horsepower Tillers—40% of Demand

Forecast for model		40	40	40	40	40
Orders		42	37	23	0	0
Projected available balance	10	48	88	48	88	48
Available-to-promise		48	20		80	
Master production schedule		80	80		80	
Safety stock = 10						

- Assume that we plan to sell 100 units per week and that these will be assembled to order.
- We expect 40 percent of the demand to be the Taylor brand.

4-Horsepower Tillers		Period				
	On hand	1	2	3	4	5
Production plan		100	100	100	100	100
Orders		100	72	54	0	0
Projected available balance	0	0	0	0	0	0
Available-to-promise		0	28	46	100	100
Master production schedule		100	100	100	100	100
Safety stock = 0						

- Assume that we plan to sell 100 units per week and that these will be assembled to order.
- We expect 10 percent of the demand to be OEM.

OEM Brand 4-Horsepower Tillers—10% of Demand

Forecast for model		10	10	10	10	10
Orders		10	12	3		
Projected available balance	15	15	13	13	13	13
Available-to-promise		15	−2	7	10	10
Master production schedule		10	10	10	10	10
Safety stock = 15						

3 Advanced Sales and Operations Planning

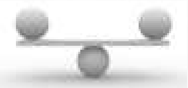
- The middle portion of the table is the master schedule for our Taylor Brand tiller.
- We expect demand to be 40 percent of 4-horsepower tiller demand. Our plan is to make to demand, but just to be safe we want to carry 10 of these in inventory as safety stock. We have firm orders for 42 of these in period 1, 37 in period 2, and 23 in period 3.

3 Advanced Sales and Operations Planning

- We would like to assemble these in lot sizes of 80 at a time.
- In calculating projected available inventory, we use our rule that demand is the greater of actual orders and forecast demand, so the projected available balance for period 1 is 10 (on-hand balance)+ 80 (MPS) -42 (actual demand, which is greater than the forecast)=48 units.
- Period 2 projected available balance is 48+ 80 (MPS) -40 (the forecast)- 88 units. Note here that we had to schedule another 80 units in period 2 to keep our projected inventory level above the 10-unit safety stock level.

3 Advanced Sales and Operations Planning

- Master Production Schedule Stability
  - A stable master production schedule translates into stable component schedules, which mean improved performance in plant operations.
  - Too many changes in the MPS are costly in terms of reduced productivity.
  - However, too few changes can lead to poor customer service levels and increased inventory. The objective is to strike a balance where stability is monitored and managed.

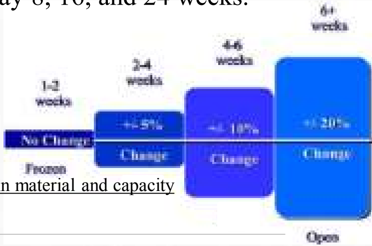


3 Advanced Sales and Operations Planning

- Master Production Schedule Stability
  - Frozen means no changes inside of eight weeks are possible. In reality, "no" may be a bit extreme.
  - If the president dictates a change, it will probably happen, but such occurrences should be rare.
  - Many firms do not like to use the term frozen, saying that anything is negotiable—but negotiations get tougher as we approach the present time. However, a frozen period provides a stable target for manufacturing to hit. It also removes most alibis for missing the schedule!

3 Advanced Sales and Operations Planning

- Master Production Schedule Stability
  - Time fencing is an extension of the freeze concept. Many firms set time fences that specify periods in which various types of change can be handled.
  - A common practice, for example, is to have three time fences, say 8, 16, and 24 weeks.



No change in material and capacity

3 Advanced Sales and Operations Planning

- Master Production Schedule Stability
  - The marketing/ logistics people could make any changes that they wanted beyond the 24-week fence as long as the sum of all MPS records is synchronized with the production plan. From weeks 16 to 24, substitutions of one end item for another would be permitted, provided required parts would be available and the production plan was not violated.
  - From weeks 8 to 16, the MPS is quite rigid; but minor changes within the model series can be made if component parts are available.

3 Advanced Sales and Operations Planning

- Master Production Schedule Stability
  - The period before 8 weeks is basically a freeze period, but occasional changes are made even within this period. To achieve the productivity necessary to remain competitive, stability in short-range manufacturing plans is essential.

3 Advanced Sales and Operations Planning

- Master Production Schedule Stability
  - Two common fences are the demand fence and the planning fence.
  - The demand fence is the shorter of the two. Inside the demand fence, the forecast is ignored in calculating the projected available balance.

3 Advanced Sales and Operations Planning

- Master Production Schedule Stability

  - The theory is that customer orders—not the forecast—matter in the near term. The planning fence indicates the time at which the master production scheduler should be planning more MPS quantities. Within the demand fence it is very difficult to change the MPS. Between the demand fence and the planning fence, management trade-offs must be made to make changes; outside the planning fence, changes can be made by the master production scheduler. Some firms refer to these as the ice, slush, and water zones.

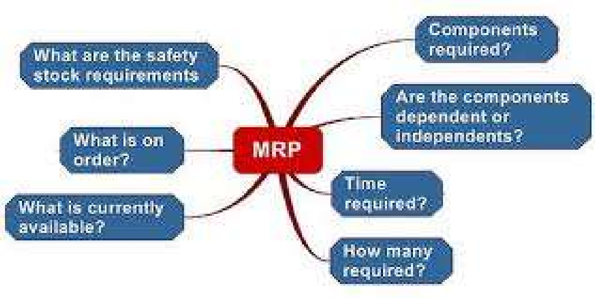
Advanced MRP

CHAPTER OUTLINE

- Determining Manufacturing Order Quantities
- Buffering Concepts
- Nervousness

3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities
  - The MRP system converts the master production schedule into a time-phased schedule for all intermediate assemblies and component parts.
  - Detailed schedules consist of two parts:
    - scheduled receipts (open orders) and
    - planned orders.



3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities
  - Each scheduled receipt's **quantity** and **timing** (due date) have been determined prior to release to the shop.
  - We determine quantities and timings for planned orders via MRP logic using the inventory position, the gross requirements data, and specific procedures for making the decisions.

3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities
  - A number of quantity-determination (lot-sizing) procedures have been developed for determining order quantities in MRP systems, ranging from ordering as required (lot-for-lot), to simple decision rules, and finally to extensive optimizing procedures.
  - This section describes four such lot-sizing procedures using a common problem.

3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities

  - The primary consideration in the development of lot-sizing procedures for MRP is the nature of the net requirements data. The demand dependency relationship from the product structures and the time-phased gross requirements mean the net requirements for an item might appear as illustrated in the following Figure.

Example Problem: Weekly Net Requirements Schedule

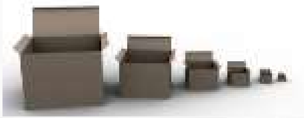
Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10

Ordering cost = C_P = $300 per order
Inventory carrying cost = C_H = $2 per unit per week
Average requirements = $\bar{D}$ = 92.1

3 Advanced Sales and Operations Planning

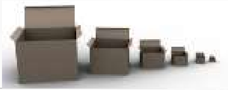
- Determining Manufacturing Order Quantities

  - First, it's important to note that the requirements do not reflect the key independent demand assumption of a constant uniform demand. Second, the requirements are discrete, since they're stated on a period by-period basis (time-phased), rather than as a rate (e.g., an average of so much per month or year). Finally, the requirements can be lumpy; that is, they can vary substantially from period to period and even have periods with no requirements.



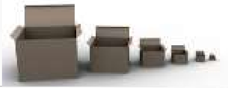
3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities
  - MRP lot-sizing procedures are designed specifically for the discrete demand case. One problem in selecting a procedure is that reductions in inventory-related costs can generally be achieved only by using increasingly complex procedures. Such procedures require more computations in making lot-sizing determinations.



3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities
  - A second problem concerns local optimization. The lot-sizing procedure used for one part in an MRP system has a direct impact on the gross requirements data passed to its component parts. The use of procedures other than lot-for-lot tends to increase gross requirements data lumpiness further down in the product structure.

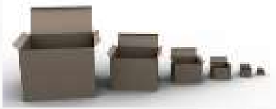


3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities

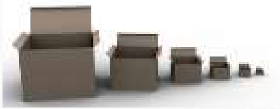
  - The manufacturing lot-size problem is basically one of converting requirements into a series of replenishment orders.

  - If we consider this problem on a local level—that is, only in terms of the one part and not its components—the problem involves determining how to group time-phased requirements data into a schedule of replenishment orders that minimizes the combined costs of placing manufacturing orders and carrying inventory.



3 Advanced Sales and Operations Planning

- Determining Manufacturing Order Quantities
  - Because MRP systems normally replan on a daily or weekly basis, timing affects the assumptions commonly made in using MRP lot-sizing procedures.



3 Advanced Sales and Operations Planning

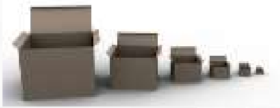
- Determining Manufacturing Order Quantities

❑ These assumptions are as follows.

- First, since we aggregate component requirements by time period for planning purposes, we assume all requirements for each period must be available at the beginning of the period.
- Second, we assume all requirements for future periods must be met and can't be back ordered.

3 Advanced Sales and Operations Planning

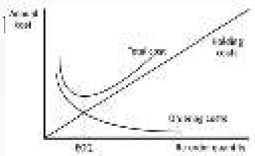
- Determining Manufacturing Order Quantities
  - Third, since the system is operated on a periodic basis, we assume ordering decisions occur at regular time intervals (e.g., daily or weekly).
  - Finally, we assume component requirements are satisfied at a uniform rate during each period. Therefore, we use average inventory level in computing inventory carrying costs.



3 Advanced Sales and Operations Planning

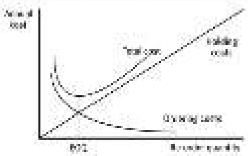
- Economic Order Quantities (EOQ)

  - Because of its simplicity, people often use the economic order quantity (EOQ) formula as a decision rule for placing orders in a requirements planning system. As the following example shows, however, the EOQ model frequently must be modified in requirements planning system applications. Because we base the EOQ on the assumption of constant uniform demand, the resulting total cost expression won’t necessarily requirements planning applications.



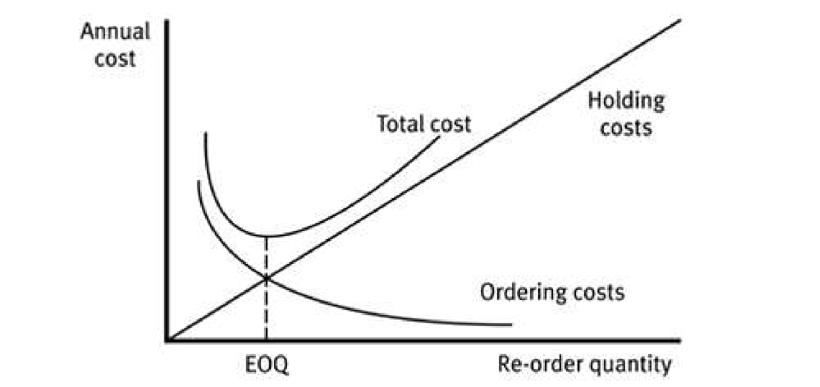
3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)
  - The following figure shows the results of ordering material in economic lot sizes for the example data. In this example the EOQ formula used average weekly demand of 92.1 units for the entire requirements schedule to compute the economic lot size. Note, too, order quantities are shown when received, and average inventory for each period was used in computing the inventory carrying cost.



3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)



3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)

Economic Order Quantity Example

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10
Order quantity	166					166	223	270	230	166		
Beginning inventory	166	156	146	131	111	207	250	270	230	166	126	126
Ending inventory	156	146	131	111	41	27	0	0	0	126	126	116

Ordering cost	$1,800
Inventory carrying cost	3,065
Total cost	$4,865

(Economic lot size $= \sqrt{2C_P\bar{D}/C_H} = \sqrt{2(300)(92.1)/2} = 166$)

3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)

  - This example illustrates several problems with using economic lot sizes. When the requirements aren't equal from period to period, as is often the case in MRP, fixed EOQ lot sizes result in a mismatch between order quantities and requirements values. This can mean excess inventory must be carried forward from week to week. As an example, 41 units are carried over into week 6 when a new order is received.

3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)
  - In addition, we must increase the order quantity in those periods where the requirements exceed the economic lot size plus the amount of inventory carried over into the period. An example occurs in week 7. This modification is clearly preferable to the alternative of placing orders earlier to meet demand in such periods, since this would only increase inventory carrying costs. Likewise, the alternative of placing multiple orders in a given period would needlessly increase the ordering cost.

3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)
  - Finally, use of the average weekly requirements figure in computing economic lot size ignores much of the other information in the requirements schedule. This information concerns magnitude of demand. For instance, there appear to be two levels of component demand in this example. The first covers weeks 1 to 4 and 10 to 12; the second covers weeks 5 to 9. We could compute an economic lot size for each of these time intervals and place orders accordingly. This proposal, however, would be difficult to implement because determining different demand levels requires a very complex decision rule.

3 Advanced Sales and Operations Planning

- Economic Order Quantities (EOQ)

Economic Order Quantity Example

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10
Order quantity	166					166	223	270	230	166		
Beginning inventory	166	156	146	131	111	207	250	270	230	166	126	126
Ending inventory	156	146	131	111	41	27	0	0	0	126	126	116

Ordering cost	$1,800
Inventory carrying cost	3,065
Total cost	$4,865

(Economic lot size = ?

3 Advanced Sales and Operations Planning

- Periodic Order Quantities (POQ)

One way to reduce the high inventory carrying cost associated with fixed lot sizes is to use the EOQ formula to compute an economic time between orders (TBO). We do this by dividing the EOQ by the mean demand rate. In the preceding example, the economic time interval is approximately two weeks (166/92.1=1.8).

- The procedure then calls for ordering exactly the requirements for a two-week interval. This is termed the periodic order quantity (POQ).

3 Advanced Sales and Operations Planning

- Periodic Order Quantities (POQ)

Periodic Order Quantity Example

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10
Order quantity	20		35		250		520		270			10
Beginning inventory	20	10	35	20	250	180	520	270	270	40	0	10
Ending inventory	10	0	20	0	180	0	270	0	40	0	0	0

	POQ	EOQ
Ordering cost	$1,800	$1,800
Inventory carrying cost	2,145	3,065
Total cost	$3,945	$4,865

3 Advanced Sales and Operations Planning

- Periodic Order Quantities (POQ)
  - Applying this procedure to the data in our example produces the following figure.
  - The result is the same number of orders as the EOQ produces, but with lot sizes ranging from 20 to 520 units.
  - Consequently, inventory carrying cost has been reduced by 30 percent, thereby improving the total cost of the 12-week requirements schedule by 19 percent in comparison with the preceding EOQ result.

3 Advanced Sales and Operations Planning

- Periodic Order Quantities (POQ)
  - Although the POQ procedure improves inventory cost performance by allowing lot sizes to vary, like the EOQ procedure it too ignores much of the information in the requirements schedule.
  - Replenishment orders are constrained to occur at fixed time intervals, thereby ruling out the possibility of combining orders during periods of light product demand (e.g., during weeks 1 through 4 in the example). If, for example, orders placed in weeks 1 and 3 were combined and a single order were placed in week 1 for 55 units, combined costs can be further reduced by $160, or 4 percent.

3 Advanced Sales and Operations Planning

- Periodic Order Quantities (POQ)

Periodic Order Quantity Example

55

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10
Order quantity	20		35		250		520		270			10
Beginning inventory	20	10	35	20	250	180	520	270	270	40	0	10
Ending inventory	10	0	20	0	180	0	270	0	40	0	0	0

Ordering cost	$1,800
Inventory carrying cost	2,145
Total cost	$3,945

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)
  - The part period balancing (PPB) procedure uses all the information provided by the requirements schedule. In determining an order's lot size, this procedure tries to equate the total costs of placing orders and carrying inventory. We illustrate this point by considering the alternative lot-size choices available at the beginning of week 1.

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)
  - These include placing an order covering the requirements for:
    1. Week 1 only.
    2. 2. Weeks 1 and 2.
    3. 3. Weeks 1, 2, and 3.
    4. 4. Weeks 1, 2, 3, and 4.
    5. 5. Weeks 1, 2, 3, 4, and 5, and so on.

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)
  - Inventory carrying costs for these five alternatives are shown below.
  - We base these calculations on average inventory per period, hence the 1/2 (average for one week), 3/2 (one week plus the average for the second week), and so on.

Periodic Order Quantity Example

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10

1. $(\$2) \cdot [(1/2) \cdot 10] = \$10.$
2. $(\$2) \cdot [(1/2) \cdot 10] + [(3/2) \cdot 10] = \$40.$
3. $(\$2) \cdot [(1/2) \cdot 10] + [(3/2) \cdot 10] + [(5/2) \cdot 15] = \$115.$
4. $(\$2) \cdot [(1/2) \cdot 10] + [(3/2) \cdot 10] + [(5/2) \cdot 15] + [(7/2) \cdot 20] = \$255.$
5. $(\$2) \cdot [(1/2) \cdot 10] + [(3/2) \cdot 10] + [(5/2) \cdot 15] + [(7/2) \cdot 20] + [(9/2) \cdot 70] = \$885.$

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)

  - In this case, the inventory carrying cost for alternative 4 (ordering 55 units to cover demand for the first four weeks) most nearly approximates the $300 ordering cost; that is, alternative 4 “balances” the cost of carrying inventory with the ordering cost. Therefore, we should place an order at the beginning of the first week and the next ordering decision need not be made until the beginning of week 5.

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)

Part Period Balancing Example

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10
Order quantity	55				70	180	250	270	270			10
Beginning inventory	55	45	35	20	70	180	250	270	270	40	0	10
Ending inventory	45	35	20	0	0	0	0	0	40	0	0	0

Ordering cost	$2,100
Inventory carrying cost	1,385
Total cost	$3,485

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)
  - When we apply this procedure to all the example data, we get the result in the previous figure. As seen, total inventory cost falls almost $500—it's 13 percent lower than the cost obtained with the periodic order quantity procedure.
  - The PPB procedure permits both lot size and time between orders to vary. Thus, for example, in periods of low requirements, it yields smaller lot sizes and longer time intervals between orders than occur in high demand periods. This results in lower inventory-related costs.

3 Advanced Sales and Operations Planning

- Part Period Balancing (PPB)
  - Despite the fact that PPB utilizes all available information, it won't always yield the minimum-cost ordering plan. Although this procedure can produce low-cost plans, it may miss the minimum cost, since it doesn't evaluate all possibilities for ordering material to satisfy demand in each week of the requirements schedule.

3 Advanced Sales and Operations Planning

- Wagner-Whitin Algorithm

  - One optimizing procedure for determining the minimum-cost ordering plan for a time phased requirements schedule is the Wagner-Whitin (WW) algorithm. Basically, this procedure evaluates all possible ways of ordering material to meet demand in each week of the requirements schedule, using dynamic programming. We won’t attempt to describe the computational aspects of the Wagner-Whitin algorithm in the space available here. Rather, we’ll note the difference in performance between this procedure and the part period balancing procedure.

Wagner – Whitin Algorithm:

Example

~ A general model for Production Planning

Terms:

Periods: 1,2,3,….N

λ_i: demand rate in period i
h : holding cost / item / period
K : setup cost
c : unit cost
$C_i(j)$: cost of producing enough items for period i thru. j at beginning of period i

Wagner – Whitin Algorithm:

Example

(B) Formula

$$C_i^{(j)} = k + c(\lambda_i + \lambda_{i+1} + \dots + \lambda_j) + h(\lambda_{i+1} + 2\lambda_{i+2} + \dots + (j - i)\lambda_j)$$

$$C_i = \min_{i \le j \le N} \left[C_i^{(j)} + C_{j+1} \right]$$

- Lowest cost from period i to N that will satisfies demand

Wagner – Whitin Algorithm:

Example

Demand

1Q	2Q	3Q	4Q
3000	2000	3000	2500

$K = \$200$

$C = \$0.1$

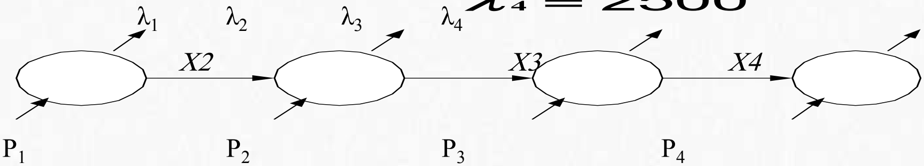
$h = \$0.02$

$\lambda_1 = 3000$

$\lambda_2 = 2000$

$\lambda_3 = 3000$

$\lambda_4 = 2500$



Wagner – Whitin Algorithm:

Example

$$C_4 = C_4^{(4)} = K + c(\lambda_4) + h(0) = 200 + (0.1)(2500) = 450$$

$$C_3 = \text{Min}\begin{cases} C_3^{(3)} + C_4 = [K + c(\lambda_3) + h(0)] + \$450 \\ \quad = 200 + (0.1)(3000) + 0 + \$450 \\ \quad = \$950 \\ C_3^{(4)} = K + C(\lambda_3 + \lambda_4) + h(\lambda_4) \\ \quad = 200 + (0.1)(3000 + 2500) \\ \quad + (0.02)(2500) \\ \quad = 200 + 550 + 50 \\ \quad = \$800 * \end{cases}$$

Wagner – Whitin Algorithm:

Example

$$C_2 = \text{Min}\begin{cases} C_2^{(2)} + C_3 = [\,K + c(\lambda_2) + h(0)] + C_3 \\ \quad = 200 + (0.1)(2000) + 0 + \$800 \\ \quad = \$1200 \\ C_2^{(3)} + C_4 = [\,K + C(\lambda_2 + \lambda_3) + h(\lambda_3)\,] + C_4 \\ \quad = 200 + (0.1)(2000 + 3000) \\ \quad\quad + (0.02)(3000) + \$450 \\ \quad = [200 + 500 + 60] + \$450 \\ \quad = \$1210 \\ C_2^{(4)} = [K + C(\lambda_2 + \lambda_3 + \lambda_4) + h(\lambda_3 + 2\lambda_4)] \\ \quad = 200 + (0.1)(2000 + 3000 + 2500) \\ \quad\quad + (0.02)(3000 + 2 \cdot (2500)) \\ \quad = 200 + 750 + 160 = \$1110 \;* \end{cases}$$

$$C_1 = Min \begin{cases} C_1^{(1)} + C_2 = [K + c(\lambda_1) + h(0)] + \$1110 \\ \quad = 200 + 300 + 1110 = \$1610 \\ C_1^{(2)} + C_3 = [K + C(\lambda_1 + \lambda_2) + h(\lambda_2)] \\ \quad + \$800 \\ \quad = 200 + 500 + 40 + 800 \\ \quad = \$1,540 \ * \\ C_1^{(3)} + C_4 = [K + C(\lambda_1 + \lambda_2 + \lambda_3) + h(\lambda_2 + 2\lambda_3)] \\ \quad + C_4 \\ \quad = 200 + 800 + (0.02)(2000 + 6000) \\ \quad + \$450 \\ \quad = \$1610 \\ C_1^{(4)} = [K + C(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4) \\ \quad + h(\lambda_2 + 2\lambda_3 + 3\lambda_4)] \\ \quad = 200 + 1050 + (0.02)(2000 + 6000 \\ \quad + 7500) \\ \quad = \$1,560 \end{cases}$$

Wagner – Whitin Algorithm:

Example

[Answer]

$$C_1 = C_1^{(2)} + C_3 = \$1,540$$

↑

To produce enough items from 1st period to 2nd period, then $C_3 = C_3^{(4)}$

↓

To produce enough items from 3rd period to 4th period.

In other words , production plan is:
" to produce 5000 items at the beginning of the first period, then to produce 5500 items at the beginning of the 3rd period ".

$$P_i = [P_1 , P_2 , P_3 , P_4] = [5000, 0 , 5500 , 0]$$

3 Advanced Sales and Operations Planning

- Wagner-Whitin Algorithm
  - The following figure shows the results of applying the Wagner-Whitin algorithm to the example.
  - Total inventory cost is reduced by $240, or 7 percent, compared with the ordering plan produced by the part period balancing procedure in following figure

Part Period Balancing Example

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	10	10	15	20	70	180	250	270	230	40	0	10
Order quantity	55				70	180	250	270	270			10
Beginning inventory	55	45	35	20	70	180	250	270	270	40	0	10
Ending inventory	45	35	20	0	0	0	0	0	40	0	0	0

Ordering cost	$2,100
Inventory carrying cost	1,385
Total cost	$3,485

3 Advanced Sales and Operations Planning

- Wagner-Whitin Algorithm
  - The difference between these two plans occurs in the lot size ordered in week 9. The part period balancing procedure didn't consider the combined cost of placing orders in both weeks 9 and 12. By spending an additional $60 to carry 10 units of inventory forward from week 9 to 12, we avoid the $300 ordering cost in week 12. In this case, we can save $240 in total cost. The increased number of ordering alternatives considered, however, clearly increases the computations needed in making ordering decisions.

3 Advanced Sales and Operations Planning

- Simulation Experiments

  - The example problem we've used to illustrate these procedures is for only one product item, without regard for its components, with no rolling through time, and with only a fixed number of weeks of requirements. To better understand lot-sizing procedures' performance, we should compare them in circumstances more closely related to company dynamics. Many simulation experiments do exactly that.

3 Advanced Sales and Operations Planning

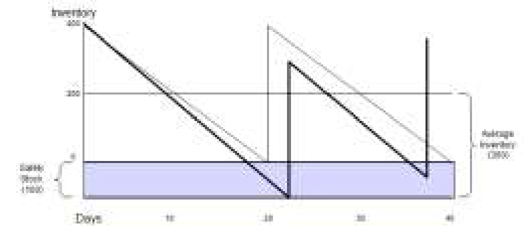
- Simulation Experiments

Summary Experimental Results

	Procedure			
	Wagner-Whitin	PPB	POQ	EOQ
Experiment 1: Percent over Wagner-Whitin cost; single level, no uncertainty	0	5.74	10.72	33.87
Experiment 2: Percent over Wagner-Whitin cost; single level, uncertainty	0	0.67	2.58	0.19
Experiment 3: Percent over nearly optimal procedure; multilevel, no uncertainty	0.77	6.92	16.91	—
Computing time	0.30	0.10	0.08	—

3 Advanced Sales and Operations Planning

- Buffering Concepts
  - In this section we deal with another advanced concept in MRP, the use of buffering mechanisms to protect against uncertainties. We, however, make the same proviso as for lot sizing:
  - Buffering is not the way to make up for a poorly operating MRP system. First things must come first.



3 Advanced Sales and Operations Planning

- Categories of Uncertainty
  - Two basic sources of uncertainty affect an MRP system: demand and supply uncertainty. These are further separated into two types:
    - quantity uncertainty and timing uncertainty.

Categories of Uncertainty in MRP Systems

	Sources	
Types	Demand	Supply
Timing	Requirements shift from one period to another	Orders not received when due
Quantity	Requirements for more or less than planned	Orders received for more or less than planned

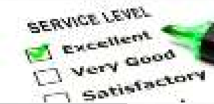
3 Advanced Sales and Operations Planning

Examples of the Four Categories of Uncertainty

	Periods									
	1	2	3	4	5	6	7	8	9	10
Demand timing:										
Projected requirements	0	0	0	0	0	0	372	130	0	255
Actual requirements	0	0	0	372	130	0	0	255	143	0
Supply timing:										
Planned receipts	0	0	502	0	0	403	0	0	144	0
Actual receipts	502	0	0	0	0	403	0	0	144	0
Demand quantity:										
Projected requirements	85	122	42	190	83	48	41	46	108	207
Actual requirements	103	77	0	101	124	15	0	100	80	226
Supply quantity:										
Planned receipts	0	161	0	271	51	0	81	109	0	327
Actual receipts	0	158	0	277	50	0	77	113	0	321

3 Advanced Sales and Operations Planning

- Safety Stock and Safety Lead Time
  - There are two basic ways to buffer uncertainty in an MRP system.
    - One is to specify a quantity of safety stock in much the same manner as with statistical inventory control techniques.
    - The second method, safety lead time, plans order releases earlier than indicated by the requirements plan and schedules their receipt earlier than the required due date.
  - Both approaches produce an increase in inventory levels to provide a buffer against uncertainty, but the techniques operate quite differently, as the following figure shows.



Safety Stock and Safety Lead Time Buffering

Order quantity = 50 units

Lead time = 2 periods

No Buffering Used		Period 1	2	3	4	5
Gross requirements		20	40	20	0	30
Scheduled receipts			50			
Projected available balance	40	20	30	10	10	30
Planned order released				50		

Safety Stock = 20 Units		1	2	3	4	5
Gross requirements		20	40	20	0	30
Scheduled receipts			50			
Projected available balance	40	20	30	60	60	30
Planned order releases		50				

Safety Lead Time = 1 Period		1	2	3	4	5
Gross requirements		20	40	20	0	30
Scheduled receipts			50			
Projected available balance	40	20	30	10	60	30
Planned order releases			50			

THIS IS THE LAST SLIDE

Thank you.