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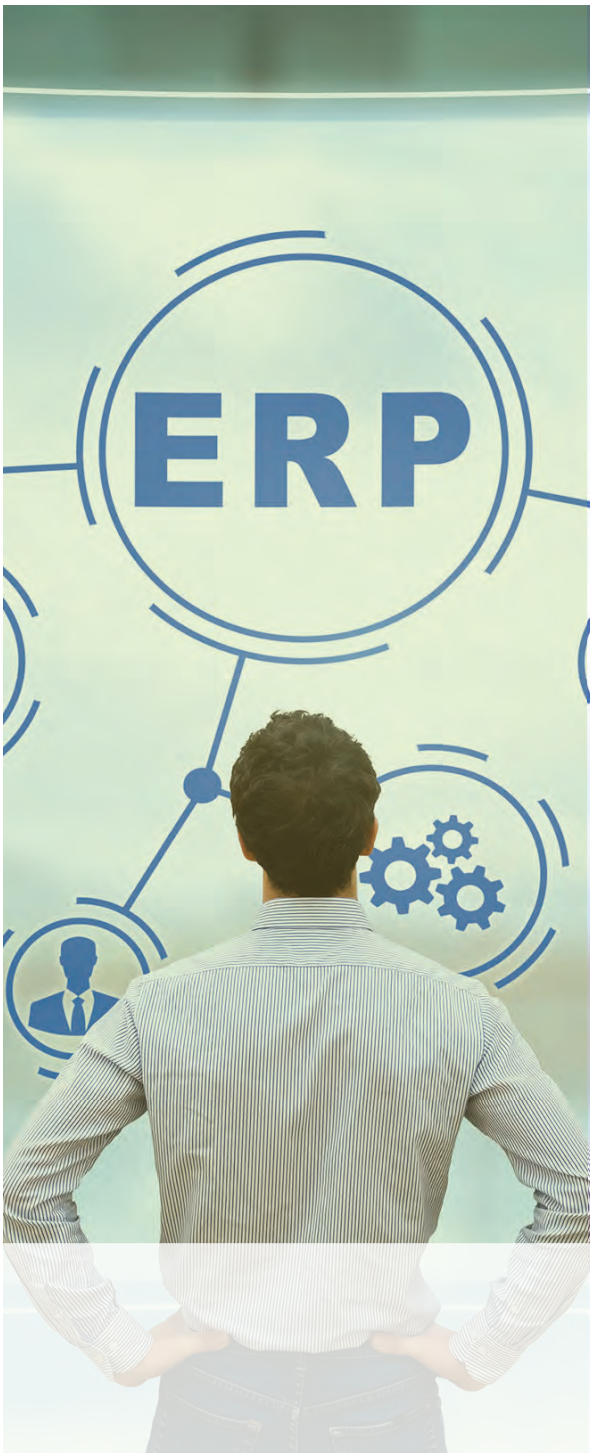
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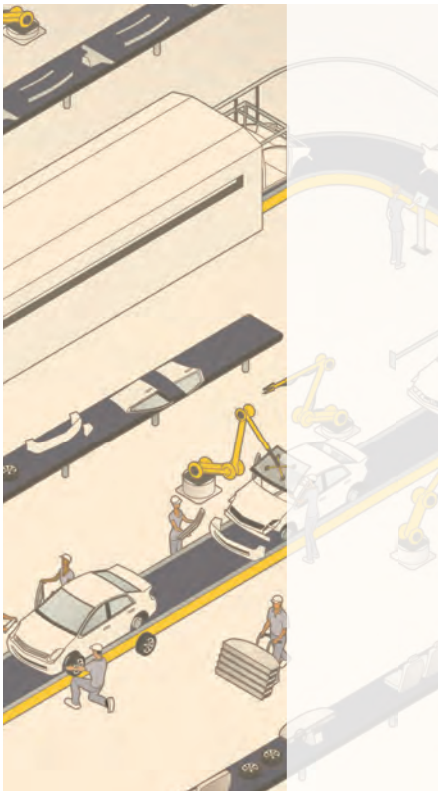


COST
INPUT-OUTPUT
OPERATIONS MANAGEMENT
REQUIREMENTS
PLANNING


LEAN

ANADOLU UNIVERSITY

Operations Management

Editor

Prof.Dr. Celal Hakan KAĞNICIOĞLU

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OPERATIONS MANAGEMENT

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Preface

Dear Reader,

The growth in population and economy and climate changes in the world make the natural resources scarce. Demand for these resources is intensifying as new consumers emerge. Global and local companies in the world try to use these scarce resources for their operations. Since these resources are limited, it is getting more and more difficult for these companies to supply them. Moreover, high competition in global markets force the companies to manage their operations effectively and efficiently. Scarce resources are not just the natural resources for the companies but also workforce, machines and devices, facilities, capital, time, etc. Therefore, companies need to manage all of these resources while having some profit as profit seeking companies.

Every organization has some functions in order to compete in the market. The existence of the organizations starts with the production. The output of this production can be goods and/or services. However, production/operations function is not enough for the success of the company. Other functions of the company such as marketing, finance, accounting, human resources and research and development are also very important for the survival of the company. So, there are many functions of the company and the communication and interaction of these functions are essential for the competition of the company in the market. Production/Operation is the heart of this communication with its performance and the performance of it depends on well management of this function.

Operations management is the administration of business operations to generate the highest level of efficiency possible in the company. Production/Operations management deals with converting inputs such as materials and labor into outputs such as goods and services as efficiently as possible to maximize the profit of a company. Operations management is very important for the company and concerned with designing and controlling the process of production and redesigning business operations in the production of goods and/or services. The primary focus of operations management is to have the responsibility of using as few resources as needed and effective in terms of meeting customer needs and requirements while ensuring efficient business operations. The scope of operations management is primarily involves planning, organizing and supervising in the contexts of production, manufacturing or the provision of services.

The objective of the overall content of this book is to provide general information about operations management concepts and techniques. Moreover, new methods and techniques are also presented by the emergence of new technologies. Therefore, current and new operations management trends and applications are tried to be introduced in this book in order to help the individuals who wants to work in this area and companies that wants to gain competitive advantage in the market while achieving its overall aims.

This book is consisted of eight chapters. The first chapter is an introductory chapter which gives general concepts of operations management with the history of it. Classification of production processes structures and contemporary operations themes are described in this chapter. In the second chapter, company strategy, operations strategy, the relations and construction of them are explained along with productivity. Third chapter covers the design of the product and selection of the production process for the success of the company. Fourth chapter is about types of facility layouts by their pros and cons for the company and describes capacity planning. Inventory management and production and resource planning are the fifth and sixth chapters which show the effective and efficient ways of using scarce resources. Seventh chapter explains the emerge of lean systems with its philosophy and principles. Besides, tools and techniques used in lean systems are introduced. The last (eight) chapter includes basic concepts and philosophy of supply chain management and logistics and provides general information about the structure and sustainability of supply chain management.

I do really want to thank everybody who has contribution for the publishment of this book, especially writers of the chapters. I hope this book will be very satisfactory and comprehensive for the readers who are willing to learn and understand the basic and current issues in operations management as well as new tools and techniques.

Editor

Prof.Dr. Celal Hakan KAĞNICIOĞLU

Chapter 1 Introduction to Operations Management

After completing this chapter, you will be able to;

Learning Outcomes

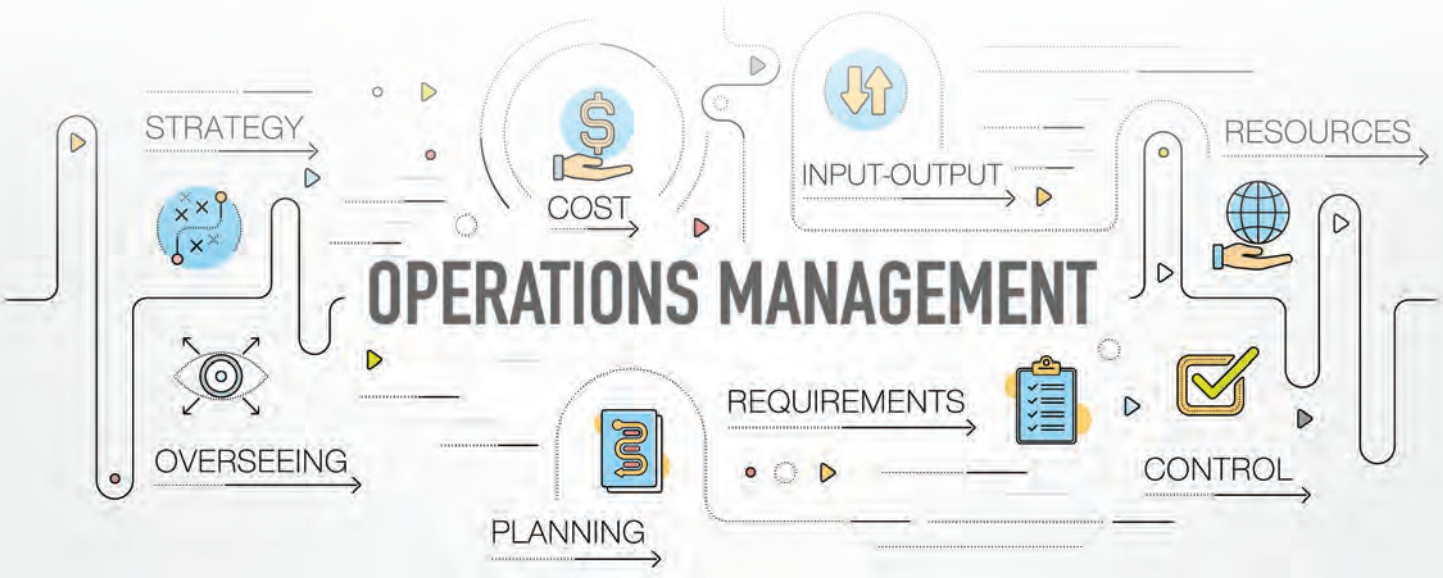
1. Define the concept of operations management and related concepts of operations management.
2. Explain the history of operations management.
3. Explain the current issues in operations management.
4. Analyze the scope of operations management.
5. Explain the classification of production processes structures.
6. Analyze the contemporary operations themes.

Chapter Outline

Introduction
Definition of Operations Management
History of Operations Management
Current Issues in Operations Management
Scope of Operations Management
Classification of Production Processes Structures
Contemporary Operations Themes

Key Terms

Operations
Production
Operations Management
Flow processes
Job-shop Processes
Cellular Processes
Project Processes



INTRODUCTION

In today's real life it is whether understood or not, operations around us are performed in different ways continuously. When we go to a bank to draw some money or a restaurant to have lunch, many operations are done. As it is given in these examples, these operations are not just about production lines and value added manufacturing but also about services in public and private sectors. Operations management is really important to any organizations for the performance of their operations from the point of view of their customers. Customers evaluate the organizations by the capabilities of operations provided or sometimes not provided. Once the customers have some positive or especially negative opinion about the performance of the organization, it is very difficult to change that opinion.

We always come in contact with many different kinds of goods or services, all of which are produced under the supervision of operations managers. No organization can survive without effective management of operations. Operations are the starting point and engine of an organization and they create value for the organization and overall economy. Management of operations in an organization is not just related to itself since both customers and suppliers are located throughout this process. While suppliers in the supply chain are the sources for the operations in the organization, customers are the consumers of the output of these operations. A huge amount of two-sided information flow is taken place in the organization from the customers and suppliers. Therefore, it is not an easy job to handle and manage all this information for effective and efficient operations.

The first and essential goal of every organization is to maximize its profit. Operations management is a vital element for the profitability of an organization. The existence of an organization starts with the production/operations and effective management of these operations results with the success of an organization. Thus, operations/ production is one of the most important key elements of an organization.

DEFINITION OF OPERATIONS MANAGEMENT

Operations is responsible for the production of goods and services. According to the Business Dictionary website, operations are defined as "Jobs or tasks consisting of one or more elements or subtasks, performed typically in one location". Another definition from the website of My Accounting Course is "Operations are the business activities that a firm engages in to convert materials into finished products or services, sell them to customers, and earn a profit". So it can be said that operations transform resources into required goods, services, or results, and create and deliver value to the customers. Operations are not just a limited narrow-scoped function; rather it is a company-wide and inter-firm activity including many various areas and uses these in order to satisfy customers and stakeholders. It is not to be forgotten that operations take place in many areas of an organization in different forms.

Goods are tangible items (pencil, apple, chair) that satisfy the needs and requirements of human and provide utility. Goods can be consumable items useful to people, however they are scarce items in relation to the demand, therefore some effort is needed to get them. Some examples of goods can be computers, cars, engines for trucks and so on. **Service** is a kind of economic activity that is intangible and a set of activities providing some combination of time, location, form or psychological value. Transfer of goods, such as the cargo service delivering a television, and the use of expertise or experience, such as a person having millions of dollars visits a financial investment expert are some examples for the services. As it is seen in all these examples, goods and services are all around us. Although at the end of some operations, goods or services are provided, for some operations both of them are provided together. When you go to a restaurant, you order some meals and wait for them. These meals are cooked for you and then serviced to your table. So, in this example, cooking the meal is the production of goods and bringing it to your table is the production of services.

Outputs of a production system are goods and services.

Operations management is the business function that plans, organizes, coordinates and controls the resources needed to produce a company's goods and services (Reid & Sanders, 2013, p. 3). In other words, operations management designs, operates and improves production systems to get work performed. The chair we sit, the television we watch and the treatment we have are provided by the people who do these operations. Those people design the system and operations, ensure the quality of them, make the production and deliver the services to us as customers. They work together with customers, suppliers and other global partners by using the highest technology. Operations are more than planning and controlling but doing it. Production is the creation of goods and services. In a company, a value is created in the form of goods and services by the conversion of set of inputs into outputs. For the conversion of inputs into outputs, many activities are involved. And these activities are involved in operations management.

A group of interrelated activities, which are involved in the production of certain goods and services, is called **operations management**.

Operations management is a management function that involves the management of people, equipment, technology, information and many other resources used for the operations. It is the central core function of every organization whether it is a small or big organization and producing goods or services.

Operations management is concerned with many activities for the conversion of inputs such as material, energy, knowledge, etc. into outputs for the satisfaction of the customer.

The main objective of operations/production management is the production of goods and services of right quality and quantity at the right time and right manufacturing cost (Kumar & Suresh, 2009, p. 7).

1. **Right Quality:** The quality of a product is established based upon the customers' needs and requirements. The right quality does not mean the highest and the best quality. Quality is determined by the cost of the product and the technical specifications as suited to the specific requirements.
2. **Right Quantity:** The manufacturing company should have the production amount in the right quantity. If they are produced more than the demanded, the capital will block up in the form of inventory and if the quantity is produced less than the demanded, it leads to shortage of products.
3. **Right Time:** One of the most important factors is the timeliness of delivery to judge the effectiveness of the production department. Therefore, the production department must make the optimal utilization of input resources to achieve its objective.
4. **Right Manufacturing Cost:** Manufacturing costs are determined before the product is actually manufactured. Hence, all attempts should be made to produce the products at the pre-determined cost, so as to decrease the difference between actual and the standard (pre-established) cost.

In companies, it is desired to manage all the operations effectively and efficiently. **Efficiency** means doing something at the lowest possible cost. Generally, it is said that the goal of an efficient process is to produce a good or provide a service by using the smallest input of resources. **Effectiveness** means doing the right things to create the most value for the company. It is often possible that maximizing both effectiveness and efficiency simultaneously creates conflict between the two goals. In this situation, the company needs to tradeoff and choose between efficiency and effectiveness in some degree depending on the conditions.

Goods or services are the results of transformation or conversion of inputs into outputs. Many different types of inputs such as capital, labor, machine, etc. are used in transformation or conversion for the creation of outputs (goods and services). In order to be assured about the required outputs are obtained, the company measure the transformation process and the outputs at various points and compares the measurements by the established standards to

determine whether corrective action is needed. The operation system related to this input-process-output is shown in Figure 1.1.

In a truck factory, sheet steel is cut according to the desired sizes and then put into mold and pressed. It is formed into different shapes, painted and finished. At the end of this transformation, a truck door is created and assembled to the truck. In a steel factory, iron, mangan, sulphur and other elements are mixed together in high temperatures and steel is produced. In a bank, the customer draw some money or send some money to the related person or in a barbershop you have a haircut. As it is given in these examples, operations can take various forms.

The transformation process can take the following forms:

- **Physical:** in manufacturing operations such as automobile manufacturing.
- **Chemical:** in manufacturing operations such as paper manufacturing.
- **Locational:** in transportation or warehouse operations such as delivery of a refrigerator to home.
- **Exchange:** in retail operations such as buying a shirt from a retail shop.
- **Psychological:** in entertainment operations such as going to a holiday.
- **Informational:** in communication operations such as calling a friend from a cellular phone.

The inherent nature of an operations function is to add value during the transformation process. Value-added is the difference between the cost of inputs and the value or price of outputs. In another words, it can be said that value-added is the contribution of the company to the inputs such as special manufacturing or processing. For profit seeking companies, the value of outputs is measured by the prices that customers are willing to pay for those goods or services. Companies use the money taken from the value-added for many activities such as research and development, machines and equipment, salaries of the workers, new investments and profits. Therefore, when the value-added is getting greater, the budget available for many of these associated activities is getting greater (Stevenson, 2009, p. 7).

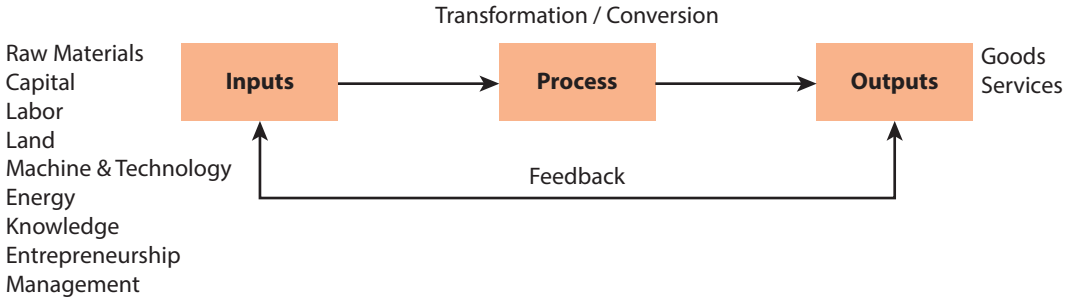


Figure 1.1 Operations System

Production of goods and services are highly interrelated in today's production system. Services such as transportation, banking, consulting and communication are very important for supporting manufacturing, and moreover, goods support all service companies. The need to treat both manufacturing and service is a critical theme in operations due to the pervasive and intertwined nature of both manufacturing and service (Schroeder, 2007, p. 13).

Some of the important key concepts of operations management are resources, systems, transformation and value addition activities.

Resources involve human, materials and capital inputs to the production process. Human resources are the critical and the most important assets of an organization. Most of these human resources are now working in planning and controlling activities due to technological improvements in business. Material resources are the facilities and materials like equipment, inventories and supplies. Capital is a vital asset involving stocks, bonds, taxes, etc.

Systems are the set of inputs in interaction designed to achieve goals according to the plan. Business is a system which contains subsystems such as operations, finance and marketing for the survival and success of the organization. The success of any system for achieving goals depends on its design and control. Arrangement of elements in a system is related to its design and the system reaches its objectives by the existence of the interactions between inputs, transactions and outputs. System control is a group of activities to make sure that planned and targeted goals are achieved by these activities.

The purpose of transforming all the inputs into goods and services is to have a higher value than the original inputs. Otherwise, it doesn't have any meaning. Operations department should focus on the transformation efficiency and effectiveness (Kumar & Suresh, 2009, p. 11).

Management of manufacturing and services are critical and different, but it is easily seen that both depend on each other in modern production systems. Especially in recent years, many manufacturing companies have offered an array of services to satisfy their customers in order to be competitive. For example, for automobile customers, the maintenance and repairment services are as important as the automobile itself. In that sense, therefore operations should not be seen in terms of manufacturing versus services but, rather, as a combination of joint efforts throughout the entire supply chain to provide customer satisfaction. Although, managing systems produce goods, services or a combination of them, there are some differences between the production of goods and the production of services.

Some of the important differences between these are as follows (Stevenson, 2009, p. 9; Martinich, 1997, p. 8):

1. Service operations' inputs variability is greater than the manufacturing operations'. Each customers' needs and requirements can be different from each other in service operations such as repairment of the autos or treatment of the patients. Manufacturing operations often have a greater ability to control the amount of variability of inputs and thus achieve low variability in outputs.
2. Customer contact is much more in service operations than in manufacturing operations. In service, production and consumption occur almost at the same time. Although the customer goes to the barbershop to have a haircut, so barber and the customer are in the same place. However, manufacturing can take place in a far place from the customer and production and consumption are far from each other.
3. While most of the services need higher labor content, some manufacturing operations do not need that much labor content. Highly automated manufacturing operations need just a few workers.
4. Productivity measurement of manufacturing can be more straightforward and easier because of a high degree of uniformity of many manufactured goods than that of services. Variation of needs and requirements of customers make the measurement of service productivity more difficult. Customers can require different types of haircuts and each type of haircut can last various time of period.
5. Manufacturing systems usually rely more heavily on raw material inputs than do service systems. While manufacturing of a refrigerator requires hundreds of raw material and parts, haircut service requires just a few materials.
6. Goods which are the outputs of manufacturing can be stored for later use and transported over space before use, but services usually cannot be stored. When more chairs are manufactured than the demand, some of them are stored in the warehouse to sell later. However, it is not possible to store the haircut or health treatment.
7. Manufacturing can be separated from the consumer both in space (stated above) and in time more easily than can the production of services. A television is manufactured in China six months ago before it is sold in Turkey. However, as it is mentioned most of the services have direct involvement with consumers in space and in time.

Table 1.1 gives the general differences between the production of goods and service operations. It is important to know that most systems are a mixture of goods and services.

Table 1.1 Some Differences between Production of Goods and Services.

Characteristics	Goods	Services
Customer contact in space	Low	High
Uniformity of input	High	Low
Labor content	Low	High
Uniformity of output	High	Low
Output	Tangible	Intangible
Measurement of productivity	Easy	Difficult
Raw material intensity	High	Low
Inventory	Much	Little
Customer contact in time	Rarely	Frequently

The activities of business organizations are usually divided into several functions depending on what and how they produce the products. The four primary functions of an organization are marketing, finance, operations and human resources. The degree of importance of these functions can vary from one organization to another. However, for most companies operations is the technical core or hub of the organization, interacting with other functional units and suppliers to produce goods and services. Operations function combines many of these organizational functions and provides an integrated view of business organizations. Although these primary functions involve different activities, most businesses are supported by these functions and the interaction of these functions are very important for the achievement of the goals of the organization. Moreover, these functions have to follow the strategic direction developed at the top level of the organization. There are huge amounts of information flow among these functional units for the success of the organization (Reid & Sanders, 2013, p. 22). Information flow between operations and other business functions is given in Figure 1.2.

Many of the decisions given in the operations function depend on information flow coming from other functions such as marketing, finance and so on. Moreover, all of the functions cannot be well managed unless information comes from operations function.

All the functions (operations, marketing, finance, etc.) of an organization must interact to each other to achieve the goals of the organization.

Marketing cannot do its job (meeting needs and requirements of the customer) properly if marketing manager do not understand what operations can produce, what due dates it can and cannot meet, and what types of customization operations can deliver. Marketing department can make some promotions in the market. However, if the operations cannot produce the desired product, the sales will not be made. On the other hand, if the operations managers do not have enough information about the customer's needs and requirements from the marketing department, the designed and produced products in the operations department are not the products meeting the needs and requirements of the customers.

People working in finance department need to have some idea and knowledge about operations concepts and needs of the operations in order to understand the need for capital investment, make or buy decisions, plant expansions, or relocation and etc. Moreover, they have taken financial constraints and methods of evaluating financial investments into consideration when they want to make large financial expenditures. It is very important to corporate and understand each other's limitations for operations and finance functions for the survival of the organization.

Information system is a function that enables information to flow throughout the organization and allows operations management to operate effectively. While jobs are done in operations unit, many information is needed such as forecasts of demand, required quality level, inventory level, supplier deliveries, and so on. Information system

network has to be designed according to the needs of the operations management function. Besides, this designed system has to be flexible in order to meet the changing and developing needs of the operations function.

In order to hire the right people to the right jobs, human resource managers must have information about the job requirements. On the other hand, operations managers need to understand job market trends, hiring and firing costs and training costs to manage the employees effectively.

One of the most important jobs of accounting function is to determine the cost data, and to be effective in determining the cost data, many information like inventory levels, capacity, output rates, etc. are required. For the operations management side, managers give decisions about the cost management and to be effective in these type of decisions they need information about the cost of inputs such as wages, raw materials, energy and so on.

Most organizations have additional supporting functions such as engineering, research and development, public relations function. For the success of the organization in today's competition, coordinated interaction and decision making among these functions are very important.

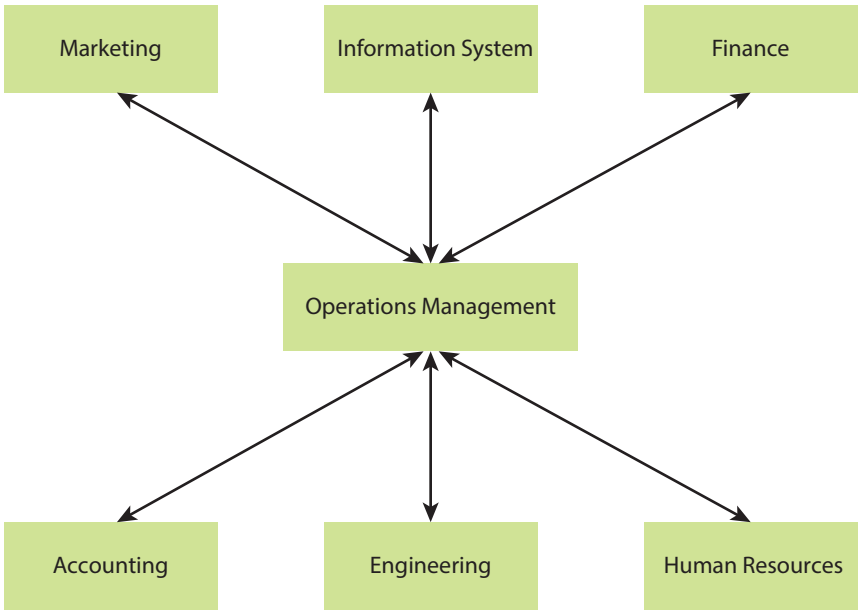


Figure 1.2 Information Flow Between Operations and Other Functions

Further Reading

Six Reasons Manufacturing is Central to the Economy

Paul Krugman recently argued that "manufacturing is one of the bright spots of a generally disappointing recovery, and there are signs — preliminary, but hopeful, nonetheless — that a sustained comeback may be underway." He points out that the gap between what we sell and what we buy has been improving. This must be set against a background of a manufacturing decline in the United States of historic dimensions; even without adjusting for inflation, the trade deficit in goods for the United States between 2000 and 2010 was 7 trillion dollars. A turnaround in the attention of more perceptive economists and a turnaround in manufacturing may be in the works. But before that, the crucial question is: Why is manufacturing so important?

1. Manufacturing has been the path to development

It has been the strategic achievement of rich nations over the last several hundred years to create a high-quality manufacturing sector in order to develop national wealth and power, as Erik Reinert shows in his book "How Rich Countries Got Rich…and Why Poor Countries Stay Poor." From the rise of England in the 19th century to the rise of the US, Germany, Japan and the USSR in the 20th, to the newly industrializing countries like Korea, Taiwan, and now China, manufacturing has been the key to prosperity.

2. Manufacturing is the foundation of global "Great Power"

The most powerful nations in the world — the "Great Powers" — are those that control the bulk of the global production of manufacturing technology. That is, it isn't enough simply to have factories and produce more goods, you have to know how to make the machinery that makes the goods. The key to power, then, is to make the "means of production."

As the machinery industries go, so goes Great Power. My own research shows that about 80% of the world's production of factory machinery has been controlled by what we would consider the "Great Powers." Until the 1950s, the US had produced about 50%; we now produce less than China's 16%.

3. Manufacturing is the most important cause of economic growth

The growth of manufacturing machinery output, and technological improvements in that machinery are the main drivers of economic growth. No machinery industries, no sustained, long-term economic growth. Just consider the explosion of the Internet, iPhones, and the like — all made possible by a small subset of production machinery called semiconductor-making equipment (SME), which itself is dependent on other forms of production machinery, such as the machine tools that grind the lenses they use or the alloys of metal the metal-making industries output. These technologies reproduce themselves, as when an SME makes the semiconductors that then go to make more SMEs, or when a machine tool makes the metal components that not only go into other pieces of machinery, such as cars but are used to produce yet more machine tools. The technological and productive potential of machine tools and SMEs affect each other as well, leading to the explosive economic growth of the last two hundred years.

4. Global trade is based on goods, not services

A country can't trade services for most of its goods. According to the WTO, 80% of world trade among regions is merchandise trade — that is, only 20% of world trade is in services. This closely matches the trade percentages that even the US, allegedly becoming "post-industrial," achieves. If in the extreme case an economy was composed only of services, then it would be very poor because it couldn't trade for goods; its currency would be worth very little. The dollar is also vulnerable in the long-term. A "post-industrial" economy is really a pre-industrial economy — that is, poor.

5. Services are dependent on manufactured goods

Services are mostly the act of using manufactured goods. You can't export the experience of using something. Retail and wholesale, which make up about 11% of the economy, are the act of buying and selling manufactured goods. The same goes for real estate, another 13%, which is the act of buying and selling a "real" or physical asset, a building. Even health, which makes up about 8% of the economy, is the act of using medical equipment and drugs (all figures from 2010, value-added).

Finance involves the redirection of surplus resources that the nonfinancial sector of the economy produces, which means that indirectly, even finance is dependent on manufacturing. The cycle of rise and decline usually runs like this: some clever society figures out how to take advantage of the current technologies of production, thus generating huge surpluses, which either the financial forces, the very wealthy, or the military then appropriate for their own wealth and power; they kill the goose that is laying the golden eggs. To sum up: the health of the economy is critically dependent on the health of the manufacturing sector.

6. Manufacturing creates jobs

Most jobs, directly or indirectly, depend on manufacturing — and reviving the sector could provide tens of millions of new jobs, eradicating the Great Recession. In 2005, the Japanese manufacturing sector was 20.2% of its economy, in Germany it was 23.2%, and in the US manufacturing accounted for 13.4%, according to the OECD. Using 2005 figures, if the US had the same percentage as Japan, we would have 7 million more high-quality, long-term, well paying jobs. If we were equal with Germany, we would have 10 million more. And according to the Economic Policy Institute, each manufacturing job supports almost three other jobs in the economy. That makes sense, considering the other five reasons that manufacturing is central to the economy.

Thus, there are six solid reasons that we need to rebuild the manufacturing sector of the United States. It's time for the United States to wake up before it's too late and rebuild the foundation of a strong, prosperous, middle class economy.

Source: Roosevelt Institute, 2011

Learning Outcomes

1 To define the concept of operations management and related concepts of operations management.

Self Review 1	Relate	Tell/Share
What are the characteristics of an operations system?	Associate operations management with human resources for the success of an organization.	Tell the relations of operations management with research and development function by giving examples.

HISTORY OF OPERATIONS MANAGEMENT

Production/Operations systems have existed since the existence of human beings. The singular production has started for the needs of human beings and then mass production has come to our era by many evolutions. The production of goods for sale and the modern production system had their roots in *the Industrial Revolution* (Stevenson, 2009, p. 22).

Modern operations management started by the Industrial Revolution. Before this, production of every piece was unique, hand fitted, and made entirely by one person, known as craft production. Industrial Revolution began in the 1770s in England and spread to the rest of Europe and to the United States during the 19th century. Some important changes in the 18th century changed the structure of production such as using machine power instead of human power. This change took place by the invention of steam engine. A large amount of coal and iron are provided materials for generating power and making machinery. The new iron machines were much stronger and more durable than the wooden ones. By the development of standard gauging systems, a major change occurred in the production and Industrial Revolution was accelerated. This system increased the size of the factories and also increased the number of standard products produced. Despite many changes and innovations in the companies, management of the production system did not progress much in those days. Around the same time, Adam Smith's "Wealth of Nations"(1776) proposed the division of labor, in which the production process was broken down into a series of small tasks, each performed by a different worker. The specialization of the workers on limited and repetitive tasks allowed them to become very proficient at those tasks and further encouraged the development of specialized machinery (Russell & Taylor, 2009, p. 6).

Industrial revolution is a movement that changed the way of production of goods from labor power to machine power.

Eli Whitney introduced the interchangeable parts in 1790s and manufacturing of many goods, such as firearms, clocks, watches, etc. could be done in huge lots by standard parts instead of manufacturing in a customized one-at-a-time. This situation brought the necessity of systematic measurement, inspection, a standard method of production and supervision to check the quality of production.

In the early 1900s Frederick W. Taylor, father of scientific management, approached the management of work as a science. Based on observation, measurement, and analysis, he identified the best method for performing each job. After it was determined, the methods were standardized for all workers, and economic incentives were established to encourage workers to follow the standards. This is called motion study. Other than this, he made contributions on personnel selection, planning and scheduling and the field of ergonomics (Heizer, Render, & Munson, 2017, p. 47).

Taylor's scientific management ideas were accepted and applied by many experts such as Frank and Lilian Gilbreth, Henry Gannt. Frank and Lilian Gilbreth developed principles of motion economy that could be applied to very small parts of a task. Besides Lilian emphasized the importance of job satisfaction, job standardization, incentive wage plans, and job simplification and recognized the effects of fatique and stress on management. Henry Gannt discovered the value of non monetary incentives for the motivation of the workers and developed a system for scheduling, famously known as Gannt charts.

In the early 1900s, Henry Ford applied some of the principles of scientific management to improve the efficiency of operations. He made the production of the Model T in 1913 and reduced the time required to assemble a car from about 730 hours to one and a half hours by the first moving assembly line. In this production line, each automobile chassis moved along a line mechanically and workers made a small amount work before it moved to the next workstation. Short production lead time for the Model T allowed it to be produced in huge lots and made the price of it affordable for the average person. Production of Model T combined the scientific management with the division of labor and interchangeable parts to develop the concept of mass production. Other important advantages of this system are product simplification, component standardization, inventory control and materials management.

important

The creation of the assembly line by Henry Ford at his Highland Park plant, introduced on December 1, 1913, revolutionized the automobile industry and the concept of manufacturing worldwide.

Although scientific management philosophy dominated in the early twentieth century, the results of Hawthorne studies changed the idea of increasing worker productivity can only be made by financial incentives. Until Hawthorne studies, social and psychological aspects of work were not considered significant. This study showed that some other factors affect the productivity of the workers based on the fields of psychology such as work environment, social group pressure and employee-management relations. Since these studies were initiated in 1927 at the Hawthorne plant of Western Electric Company, it is called Hawthorne Studies.

In the nineteenth and early twentieth century mathematical models and analysis were rarely used to solve the problems of operation and production. Some of the important studies made were Max Weber's mathematical model in the nineteenth century to evaluate location decisions, F. W. Harris's mathematical model for inventory order size in 1915, A.K. Erlang's queuing models and stochastic systems in the 1930s and W. Shewart and his friend's statistical procedures for sampling and quality control in 1930. Quantitative models and techniques were created by the group of operations researchers in World War II and they were developed and widely used in manufacturing and services. Besides, these models were used for forecasting, inventory management, project management and other operations management fields.

During the 1960s and 1970s management science techniques were widely used and computers and automation provided many developments in the application of operations management models. J. Orlicky developed Material Requirements Planning then O. Wight and G. Plossl developed MRP into manufacturing resource planning.

During the 1970s, Japanese companies came into play in the World economy, especially in the production of steel, automobiles, housewares and electronics. Japanese company introduced a management philosophy that goods are produced to meet customer demand exactly, in time, quality and quantity. This Japanese production system which is called Just-in-Time (JIT), increased the productivity of the operations and the quality of the products and made the Japanese companies very competitive in the World market. In the 1980s and 1990s Japanese companies started to apply a new phase of quality control and management known as Total Quality Management (TQM) including principles such as customer focus, involvement of all employees, continuous improvement, training of workers and etc..

In the 1980s to the 1990s, a new phase of quality control and management began by Japanese companies, known as Total Quality Management.

By the developments in hardware and software systems many computerized tools and methods have been started to use in operations such as computer aided design (CAD), computer aided manufacturing (CAM), computer integrated manufacturing, etc. Although mass production has the advantage of producing in large volumes, it cannot adapt very well to rapid changes in customers' needs and requirements. Today's market is defined by product proliferation, shortened product life cycles, shortened product development times, changes in technology, more customized products and segmented markets. It is not possible to meet the demand of a market which is defined in this way by mass production. Japanese manufacturers developed a new production method which is called lean production. Lean production gives the manufacturer flexibility and high quality in operations. Much less usage of space, inventory and workers changed the rules of production (Russell & Taylor, 2009, p. 7).

Now, by using high technology and new methods manufacturers are trying to be more competitive in this rapidly changing market. Since customer is the king of the market, everything tried to be done by the companies are for the satisfaction of the customers. However, speed and flexibility are the most two important features that need to be achieved by every manufacturer in order to survive in this market which is highly competitive.

One of the most important trends within companies today is time-based competition which is developing, producing and delivering new products to customers faster than competitors.

Learning Outcomes

2 To explain the history of operations management.

Self Review 2	Relate	Tell/Share
What are the effects of the industrial revolution to the operations system?	Associate improvements in operations management after the Japanese manufacturers in the market.	Tell the improvements in the production/operations systems by the introduction of Internet.

CURRENT ISSUES IN OPERATIONS MANAGEMENT

Operations management is a very dynamic and developing field. Many factors such as competition, customers' changing demand and improving technology cause the change and evolution of operations management in the global world. Due to the rapid changes of this environment, operations management faces many challenges in the field. Some of the important challenges are as follows (Stevenson, 2009, p. 29; Chase, Jacobs, & Aquilano, 2006, p. 19; Heizer, Render, & Munson, 2017, p. 57):

- **Coordination of the relationship between the company and the suppliers:** Many companies prefer to buy parts and services from outsourcers instead of producing them internally. This decision increases the level of outsourcing and related activities such as wrapping, packaging, moving and loading. Moreover, a lot amount of time and cost spent for these activities. The responsibility of these outsourced goods and services brings the question of safety for the companies. The outsourced goods and services must be controlled strictly whether they are required standards or not. In order to overcome this difficulty companies need fast and reliable communication by the suppliers. When the companies are successful in these activities, this leads to increase the scope of outsourcing and other major company functions such as information systems, product development and design, engineering services and distribution that are outsourced. Increase in the amount and type of outsourced goods and services is a significant challenge for the operations managers in the future. Besides shorter product life cycles, demanding customers and fast changes in the technology, materials and processes require the suppliers to be in tune with the needs of end users.
- **Globalization of supplier, production and distribution networks:** After the effects of globalization in the companies and production systems, length of the most of the supply chains increased. Many companies increase the level of outsourcing by buying goods or services instead of producing them. Therefore, global supply chain makes it difficult for the companies to manage it. Commonly used global supply chain activities in companies has challenged managers to use all the information for decision making. Besides, where to locate the control of information flow (centralized or decentralized) is another big problem for the companies. In order to use the resources of the company optimally such as inventory, workers and machines, internal and external information flow must be controlled to take the advantage of this bulk of information.
- **Increased co-production of goods and services:** Easy and almost costless usage of internet in the communication has given many opportunities for both companies and customers. Customers have the option of communicating directly with a company to monitor and control the status of the

orders given. Besides, information flow between two sides gives the company an opportunity of having more effective and efficient operations. Operations in the company become more value-added and focused by information sharing and reduces the cost of operations and increases customer satisfaction. However, these opportunities can be threats for a company if the company cannot take the advantage of these opportunities.

- **Managing customer contact:** Today companies try to become more customer focused and interact well with them. For this purpose, they provide some services such as help lines, call centers, checkout counters. However, if the personnel in these service departments are not sufficiently trained, it causes frustration and many unsatisfied customers. The most important point here is to be careful about the resource utilization decisions and be aware of the danger of losing customer while staffing personnel and exposing costs for these types of services.
- **Being aware of the power of operations in a company as a competitive weapon:** When successful organizations are examined it is seen that functional units of this organization work synchronized and coordinated. All the functional units do their jobs in integrity. However, the most successful and profitable companies rely on their effective and efficient operations and the interaction and support of it by other functional units. Although no single functional unit can do their job without any interaction, it is not to be forgotten that operations have a key role for the successful competition of the company in the market. All the managers in different levels and functions must keep in mind and not ignore the importance and place of the operation unit in the company.
- **Necessity of shortening the product development phase:** Everything is changing rapidly such as life styles, way of doing jobs, needs, requirements of customers in today's world. The companies feel a lot of pressure on them to follow this change. Otherwise, they cannot compete in the market in a short period of time. Since no company finishes continuous improvement, many of them make changes for new needs and requirements. For this reason, you need to be fast enough to present new products for new needs and requirements as a company in order to compete. The first condition of presenting new products to the market is to shorten the product development phase which is a highly challenging issue.
- **Increasing importance of e-business:** By the emergence of the Internet, e-business increasingly takes place among companies and customers. Moreover, e-business has added new dimensions to business both in buying and selling activities and this change in business has presented new challenges.

E-business is any type of business or commercial transaction including share of information across the internet.

Learning Outcomes

3 To explain the current issues in operations management.

Self Review 3	Relate	Tell/Share
What are the effects of globalization in an operations system?	Associate the success of operations management activities with effective communication in an organization.	Tell the relations of operations management with sustainability for the success and competition of the company.

SCOPE OF OPERATIONS MANAGEMENT

Although the scope of operations management changes from one company to another one, for most of the companies scope of operations management is nearly the same. Some factors such as size, sector, products, the strategy of the company can be effective in determining the scope of operations management. However, it can be said that the scope of operations management is getting wider and wider from the beginning of the 20th century till the present time. Some of the most important reasons of it are high competition in the market, changing environment, improving technology, growing customer's requirements and expectations.

The scope of operations management, as it is shown in Figure 1.3, includes many activities such as product design, process and technology selection, job design, location of facilities, plant layout and material handling, production planning and control, quality control, forecasting, capacity planning, scheduling, inventory control, maintenance, materials management, distribution and logistics and after sales service. Some of these activities are described below.

Location of Facilities: Decision taken about the location of the facility is a strategic decision which involves long-term commitment about the geographically static factors that affect a manufacturing company. Selecting the location of a facility is a very important decision for a company since large investments such as the construction of the plant, are done and it is very difficult or too costly to turn back. Wrong selection of the location of the facility may cause to waste of all the investments. Therefore, selection of the location of the facility should be based on the company's strategy and plans, process and product types, raw materials, proximity to the market, government policies and incentives, transportation networks, labor supply, environmental regulations and many other factors.

Plant Layout and Material Handling: Plant layout is the physical arrangements of facilities, including personnel, equipment and materials. Plant layout requires the integration of capacity needs, personnel levels, technology, inventory requirements in order to determine the optimal flow of personnel, materials and information. The basic purpose of plant layout is to reach the required quality and quantity of output by the arrangements of all the physical materials such as machine, man and storage space in the plant.

Material handling is the movement, protection and control of materials, parts, semi-finished products, finished products throughout manufacturing, packing, stocking, distribution and disposal. Many different types of material handling devices such as forklifts, conveyors and carts are used for these operations.

Material handling is the art and science of moving, packing and storing of products in any form.

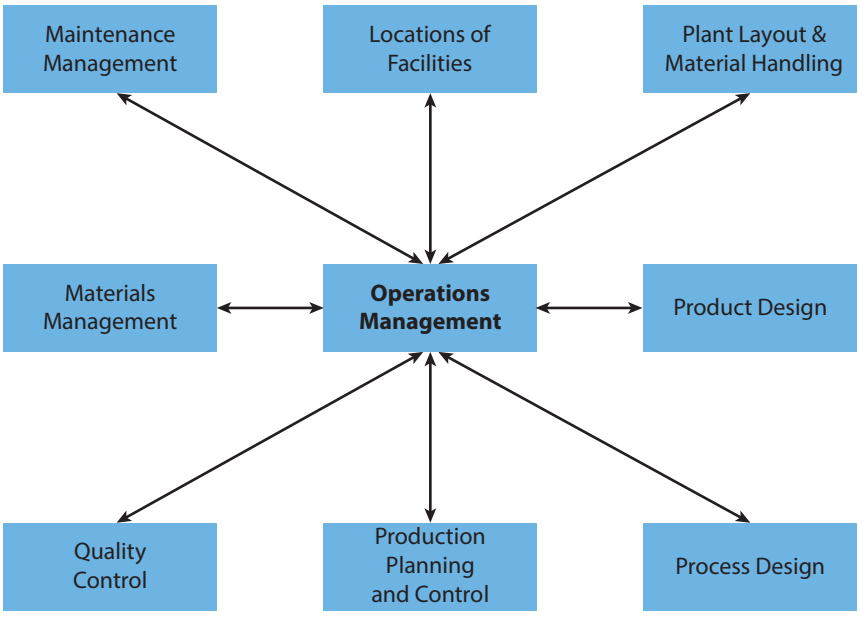


Figure 1.3 Scope of Operations Management

Product Design

Product design is one of the most important operations decisions in the company. It is the connection of materials, technology and art by transforming ideas into real products and concepts for the satisfaction of customers. Design specifications of a product directly affect the operations. Every company has to design, develop and present new products to the market in order to survive. Development of new products and presenting them in the market is a big challenge and risk for the companies. By product design and development, needs and requirements of customers are translated into technical specifications for the product and it provides links between marketing, operations, finance and other related functions of the company for the activities required to manufacture the product.

Process and Job Design

Process design is an important decision for an overall process route in converting the raw materials into finished goods. These decisions include the selection of a process, choice of technology, process flow analysis and layout of the facilities. Hence, the important decisions in process design are to analyze the workflow for converting raw materials into finished products and to select the workstation for each included in the workflow. Design of work systems can also be included in process design depending on the structure of the operations. The selection of production process usually affects the quantity and skill level of personnel required. Design of jobs, development of job standards, organization of work and the role and responsibility of personnel in the operations are important activities for the effectiveness of the organization. Depending on the type of products produced and the skill variation of the personnel various number of tasks are assigned to jobs for the most possible efficient performance of operations.

Production Planning and Control

Integration of production planning and control system is an obligation in a company for effective and efficient operations. Moreover, this integration provides overall success of the company and customer satisfaction. Production planning and control is the process of planning the future production, preparing the exact route of each product, determining the starting and finishing dates for each product, to give production orders to shops and to track the progress of products according to orders.

Production planning deals with basic concepts of what to produce, when to produce, how much to produce and where to produce. It is about the long-term view of overall production planning and tries to ensure the right quantity and quality of production inputs available for the production by taking into account capacity limitations. Production planning is directly related to scheduling, dispatch, inspection, quality, inventory and resource utilization.

Production control tries to evaluate the performance of the operations system whether targeted plans are achieved or not. Besides, it ensures the optimum utilization of resources, quality management and cost savings. Some of the main objectives of production control are the regulation of inventory management, organization of production schedules and optimum utilization of resources.

Quality Control

Quality control is a type of system which is used to assure the required level of quality in operations in a company. Quality control can be achieved by training people, benchmarking product quality and testing products to check for statistically significant variations. Quality control tries to prevent defects at the source and uses an effective feedback system and corrective action procedure. The purpose of quality control is to keep the product and product manufacturing consistent and in line with customer requirements. Well-defined controls and standardization in the process are essentials of quality control. Most companies have quality control departments that determine set of standards for each product type. Quality control has to address both deviations from target value and the high variability around target value. Quality control ensures the company both high product quality and brand recognition in the market. When the company presents good quality products, this will provide customer loyalty, new customers, good position in the market, safety, and reduction of liability risks.

Quality control is a system that is used to maintain a desired level of quality in a product.

Materials Management

Materials management is one of the most important functions of an organisation that deals with the acquisition, control and use of materials needed and flow of goods and services connected with the production process having some predetermined objectives in view. Minimizing materials cost including purchase, receive, transport and store is one of the main objectives of a company. Seamless flow of materials throughout the operations is crucial for the efficiency of operations and continuous supply of materials must be provided for the achievement of it.

important

Materials management is responsible for purchasing the highest quality equipment and products at the lowest possible cost for the organization and also responsible for managing purchasing, inventory control functions, shipping and receiving, also planning and administering department budgets.

Maintenance Management

The purpose of maintenance management is to control the allocation of resources, time and costs to ensure the efficiency and adequacy of the maintenance operations, avoiding waste of resources or even periods of downtime due to faulty equipment (Machado, n.d.). In other words, it can be said that maintenance management does not mean to repair broken machines but to keep the machines running at high capacity and produce high quality products at the lowest cost possible. Another important function of maintenance management is to ensure the availability of the machines, facilities and services needed by other departments of the plant for the performance of their functions at optimal return on investment.

Learning Outcomes

4 To analyze the scope of operations management.

Self Review 4	Relate	Tell/Share
What types of decisions are taken in operations management?	Associate the scope of operations management by the critical decisions given in the organization.	Tell the scope of operations based on the interrelationships of structural, functional and environmental aspects.

CLASSIFICATION OF PRODUCTION PROCESS STRUCTURES

When the market is analyzed, it is seen that different types of products are produced by different types of companies. Companies that produce the same type of products can use different types of processes. This is not a surprise since the structure and purpose of them are varying from one company to another. Some companies are small like coffee shops, some companies are very big like automobile producers.

Processes can be classified according to physical configuration, material and product flow, product variation and volume expectation. In this textbook processes are classified according to product flow and volume expectations into the following four categories:

1. Flow processes
2. Job-shop processes
3. Cellular processes
4. Project processes

Flow Processes

When the products that are produced in the production system follow the same type of processing in the same sequence, then this process which is called *flow process*, is the most efficient one. Inflow processes the whole production process is separated into tasks or operations that must be performed. The tasks or operations are loaded to work stations that are arranged sequentially as shown in Figure 1.4. The product moves from one workstation to another in a sequential manner from beginning to end. Machines, tools, operations and material handling are mostly specialized since all products follow the same sequence of operations in the same direction. In this type of production a very high volume of standardized products are produced. The product variety is too narrow because of the structure of this process. Paper, automobiles, books are usually produced by flow processes. There are three types of flow processes which are continuous flow processes, repetitive or discrete flow processes and disconnected or batch flow processes (Martininch, 1997, p. 329).

Flow process is the continuous movement of products through the production process and when one task is finished the next task starts immediately.

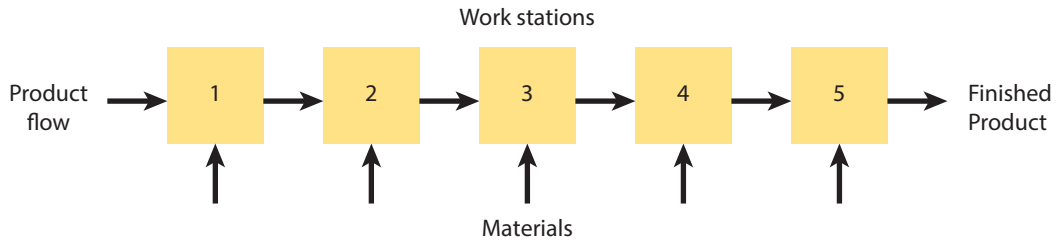


Figure 1.4 Flow Process Structure

Continuous Flow Processes

Continuous flow processes are used when a process runs all day for each day of the year on a continuous basis. In other words, it is for 24 hours and 365 days of a year. It is designed for the production of high volumes of a narrow range of products. These processes have a highly interconnected structure and the materials move continuously through the system. The transformation of the product occurs continuously. The product is usually physically continuous rather than in discrete units. Good examples for this process are paper, chemicals or gas. This process can sometimes be discrete in the production of beverages, detergent and candy, since they are put into bottles, cans or boxes. The starting investment for the factory is too high, but the operating expenses are low.

Repetitive or Discrete Flow Processes

These processes are similar to continuous flow processes and it is also called mass production. The work stations are tightly connected to each other and one general type of product is produced depending on the sequence of activities. The product is a discrete product and it is processed and transferred between workstations one by one in a synchronized manner. Since all the operations are the same for all the products, it is called repetitive. On the other hand, the work required to make them can be divided into discrete tasks. Because of doing the tasks in the same sequence for all the products, the shape of the structure of the processes is a line of work stations. That's why it is also called line processes or assembly lines. In assembly lines, workers or machines do their tasks at each workstation sequentially on a moving line. The most important drawback of this process is that it is impossible or difficult to produce different types of products in these lines. However, efficiency is very high, products are produced in huge lots and minimization of cost can be achieved easily. Many automobiles and computers are produced by this type of processes.

Batch or Disconnected Flow Processes

Batch flow processes are tried to take the advantage of common flow of materials and the flexibility of producing a variety of products in different volumes. Since there are some unbalanced work stations, different stages of production cannot be synchronized. Batch flow processes do not take all the advantages of other types of flow processes due to the structure of them. Textiles and toys are some examples of batch flow processes.

Equipment and job specialization, simple material handling, low work-in process inventories, efficient space utilization, easy quality conformance and production scheduling are some essential advantages of continuous and repetitive flow processes. However, inflexibility, high initial costs, boring jobs and vulnerability of the production system are the primary disadvantages of these processes.

Job-Shop Processes

In manufacturing, *job-shop processes* are used for the production of several different products that follow different types of processing and different sequences for different products. Job-shop processes that are sometimes called make to order production, usually produce products only to customer order in small batches. These products are made-to-order products and the production flexibility is too high. The general-purpose machines are used and spatial layout and the material handling system are generally designed for the flow of products throughout the system in different ways. There are work centers or designated areas that are organized around common activities in the plant. All the personnel and equipment in the work center are devoted to the same general processing such as painting, welding or cutting. Depending on the variety of products, products move among different work centers in different sequences. Job shop's layout is designed to attain flexibility which means production of wide variety of products in small quantities. These products can be customized products. While detailed planning is important for sequencing the requirements of each product, high level of inventory and highly skilled workers are unavoidable. Although flexibility and low initial costs are general advantages of this process, low efficiency, highly-paid workers, high work-in process inventories, more space, difficult quality conformance are some main disadvantages of this process. A tool and a die shop that is able to produce unique tools is an example for job-shops.

Job-shop process is a type of production process in which small amounts of a variety of custom products are made.

Cellular Processes

Cellular processes give the manufacturer an opportunity of the efficiency of flow processes along with the flexibility of job-shop processes. It is a hybrid production process that is considered as a mixture of mini flow processes called as work cells and a job-shop operation. When productivity becomes a big problem for a job-shop manufacturer, the company tries to convert its processes into a cellular design to increase efficiency. On the other hand, the manufacturer that makes production by flow processes tries to make production by cellular processes in order to increase flexibility.

In order to convert the processes into cellular processes, the company divides its products into families or group of products that requires similar processing in the same sequence. A work cell is designed to perform these steps in the designated sequence for all the products in the family. Some products are not suitable for any cell so they cannot be produced totally at a single cell, therefore some of the processes are performed in a job-shop subsystem (cell) in any sequence. Cellular processes enable companies to produce different types of products with little waste and provide a smooth flow of work through the process with minimum transport and delay.

Group technology is the basis for cellular processes and many other technologies like computer aided design. Group technology is the process of dividing parts by families and subsequently assigning equipments to a specific family or families of parts.

The primary benefits of cellular processes are to make the production fast and decrease the in-process inventories. Decreasing material handling, transportation, setup times, throughput time, space

requirement and improving workers satisfaction and quality are some other benefits of this process. The most important disadvantage of this process is the difficult implementation of this process that requires a considerable amount of work, expertise and experience.

Cellular process is the production of similar products using cells or workstations to facilitate operations by the elimination of setup and unneeded costs among operations.

Project Processes

The environment of the *project process* is often large-scale and complex depending on the nature of the product. The product to be produced technically does not flow in a project since materials, labor and equipment are brought to the project place and the project itself is usually stationary. Weight, size, bulk or some other factors make it extremely difficult or impossible to move the product. One-of-a-kind and customized products are produced in this type of process. Although similar skills and equipment are usually used for all the products produced, the product types are varied greatly because of the type and sequence of processes performed. For example, many different kinds of bridges can be made by similar skills and equipment. Project processes take a long time like two to three years to complete, require high investment and resources and generally produce one product at a time. Because of that they are considered as a project and called project processes.

Project process is the production of large, expensive, customized products one at a time in a long time period.

It is not so easy to manage project processes because of their complexity and allocation of wide variety of resources to the project. Another big problem is the completion of the project on time and planned budget. At the simplest way of management Gannt charts can be used. Besides, some other tools such as critical path method and project evaluation and review techniques are also used for management of the project. Since products are produced entirely according to the desire of the customer and the customer is usually involved in the design phase of it, this process is also called make to order production as it is said in job-shop processes. Bridges, highways, cargo ships, aerospace, large computer softwares are good examples of the project processes.

While the main advantage of a project process is its flexibility that produces a wide variety of products, its main disadvantage is the expense of it. These products are very expensive products due to their customized nature.

Figure 1.5 shows the types of processes based on product volume and product variation and shows the main differences between these processes.

important

The key to process selection is to balance the costs, efficiency, output and quality of each option to meet your production goals.

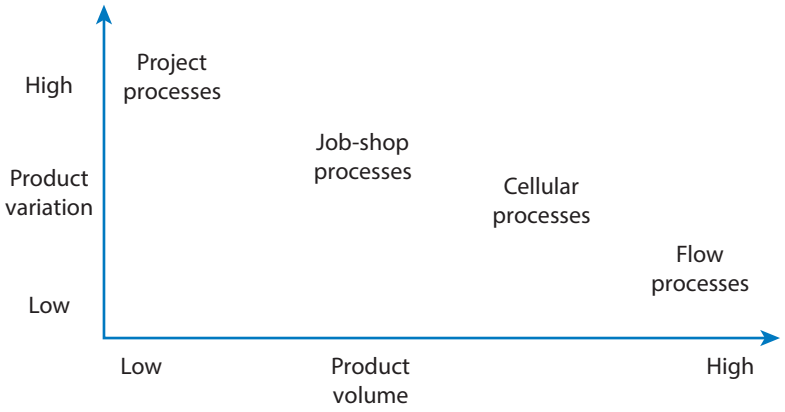


Figure 1.5 Types of Processes Based on Product Volume and Variation

Learning Outcomes

5 To explain the classification of production processes structures.

Self Review 5	Relate	Tell/Share
What are the main differences between job-shop and flow processes?	Associate the similarities of project and job-shop processes.	Tell the advantages of using cellular processes in the organization.

CONTEMPORARY OPERATIONS THEMES

Many different types of contemporary themes are appearing in operations today by changing the environment. High competition, rapidly changing customer needs, requirements and even expectations and technologic improvements are the most important trigger of these new challenging themes. These contemporary themes give opportunities to the companies in case they are able to use them in their activities and operations. Many events help shape operations management. Some of the most important latest ones are tried to be explained as follows by their effects to operations management.

Total Quality Management

One of the major developments in the late 1980s and 1990s was *total quality management* (TQM). Total quality management is the continual process of detecting and reducing or eliminating errors in manufacturing, streamlining supply chain management, improving the customer experience and satisfaction, and ensuring that employees are up to speed with training. The purpose of total quality management is to hold everybody involved in the production process accountable for the overall quality of the final product or service (Investopedia, 2019). W. E. Deming was the developer of TQM and his consultancy had a great impact on the improvement of Japanese manufacturing. Besides, quality gurus such as J.M. Juran and P. Crosby are the pioneers for the application of TQM in the companies.

Total quality management is a philosophy that involves everyone in the company in a continual effort to improve quality and achieve customer satisfaction.

Some of the most important principles of TQM are continuous improvement, involvement of everyone in the organization, customer focus, training of employees, leadership of top management, empowerment of employee. TQM involves the entire organization, from suppliers to customers. It emphasizes a commitment by all levels of management to have a continuing companywide motivation toward excellence in every direction of products and services that are important to the customers. The main purpose of TQM is to achieve and sustain long-term success for the satisfaction of a customer. It is a "race without a finishline" that stresses the process of continuous improvement covering people, equipment, suppliers, materials and processes. Walter Shewart who is a pioneer in quality management developed a circular model known as plan, do, check, act (PDCA) for continuous improvement. The PDCA cycle which is also known as Deming cycle or Shewart cycle, emphasizes the continuous nature of the improvement process. TQM also gives importance to the processes rather than results and it is a long-term investment for the company, not a quick fix. Moreover, quality is evaluated if it is measured. Therefore, implemented processes must be observed by their effects and these effects must be controlled whether they are working for the achievement of goals or not.

Briefly, it can be said that TQM focuses on both meeting needs and requirements of customers and organizational objectives.

Business Process Reengineering

Business Process Reengineering (BPR) seeks to make radical changes and redesign almost all core business processes of the company rather than evolutionary changes as it is done in TQM to achieve dramatic improvements in productivity and quality. BPR does this by observing and understanding what the organization tries to do in all its business processes, and then cuts down costs and process redundancies, eliminates steps that have no value for the customers in the processes and makes changes to achieve the desired goals. BPR helps the organizations adopt new value systems in order to increase the customer satisfaction by reducing organizational layers and eliminating inefficient activities. BPR became popular among the organizations after the article called "Reengineering Work: Don't Automate, Obliterate" by Michael Hammer published in the Harward Business Review.

BPR starts a dramatic change in the business processes and

- changes the focus of the company values more on customer needs and requirements,
- recreating core business processes by information technology,
- reorganizes a business into cross-functional teams by full responsibility,
- rethinks issues related to organization and personnel,
- improves business processes across the organization.

Since it is a change in the processes fundamentally, unless each step of BPR carries out successfully, the attempts at change can be extremely time-consuming, expensive and risky.

Business Process Reengineering involves the radical redesign of core business processes to achieve dramatic improvements in productivity, cycle times and quality.

Lean Production

Mass production is very popular and mostly used by the companies in order to cut costs of production but it is not suitable for rapid changes in demand. Today, the market is defined by product proliferation, shortened product life cycle, reduced product development times, rapidly changing technology, more customer focused and segmented market. It is not possible to satisfy such a kind of market by mass production. Japanese manufacturers changed the way of having production from mass production to *lean production* by using just-in-time concept. This concept extended the idea of identifying value provided to the customer along with lean thinking applied to every part of the business and the supply chain. Lean production gives the company to be flexible and to have high quality in production.

The removal waste is at the heart of lean thinking. Following this thinking leads companies to design, develop, run and continuously improve more competitive and less resource-hungry production systems. Waste is defined as any activity that does not add value from the customer's perspective. Lean production which is based on the Toyota Production System and is still used by that company, is concentrated on the waste generated from unbalanced workloads and overburden and tries to reduce them for increasing value and decreasing costs. Lean systems use much less of certain resources such as space, inventory and workers than typical mass production systems use to produce a comparable amount of output. Some of the wastes of a lean system are unnecessary transportation, excess inventory, unnecessary movement of personnel, equipment or machinery, idle waiting of personnel or equipment, over-production, over-processing than a customer needs or requirements and defects requiring effort and cost for corrections. By using highly skilled workforce and flexible equipment, lean systems have the advantage of high volume, low cost, variety and flexibility in some degrees. Moreover, quality is higher in lean production than mass production.

Skilled workers are one of the main elements of a lean production system and these workers are more involved in maintaining and improving the production system than the classical production systems. These workers have the authority and responsibility of stopping the operations when a

defect is discovered and work with other personnel collaboratively to determine and correct the cause of the defect to avoid its recurrence.

Lean production can be applied to all aspects of a business such as design, production and distribution. The main purpose of this system is to reduce costs by making the business more effective, efficient and at the same time responsive to market needs and requirements. Lean production concept is a very powerful concept for any business to become and remain competitive.

Lean production is to work continuously on eliminating all forms of waste that do not add any value to customer, from the production process.

Supply Chain Management

The main idea of supply chain management (SCM) is to apply system approach for the management of flow of information, materials and services from raw material suppliers through factories and warehouses to the final customer in the most streamlined and cost-effective way possible. SCM involves the integrated planning and completion of processes required to optimize the flow of materials, information and financial capital in the fields such as demand planning, sourcing, production, inventory management, storage and transportation and return of excess or defective products.

A simple version of a supply chain includes a company, its suppliers and the customers of that company. The structure of the supply chain involves raw material producer, manufacturer, distributor, retailer and final customer. However, a complex or extended version of a supply chain involves many suppliers and suppliers' suppliers, many customers and customers' customer or final customers. On the other hand, the whole organizations providing services for the delivery of products to customers such as third-party logistics providers, financial organizations, marketing researchers make the structure of the supply chain too complicated. That is why it is not easy to manage all the chains in the supply chain to get the advantages of supply chain for competition and satisfaction of the customer.

Supply chain management depends on two core ideas:

1. In the first one, practically every product that reaches a final customer shows the cumulative effort of multiple organizations. These organizations are referred to collectively as the supply chain.
2. In the second idea, while there have been supply chains for a long time, most organizations are only aware of what was happening within their "four walls." Few businesses understood, much less managed, the entire chain of activities that ultimately delivered products to the final customer. The result was disjointed and often ineffective supply chains (NC State University, 2017).

Supply chain management is becoming very popular among the companies. There are many reasons for it. Companies have started to use global sources for their sources. This situation causes globalization of supply and forces the companies to seek more effective and efficient ways to coordinate the flow of materials into and out of the company. In order to maintain such coordination it is essential to have close relation with suppliers. Moreover, today competition is very high on the base of time and quality. Delivery of required products to the customers fast, reliable and on time are the important keys of being in the market. In order to achieve these key factors companies in the supply chain must have close coordination with their suppliers and distributors. Globalization of supply and high competition along with rapidly changing technology and economic conditions are making the market vague. This vagueness requires flexibility of every company in the supply chain and sensitivity in the supply chain relations.

Today competition is moving from company to company against supply chain to supply chain. The survival of a company today does not only depend on its own ability to compete but also on the ability to cooperate within the supply chain. The relation between the organizations are now more interdependent and "win and win" relation is the main idea behind the supply chain and for this reason management of supply chain is getting more and more important.

important

The better and more effective a company's supply chain management is, the better it protects its business reputation and long-term sustainability.

Agile Manufacturing

Agile manufacturing is an approach for developing competitive advantage in today's fast changing market. The company becomes speedy and agile to focus on rapid response to the customer as a competitive advantage. An agile manufacturing strategy would use processes, tools and training, which enables it to respond to these needs and changes rapidly without jeopardizing the cost and quality of the product. An agile company has the advantage of having opportunities for meeting fast changes in customer demand.

There are five key elements of agile manufacturing

1. **Modular Product Design:** The company must design the products in a modular fashion that enables them to serve as platforms for fast and easy variation. Agile company produces products in small pieces to fit together to create the required product.
2. **Fully Connected Information Technology:** Agile company automates the rapid distribution of information throughout the company to enable lightning fast response to orders. Employees make decisions quickly by the proper implementation of information technology.
3. **Corporate Partners:** Agile company creates virtual short-term partnerships with other companies that enable improved time-to-market for selected product segments. Short-term partnerships and cooperative projects help the company to enter and adjust to new or changing markets faster.
4. **Knowledge Culture:** Creating a knowledge culture in an agile manufacturing company is vital for the sustainability of it. This means agile companies must make investments for the employee training related to agility. Agile company trains employee to achieve a culture that supports rapid change and ongoing adaptation. Employees are expected to understand the fast changes and adaptations they are involved (Lean Production, n.d.).
5. **Full Company Involvement:** An agile transition does not work when it is accepted as a responsibility of a team in a company. The whole company must be involved in it. The focus of the company must be on bringing all areas of the company to agile standards.

Planning must be prepared for the agile manufacturing company to respond to customers rapidly and offers them what they want when they want it. Besides, when the company is close to the customers, the company can respond to even minor changes in customer needs and requirements easily and quickly. Agile manufacturing must be proactive in developing and retaining markets in the face of extensive competitive forces. In order to be agile in manufacturing the company must have rapid product development, highly flexible manufacturing and highly integrated supply chain. The strategy, culture, business practices and technology of the company must be highly compatible with the market characteristics to make the company agile. It is a strategy adopted by manufacturers to enhance the performance of the company for becoming international leaders in a highly intensive competitive market for fast changing customer needs and requirements.

Agile manufacturing is the capability to survive and to be successful in a competitive environment by responding quickly and effectively to changing market needs and requirements.

Mass Customization

Mass customization of market means that the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously they can be treated individually as in customized markets of pre-industrial markets (Davis, 1987, p. 169). In traditional production there is mass production that uses economies of

scale to produce in huge lots with low cost and no variety or produces in small lots with high costs. Whereas, mass customization tries to produce mass-customized products on a large scale with relatively low cost.

Mass customization is a marketing and manufacturing technique which brings together the flexibility and personalization of custom-made products with the low unit costs associated with mass production. The main purpose of it is to produce the customized products with mass production efficiency. In mass customization, the companies try to produce one of a kind products according to the own requirements of a customer by keeping costs close to mass produced products. Companies produce some components of the product modular so this flexibility gives to the customers the opportunity of mixing and matching the components to create a semi-custom final product.

There are four primary types of mass customization which move mass production to a new level (Pine II, 1993):

1. **Collaborative customization:** Companies work in partnership with customers to offer products or services uniquely suited to each customer.
2. **Adaptive customization:** Companies produce standardized products which the customer may customize.
3. **Transparent customization:** Companies provide unique products to individual customers without overtly stating the products are customized.
4. **Cosmetic customization:** Companies produce standardized products but market them in different ways to various customers.

Some companies achieve mass customization by a strategy of producing standardized products while incorporating some degree of customization in the final product. Although several tactics can be used to make it possible, two tactics are popular among companies. These are delayed differentiation and modular design (Stevenson, 2009, p. 146).

- **Delayed differentiation:** The product is not fully produced and completion is postponed until customer preferences or specifications are known. Almost finished units can be stored until customer orders are taken, at which time customized features are incorporated according to customer requests.
- **Modular design:** It is a form of standardization and modules represent groupings of components parts into subassemblies. These subassemblies are in a point where the individual parts lose their separate identity. By mass customization the company uses modular design to assemble products with modules to achieve a customized configuration for a customer and avoids long customer wait that would occur if individual parts had to be assembled.

Mass customization has the benefits of a high volume of sales along with mass production and also high customer satisfaction that comes with owning a specially modified product. Customer satisfaction in turn leads to improved company reputation and sales.

Mass customization is the capability of producing a relatively high volume of product options for a relatively large market that demands customization, without tradeoffs in cost, delivery and quality.

Flexible Manufacturing System

A flexible manufacturing system (FMS) is an integrated, computer controlled complex of automated material handling devices and numerically controlled (NC) machine tools that can simultaneously process medium-sized volumes of a variety of part types (Stecke, 1983, p. 273). This new production system has used the advantages of the efficiency of well-balanced machine-paced transfer lines and flexibility of job shops simultaneously machining multiple part types.

FMS is an element of mass customization and flexibility of these systems is one of the most important competitive weapon of Japanese manufacturers. It is easy and fast to change the manufacturing environment to improve process efficiency and decrease production cost in this system. In flexible manufacturing

system, workstations connected to each other by computer terminals that process the end-to-end manufacturing of a product, from loading/unloading functions to machining and assembly to storing to quality testing and data processing.

When flexibility term is used in manufacturing the meaning of it is to describe a manufacturing system's ability to make adjustments for handling mixed parts, variations in assembly, variations in process sequence, production volume changes, design changes, and other changes. There usually are two types of flexibility for FMS. These are machine flexibility which refers to the system's ability to produce new types of products and change the order of the operations and routing flexibility which refers to the system's ability to use two or more machines to perform the same task and to handle big changes like quantity of volume or type of operations.

Flexible manufacturing systems can be categorized according to the number of machines in the system. Typical categories are single machine cell, flexible manufacturing cell and flexible manufacturing system.

1. **Single machine cell:** It is a single machine cell consists of one CNC machining center combined with a parts storage system for unattended operation. In this cell completed parts are periodically unloaded from the parts storage unit and raw parts are loaded into it.
2. **Flexible manufacturing cell:** It consists of two or three processing workstations (CNC) plus a part handling system which is connected to a load/unload station.
3. **Flexible manufacturing system:** It has four or more processing workstations connected mechanically by a common part handling.

The main benefit of this system is to increase production efficiency, whereby downtime is reduced because there is no need to shut down the production line to set up for a different product. One disadvantage of FMS is its need for a high amount of investment and the time required to carefully preplan the system specifications. Another possible criticism is the higher cost associated with the need for specialized labor to run, monitor and maintain the FMS; but, since this system increases production automation and reduces labor input, the result is typically a cost saving.

Flexible manufacturing system which is a highly automated system involves a set of processing workstations allowing in an integrated manner to react rapidly and economically to production-oriented aspects of an enterprise in order to cope significant changes in its operating environment.

Six Sigma

Six sigma which is popularized by Motorola, is a systematic method for improving the process and used for reducing defects, lowering cost, saving time and improving customer satisfaction. It is a comprehensive system for achieving and sustaining success in business. Sigma shows the number of standards deviations of the process. Six sigma means 3.4 defective parts per million.

This method usually uses DMAIC which is known as six sigma improvement method and explained below (Schoroeder, 2007, p. 173).

1. **Define:** It defines the project's goal and scope and identifies the selected process for information by keeping in mind the customer's quality perception.
2. **Measure:** It measures the current quality variables of the process and collects data.
3. **Analyze:** It analyzes the root causes of the quality problems of the process.
4. **Improve:** The process is changed or redesigned or modified for improving and eliminating the root causes of the quality problem.
5. **Control:** The process is being controlled to make sure performance levels are maintained.

In DMAIC, the first three steps are about the current situation of the process and the last two steps are about the development of this process. Quantitative methods are used at every step of the method such as measuring the current performance of the process or analyzing the root cause of the problem in the process. Before implementing this method, a specific critical process is selected strategically by senior management. After the selection of the process to be improved, a multidisciplinary team is formed.

One of the members of the team is a process improvement specialist called as "Black-Belt" leads the improvement team. Then the team tries to make improvements for the selected process by following the steps of DMAIC. Commitment of top management in the company is very important for the success of this implementation. Top management helps the team by promoting the process, eliminating the barriers and providing resources. Here the key person is the "champion" who is from top level management and provides direction and oversees all aspects of the process.

Six Sigma emphasizes both cycle-time improvement and reducing manufacturing defects to a level of no more than 3.4 occurrences per million units or events.

Although it is started to use in manufacturing, today it is used both in manufacturing and services. It is not just a quality improvement method but also a way to improve the revenue of the company.

Six Sigma is a data-driven approach and continuous improvement methodology for eliminating defects in a product, process or service.

Computer Integrated Manufacturing

Heart of *computer-integrated manufacturing (CIM)* is the integration of decision making and data. It is the integration of all manufacturing processes and business functions through a common database. The factory is centered on computer integration with less labor force and product and process design, forecasting, capacity planning, inventory control and many other activities that are performed under the control of computers. Computer-aided design, computer-aided manufacturing (CAM), robotics, and a manufacturing planning and control system are all integrated to each other through a common database in CIM to give the factory high flexibility.

In a CIM environment, when a change in design is required it is made at a CAD terminal and the new designed product or part is produced in the shop floor in a matter of minutes and inventory control, warehousing and shipping as a part of manufacturing system are all integrated simultaneously and accordingly. CIM systems decrease the differences between low-volume/high-variety and high-volume/low variety production.

There are different types of CIM systems depending on their complexity. While simple systems involve CAD with some numerically controlled (NC) machines, complex systems involve other related areas of business in addition such as purchasing, scheduling, inventory control, distribution and etc. The main purpose of CIM systems is to improve responsiveness of the company to the needs and requirements of the customer in terms of product variety and availability, as well as quality and productivity (Reid & Sanders, 2013, p. 82).

Computer integrated manufacturing (CIM) is a manufacturing approach that provides a complete automation of a manufacturing facility by using various technologies like computer-aided design and computer-aided manufacturing.

E-Manufacturing

After the Internet comes into our lives, it changes many things in our lives and in the business as well, such as e-commerce and e-business. Real-time and integrated business logic transactions are made easily and fast by the Internet and advanced network computing technologies. Therefore, the adoptions of e-business in enterprises are accelerating across all the business sectors in the world. For a manufacturer a plant-wide real-time information system is fundamental to its e-business execution, where an *e-manufacturing* system on the plant floor plays a critical role (Qui, 2003, p. 266). E-manufacturing is not just connecting the Internet to the plant floor but also a fundamental change in the strategic value proposition for manufacturers. Collection of systems, processes, and technologies come together for manufacturers to compete in collaboration with other manufacturers in the market. E-manufacturing enables the manufacturer to compete with competitors by synchronizing the process, orchestrating the information flow,

automating the process and workflows, giving control to managers, integrating the design process and enabling the collaborative maintenance.

E-business applications such as sales, marketing, customer service, new product development, supplier relations and logistics which are the concern of e-manufacturing are used in manufacturing companies. E-manufacturing enables the companies to achieve knowledge based value creation and manufacturing on demand. The Web is used to integrate the necessary data, information and knowledge to create value to all the elements in a supply chain: customers, suppliers and the company itself. The integration of information at different levels of the factory through the use of web-based technology is essential to offer new information services to customers and suppliers to achieve on Demand Manufacturing (Molina & Santaella, 2006, p. 215).

E-manufacturing gives the company an opportunity of monitoring the plant floor assets, predicting the variation of product quality and performance loss of any equipment for dynamic rescheduling of production and maintaining the operations, and synchronizing with the related business services to achieve seamless integration between manufacturing and higher level enterprise systems. E-manufacturing enables the manufacturers to re-configure the manufacturing capability easily along with the agility to respond quickly for changing demands while possessing the predictive intelligence on the plant floor. In this manufacturing, customer orders would be executed on the plant floor and across the supply chain, and as a result of it, it provides unprecedented levels of speed, flexibility and visibility to the production process by reducing inventory, excess capacity and uncertainty. It also gives effective and efficient configurable information exchanges among manufacturing units, customer relationship management systems and supply chain management systems (Koç & Lee, 2002, p. 1)

e-Manufacturing is a transformation system that gives to the production the ability of achieving predictive near-zero-downtime performance and also synchronizing with the business systems through the use of web-enabled and tether-free (i.e., wireless, web, etc.) infotronics technologies.

Learning Outcomes

6 To analyze the contemporary operations themes

Self Review 6	Relate	Tell/Share
What types of mass customization can the company apply for the satisfaction of a customer?	Associate the characteristics of a manufacturing company using lean system.	Tell the advantages of using Six Sigma method in a manufacturing company.

LO 1 Define the concept of operations management and related concepts of operations management.

Operations are the business activities that a firm engages in to convert materials into finished products or services, sell them to customers, and earn a profit. Goods are tangible items (pencil, apple, chair) that satisfy the needs and requirements of human and provide utility. Service is a kind of economic activity that is intangible and a set of activities providing some combination of time, location, form or psychological value. Operations management is the business function that plans, organizes, coordinates and controls the resources needed to produce a company's goods and services. The main objective of operations/production management is the production goods and services of the right quality and quantity at the right time and right manufacturing cost. Operation system is a system that transforms inputs into outputs (goods and services). The purpose of transforming all the inputs into goods and services is to have a higher value than the original inputs.

LO 2 Explain the history of operations management.

Modern operations management started by the Industrial Revolution. Before this, production of every piece was unique, hand fitted, and made entirely by one person, known as craft production. Industrial Revolution began in the 1770s in England and spread to the rest of Europe and to the United States during the 19th century. Some important changes in the 18th century changed the structure of production such as using machine power instead of human power. In the early 1900s Frederick W. Taylor, father of scientific management, approached the management of work as a science. Based on observation, measurement, and analysis, he identified the best method for performing each job. Taylor's scientific management ideas were accepted and applied by many experts such as Frank and Lilian Gilbreth, Henry Gannt. During the 1960s and 1970s management science techniques were widely used and computers and automation provided many developments in the application of operations management models. During the 1970s, Japanese companies came into play in the World economy, especially in the production of steel, automobiles, housewares and electronics by the concept of quality. In the nineteenth and early twentieth century mathematical models and analysis were rarely used to solve the problems of operation and production. Today's market is defined by product proliferation, shortened product life cycles, shortened product development times, changes in technology, more customized products and segmented markets.

LO 3 Explain the current issues in operations management.

Some of the important current issues in operations management are as follows:

- Coordination of the relationship between the company and the suppliers.
- Globalization of supplier, production and distribution networks.
- Increased co-production of goods and services
- Managing customer contact
- Being aware of the power of operations in a company as a competitive weapon
- Necessity of shortening the product development phase
- Increasing importance of e-business

Summary

LO 4 Analyze the scope of operations management.

The scope of operations management, is getting wider and wider in today's production environment. It includes many activities such as product design, process and technology selection, job design, location of facilities, plant layout and material handling, production planning and control, quality control, forecasting, capacity planning, scheduling, inventory control, maintenance, materials management, distribution and logistics and aftersales service.

LO 5 Explain the classification of production processes structures.

Production processes can be classified according to product flow and volume expectations into the following four categories:

1. Flow processes
2. Job-shop processes
3. Cellular processes
4. Project processes

The products that are produced in the production system follow the same type of processing in the same sequence, then flow process is the most efficient one. In flow processes the whole production process is separated into tasks or operations that must be performed.

In manufacturing job-shop processes are used for the production of several different products that follow different types of processing and different sequences for different products. Job-shop processes usually produce products only to customer order in small batches.

Cellular processes give the manufacturer an opportunity of the efficiency of flow processes along with the flexibility of job-shop processes. It is a hybrid production process that is considered as a mixture of mini flow processes called as work cells and a job-shop operation.

In Project processes the product to be produced technically does not flow in a project since materials, labor and equipment are brought to the project place and the project itself is usually stationary. Weight, size, bulk or some other factors make it extremely difficult or impossible to move the product. One-of-a-kind and customized products are produced in this type of process.

LO 6 Analyze the contemporary operations themes.

Many different types of contemporary themes are appearing in operations today by changing the environment. High competition, rapidly changing customer needs, requirements and even expectations and technologic improvements are the most important trigger of these new challenging themes. These contemporary themes give opportunities to the companies in case they are able to use them in their activities and operations. Some of the most important latest ones are as follows:

- Total quality management
- Business process reengineering
- Lean production
- Supply chain management
- Agile manufacturing
- Mass customization
- Flexible manufacturing system
- Six sigma
- Computer integrated manufacturing
- E-manufacturing

1 The right…… is determined when the cost of the product and the technical specifications meet the specific requirements?

a. quantity
b. time
c. quality
d. flexibility
e. pace

2 The transformation process can take some forms. Accordingly, paper manufacturing in manufacturing operations is considered as……. transformation?

a. informational
b. psychological
c. physical
d. chemical
e. locational

3 I. Customer contact is much more in services than in manufacturing operations

II. Highly automated manufacturing operations require lots of workers

III. Dependency on the raw materials is much higher in services than in manufacturing operations

IV. A hair cut service must be provided where it is produced

Which of the above statements related to some characteristic of goods and services are correct?

a. I and II
b. I and III
c. I and IV
d. II and III
e. II and IV

4 Which one of the following countries is the place where the Industrial Revolution began?

a. United States
b. China
c. Japan
d. England
e. France

5 Which one of the following experts is one of the people who developed the principles of motion economy?

a. Frank Gilbreth
b. Henry Ford
c. Adam Smith
d. Eli Whitney
e. Frederick W. Taylor

6 Which one of the followings could be the key to meet changes in customers needs and requirements quickly?

a. Shortening the product development phase
b. Increasing importance of e-business
c. Increasing co-production of goods and services
d. Coordinating the relationship between the company and the suppliers
e. Increasing the amount of labor force

7 ---------- is an important decision regarding the conversion of raw materials into finished goods because it covers an overall process route?

a. Quality Control
b. Process Design
c. Maintenance Management
d. Materials Management
e. Material Handling

8 Which one of the followings related to Job-Shop Processes is **not** correct?

a. Production flexibility is too high
b. The special purpose machines are used
c. The material handling system is generally designed for the flow of products
d. Products move among different work centers in different sequences
e. Low efficiency and high work-in process inventories are some main disadvantages of this process

Test Yourself

9 ---------- is often large-scale and complex because of the nature of the product?

a. Cellular process
b. Job-Shop process
c. Project processes
d. Flow processes
e. Agile manufacturing

10 In which one of the following mass customization types, do the companies produce standardized products which the customer may customize?

a. Cosmetic customization
b. Transparent customization
c. Collaborative customization
d. Agile customization
e. Adaptive customization

1. c	If your answer is wrong, please review the "Definition of Operations Management" section.
2. d	If your answer is wrong, please review the "Definition of Operations Management" section.
3. c	If your answer is wrong, please review the "Definition of Operations Management" section.
4. d	If your answer is wrong, please review the "History of Operations Management" section.
5. a	If your answer is wrong, please review the "History of Operations Management" section.
6. a	If your answer is wrong, please review the "Current Issues in Operations Management" section.
7. b	If your answer is wrong, please review the "Scope of Operations Management" section.
8. b	If your answer is wrong, please review the "Classification of Production Processes Structures" section.
9. c	If your answer is wrong, please review the "Classification of Production Processes Structures" section.
10. e	If your answer is wrong, please review the "Contemporary Operations Themes" section.

self review 1

What are the characteristics of an operations system?

Since operations is an organised activity, every operations system has an objective. The objective of an operations system is to produce goods and services to satisfy customer needs and requirements by maximizing the profit. The system transforms or converts the various inputs to useful outputs. This transformation can be physical, chemical, psychological, etc. It does not operate in isolation from the other organisation system. This system affects other systems or subsystems and is affected by other systems. There exists feedback about the activities, which is essential to control and improve system performance. When there is a difference between the planned and actual one, adjustments or changes are made for the revision of it.

self review 2

What are the effects of industrial revolution to operations system?

During the industrial revolution, machinery gave the factories an opportunity of growing in capacity and greatly increasing their output. In spite of this growth, there was considerable inefficiency in production because of the difficulty of planning. Two experts helped to overcome these difficulties in the early 20th century: Frederick W. Taylor and Ford. Taylor, father of the scientific management, developed a scientific approach for operations management, collecting data about production, analyzing this data and using it to make improvements to operations. Ford increased efficiency in production by introducing moving assembly lines for production and improved the supply chain through just-in-time delivery.

Suggested Answers for "Self Review"

What are the effects of globalization in an operations system?

self review 3

Globalization is defined as: "a process of interaction and integration among the people, companies, and governments of different nations." in Globalization101.org website. Globalization causes a reduction in trade barriers, advancements in information technology, and transportation technology. Companies face competition from the company across the street, as well as, from across the country and across the world. Globalization affects everything in the market from customers to suppliers and companies which compete with others abroad will have to improve quality while lowering prices to remain competitive. In this situation, operations manager is the one who engages in the four functions of planning, organizing, leading, and controlling to ensure that the product or service remains competitive in the market. Besides, operations manager must use the company's creative skills for innovation as a competitive weapon. This will be a key factor for success in international business around the globe.

What types of decision are taken in operations management?

self review 4

The scope of operations management is defined to be ten important decisions in operations management are as follows:

1. Design of products and services
2. Management of the quality
3. Management of strategic process
4. Strategic location
5. Layout strategy
6. Human resources
7. Supply chain management
8. Inventory management
9. Scheduling
10. Maintenance

What are the main differences between job-shop and flow processes?

self review 5

The main difference between job-shop and flow processes is in the variety of products and volume of production. In job-ship processes there is a high variety of products and low volume. Inflow processes the variety is low but the volume of production is high. Moreover, in job-shop processes general purpose machines are used with highly skilled workers. In flow processes, specialized equipment is used with less skilled workers. In flow processes production planning and control is more complex, inventory is higher, efficiency is higher, cost is lower and material handling is most automated than job-shop processes.

What types of mass customization can the company apply for the satisfaction of a customer?

self review 6

There are three types of methodologies which are individual customization, niche market customization and huge varieties of standard products. Individual customization is most well documented in items such as clothing, cars and glasses that are sold to a large number of different customers. This type of customization is the most difficult type by its low efficiency and high cost. The companies try to overcome this difficulty by focusing on it. Niche market customizers have only a few clients but build and sell customizable products in large batches, often to other businesses. Finally, mass customizers offer a plethora of standard products, often with catalogs well over an inch thick, that they produce to order. There is a great variety of products offered to customers.

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Chapter 2 Operations Strategy and Productivity

After completing this chapter, you will be able to;

Learning Outcomes

1. Define the business and operations strategies,
2. Explain the role of operations strategy in the organizations and the relationship between operations strategy and business strategy
3. Explain the approaches in developing the operations strategy
4. Define the concept of productivity and the productivity measures and compute the productivity measurement

Chapter Outline

Introduction
Business Strategy
Operations Strategy and the Relationship between Operations Strategy and Business Strategy
Developing an Effective Operations Strategy
Productivity

Key Terms

Business Strategy
Mission
Situation Analysis
Operations Strategy
Competitive Priority/Factors
Productivity
Total, Partial, and Multifactor Productivity

INTRODUCTION

In today's highly global markets, companies should have strategic (long term) plans in order to gain and/or sustain their competitiveness. These plans must include the company's long term aims and methods that differentiate them from their competitors. The decision makers should make decisions supporting this long term plan. Otherwise, each worker will use his/her effort to achieve his/her aims instead of the company's aims and therefore companies will fail.

The activities of a company could be thought of as a football game. For example, each team develops a strategy before the game begins. Each player takes a role in supporting this strategy. Indeed this strategy is a "game plan" that is designed by the team for winning the game. Now, just think that each player decides the game plan individually. In this case, the winning chance of the team will not be very high. A successful football team is composed of a group of players which use their individual talents for supporting the winning strategy. It is also the same for a company (Reid & Sanders, 2012, p. 30).

In this chapter the business strategy will be defined, and the factors and techniques which are important in constituting a business strategy. After explaining of operations strategy, the characteristics of the relationship between business and operations strategy, and the approaches used in the development of operations strategy, will be discussed respectively. The last section focuses on productivity and productivity measures.

BUSINESS STRATEGY

The term strategy is one of the most-used terms in business terminology. However 'strategy' could not be defined easily there is no doubt that the word has a military origin. The word 'strategy' derives from the Greek word 'strategos' meaning 'leading an army in order to achieve a specific aim by using the resources'.

There are some particular similarities between military and *business strategy* including, having objectives that drive the military and business towards its goals; drawing the ways to these goals; focusing on long term rather than short term, and focusing on the big picture accordingly; and avoiding of daily activities (Barnes, 2008, p. 22; Slack, Chambers, & Johnston, 2013, p. 70).

Based on these characteristics 'strategy' could be defined as long term decisions that shape the direction of the organizations. However, the term 'operations' used in 'operations strategy' is thought as operational at first glance, it is not the same as 'operational'. Since operations mean the resources used in creating the products and/or services, it has a strategic role (Slack, Chambers, & Johnston, 2013, p. 70).

Operations are not the same as operational, it is strategic.

Business Strategy: A long-range plan for a business

In an organization, there exist three levels of strategy and it is illustrated in Figure 2.1.

Figure 2.1 Hierarchy of Strategy (Wheelen et al., 2017, p. 50)

Corporate level strategy is the top level of strategy. If there are more than one businesses unit in an organization, corporate level strategy come into play and specifies what these businesses should be, which resources are necessary and how they will be allocated, and how the business units and corporate center will be connected and managed.

In the middle, in business level strategy, the strategy is concerned with a particular business unit, and it specifies how this business unit should compete within its market, and what its strategic goals and objectives should be. In organizations with a single business, corporate level strategy and business level strategy are the same.

The bottom level strategy is called functional level strategy and it is primarily concerned with the individual functions like operations, marketing, finance, etc. This strategy is developed to support the business strategy, to define the strategic objectives of each function, and the allocation of resources in order to achieve those objectives (Barnes, 2008, p. 23).

Business strategy is based on the strategic decisions of managers who are responsible for considering many factors. These decisions include (1) defining a mission, (2) making environmental scanning, and (3) identifying and developing the company's core competencies which are also called as the company's strength. Since these three factors are vital for the business strategy, these three factors will be the focus of the following section (Krajewski, Ritzman, & Malhotra, 2015, p. 29; Reid & Sanders, 2012, p. 32).

Mission

A company's *mission* is the reason or purpose of its existence. Mission statement basically has to answer three questions which draw the boundaries and focus of the organization (Stevenson, 2014, p.47; Reid and Sanders, 2012, p.32). These questions are:

1. What will be the business of the company? ("selling smartphones", "producing goods" etc.)
2. Who are the consumers and what are their known habits for buying? ("graduates", "undergraduates" etc.)
3. How will the company contribute to the business? ("by providing the highest customer service" etc.)

The mission statements of the some well-known companies are stated below (Stevenson, 2014, p. 44; Reid & Sanders, 2012, p.33):

Microsoft:	To help people and businesses throughout the world to realize their full potential.
Dell Computer Corporation:	To be the most successful computer company in the world
IBM:	To translate advanced technologies into values for our customers as the world's largest information service company
Starbucks:	To inspire and nurture the human spirit—one cup and one neighborhood at a time.

A mission statement is a statement that adds more details to the mission in order to draw the scope of the mission (Stevenson, 2014, p.47). If a company has not a well-defined mission, it may lead to focus on opportunities about which the company has no experience, and consequently, it may lead to miss opportunities altogether.

Mission: The reason for the existence of an organization.

Environmental Scanning

The second vital factor for business strategy is *environmental scanning*. Environmental scanning could be defined as the process of monitoring the environment in which the company operates (Reid & Sanders, 2012, p.33). This environment changes continually and the company has to adapt to the changes as quick as possible. In the process of scanning the external environment, managers are monitoring the trends in the market, industry, and society for opportunities and threats. In order to have and/or maintain a competitive advantage, companies need an environmental scanning process (Krajewski, Ritzman, & Malhotra, 2015, p.29; Reid & Sanders, 2012, p.33).

Environmental Scanning: Monitoring the external environment for changes and trends..

External environment also includes economic trends, technological changes, and political and social changes (Krajewski, Ritzman & Malhotra, 2015, p.29; Reid & Sanders, 2012, p. 34). To remain competitive companies have to be ready to update their business strategy in the light of environmental scanning, because it allows them to identify the opportunities and threats. If there is a gap between the needs of the customers and the offers of our competitors, this gap will be an opportunity for our company and we can change our business plan accordingly. On the other hand, our company may be the leader of its industry, but while monitoring the environment we can realize that our competitors are meeting the requirements of the customers better than us. In this case we have to consider this threat and change our strategy in order to be competitive.

In today's highly competitive environment, it is obvious that just because a company is the leader of its industry does not mean it will continue to be a leader in the future (Reid & Sanders, 2012, p. 33). To have and/or maintain their competitiveness, companies must consider the changing trends and patterns in the environment. One of these trends is marketplace trends. These trends include the changes in customers' needs and expectations; and ways used in meeting those expectations by our competitors. Based upon the environmental scanning companies could see the trends in the market and update their business strategies in order to remain competitive. Another trend in marketplace is the changes in the use of technology, such as point-of-sale scanners, automation, computer-assisted processing, electronic purchasing, and electronic order tracking. One rapidly growing trend is e-commerce. E-commerce has a significant role for retailers (Reid & Sanders, 2012, p. 34).

In addition to marketplace trends, companies also consider economic, politic, and social trends and the availability of resources (Krajewski, Ritzman & Malhotra, 2015, p. 29; Reid & Sanders, 2012, p. 34). Economic trends that affect the business could be a recession, inflation, interest rates, and general economic conditions.

Political trends are related to the changes in local, national, and international relations that affect the business. For example, as a result of globalization companies seek customers and suppliers all over the world. Many of them form partnerships with international companies which are called strategic alliances in order to take the advantage of being global. Social trends include changes in society. An example of this trend could be the awareness of the danger of smoking, which affects the tobacco industry. In order to survive companies in tobacco industry change their strategy and seek customers from different countries where smoking is still socially acceptable and they diversified their product lines (Reid & Sanders, 2012, pp.34-35). Finally, changes in vital resources may lead to redesigning the business strategy. For instance, since oil reserves are limited, automobile manufacturers designed cars

that use hydrogen and electricity as an alternative supplement to gasoline as fuel (Krajewski, Ritzman, & Malhotra, 2015, p. 29).

Core Competencies

The third important factor in business strategy is the understanding of the company's strengths (Reid & Sanders, 2012, p. 35). In order to define a long-term plan, good managerial skills are not enough; companies also need to take the advantage of what they do well when compared with their competitors. That is called the organization's *core competencies*, in other words, unique strengths of organizations (Krajewski, Ritzman, & Malhotra, 2015, p.30).

Core Competencies: The unique strengths of a business.

Core competencies include:

1. **Workers:** Skilled, responsive, creative and flexible workers with strong technical capability allow organizations to respond to the needs and expectations of the customers on time. As the customers are directly connected to the employees, this competency is more important in service companies.
2. **Facilities:** The location of the facilities could be an advantage because of building new facilities need a long lead time. Besides, if the facilities could adapt the changes in variety and level of volume of products and services, in other words if the facilities are flexible, companies could gain a competitive advantage.
3. **Market & financial know-how:** Companies those can easily attract and raise capital from stock sales, market and distribute its service or products, or differentiate their products from similar services and products will gain/sustain a competitive advantage.
4. **Systems & technology:** An organization that has expertise in information systems, internet technologies and applications; latest production technology and quality control techniques will also have a big competitive advantage (Krajewski, Ritzman, & Malhotra, 2015, p. 30; Reid & Sanders, 2012, p.35).

SWOT

In order to formulate an effective strategy, companies need to make a situational analysis that examines the internal and external environment of the company. They must consider all the factors that could have either positive or negative impacts. For example, they have to question what the competitors are doing, or planning to do, and how they could respond to these plans with their strengths and weaknesses. This approach is called 'the SWOT approach' which is the acronym of strengths, weaknesses, opportunities, and threats (Stevenson, 2014, p. 47).

After performing the SWOT analysis the company shows the results in a four box table, and uses the findings to define the main issues that must be addressed in strategic plans (Whalley, 2000, pp. 66-67). Figure 2.2 illustrates a four box SWOT table.

	Positive	Negative
Internal factors	Strengths	Weaknesses
	- Technological skills - Leading brands - Distribution channels - Customer loyalty/relationship - Production quality - Scale - Management etc.	- Absence of important skills - Weak brands - Poor access to distribution - Low customer retention - Unreliable product/service - Sub-scale - Management etc.
External factors	Opportunities	Threats
	- Changing customer tastes - Liberalization of geographic markets - Technological advances - Changes in government politics - Lower personal taxes - Change in population age structure - New distribution channels etc.	- Changing customer tastes - Closing of geographic markets - Technological advances - Changes in government politics - Tax increases - Change in population age structure - New distribution channels etc.

Figure 2.2 SWOT Table (Whalley, 2000, p. 67)

In order to convert the SWOT analysis results to action plans, companies have to ask themselves some key questions. These questions are illustrated in Figure 2.3 which is called as advanced or enhanced SWOT analysis.

	Strengths	Weaknesses
Opportunities	How do I use these strengths to take advantage of these opportunities?	How do I overcome the weaknesses that prevent me taking advantage of these opportunities?
Threats	How do I use my strengths to reduce the likelihood and impacts of these threats?	How do I address the weaknesses that will make these threats a reality?

Figure 2.3 Enhanced SWOT Analysis Table (Whalley, 2010, p. 67)

Learning Outcomes

1 To define the business and operations strategies.

Self Review 1	Relate	Tell/Share
What is the role of business strategy in defining a company's long-term plan?	Associate business functions with long-range plans.	Tell the decisions that are made in defining the business strategy: mission, environmental scanning, and the company's core competencies.

OPERATIONS STRATEGY AND THE RELATIONSHIP BETWEEN OPERATIONS STRATEGY AND BUSINESS STRATEGY

Business strategy provides a broad scope for the entire organization which provides an overall direction for the organization. Operations strategy has a narrow scope since it relates primarily to the operations of an organization (Stevenson, 2014, p.51). Once a business strategy has been developed, an operations strategy must be formulated. Operations strategy could be defined as a plan that is designed for operations function that supports the business strategy (Reid & Sanders, 2012, p.31). The term 'operations strategy' sounds at first like 'operational' which emphasize day-to-day activities while 'strategy' is usually regarded as the opposite of daily routine activities. But operations is not the same as 'operational', operations have a strategic role (Slack, Chambers, & Johnston, 2013, p.70). Operations strategy deals with products, processes, methods, resources, quality, cost, lead time and scheduling (Stevenson, 2014, p. 51).

The Role of Operations Strategy in the Organizations

Until the 1970s and early 1980s, operations strategy was often neglected by United States companies. Until then,companies focused primarily on marketing and financial strategies, and they emphasized mass production which means producing standard products in big quantities (Reid & Sanders, 2012, p. 31-32; Stevenson,2014, p.52).

Many of the managers did not have an operations background and therefore they did not fully appreciate the importance of the operations function (Stevenson, 2014, p.52). After 1980s Japanese companies began offering low-cost and high-quality products, U.S. companies started to lose market share to their Japanese competitors. In order to survive, many U.S. companies started to copy Japanese approaches. But the copying process often proved unsuccessful, because it really took time to understand the Japanese approaches. It became clear that the success of Japanese companies is based on their operations strategy; which means that all their resources were designed to support the company's business plan.

Harvard Business School Professor Michael Porter says that companies often do not understand the differences between *operational efficiency* and *strategy*. Operational efficiency could be defined as

performing operations well when compared to the competitors. But a strategy is a plan for competing in the market. Operational efficiency and strategy must be linked; otherwise the company could be *very efficient but perform the wrong task*. Operations strategy assures that all the tasks performed by the operations function are the *right tasks.*

The Relationship Between Operations Strategy and Business Strategy

In practice, many of the companies consider that the operations strategy will improve their operations performance over time. In order to do this, companies should change their position where they contribute very little to competitiveness of the business to the point where they are directly responsible for the competitiveness of the company. This change could be defined as changing the master skills to first 'implement', than 'support', and then 'drive' the operations strategy.

Implementing Business Strategy

The main and the basic role of operations function is to implement the business strategy. You know there is a strategy, but you cannot touch it and you cannot even see it; all you can see is how the operation behaves in practice. For instance, just think an insurance company whose business strategy is moving to an entirely online service; the operations function of this company will have to support the design of all the processes which allow customers to access online information, issue quotations, request further information, check credit details. Send out documentation etc. If the implementation process is inefficient; even the most original and brilliant strategy will be failed and totally ineffective.

Supporting Business Strategy

Supporting strategy allows the organization to improve and achieve its strategic goals by developing their capabilities. For example, if a mobile phone manufacturer aims to be the first in the market with new product innovations, it needs to improve the capability of coping with instant innovation. To provide novelty, the organization must develop flexible processes, hire workers who understand new technologies, and improve supplier relations in order to supply new parts to the customers as quickly as possible.

Driving Business Strategy

The third and the most difficult strategy is driving business strategy. In this strategy, the role of operations is to drive strategy by giving it a unique and long-term advantage. For example, if a specialist food service company supplies restaurants frozen fish and fish products, it has to build up close relations with the customers and suppliers around the world. Besides, it has a small factory in which it develops and produces exciting new products. In this case, the success of the company is derived from its unique operations capabilities and it means the operations drive the business strategy (Slack, Chambers, & Johnston, 2013, pp. 70-71).

Operations should try to implement, support and drive the business strategy.

The Contribution of Operations to Business Strategy: Hayes and Wheelwright's Four Stages of Contribution

Harvard university professors Hayes and Wheelwright proposed a four stage model for evaluating the role and the contribution of the operations to business strategy. The model illustrates the progress of the operations function from the negative role (stage 1) to being the central element of competitive strategy (stage 4). The stages are shown in Figure 2.4.

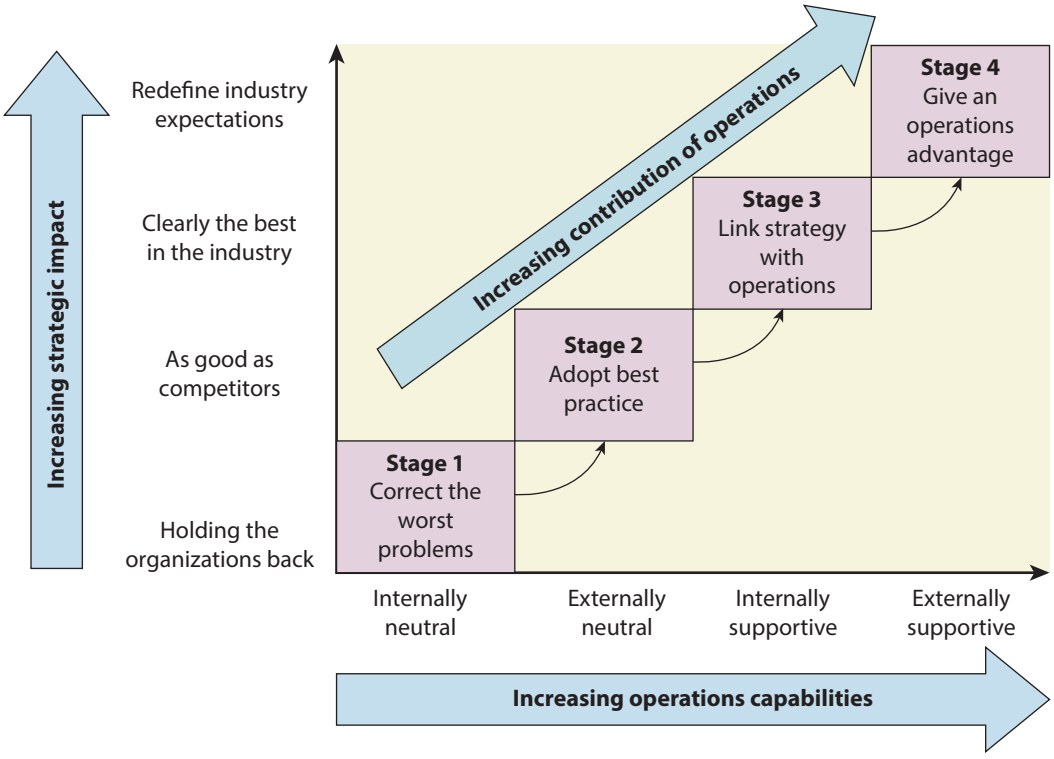


Figure 2.4 The Four-Stage Model of Operations Contribution (Slack, Chambers, & Johnston, 2013, p. 72)

Stage 1: Internal Neutrality

In this stage, the contribution of operations function is at the poorest level. The contribution of operations function to competitive success is very little or it is holding the company back from competing well. It is inward-looking which means the main goal in this stage is being internally neutral. It only attempts to improve competitiveness by 'avoiding making mistakes'.

Stage 2: External Neutrality

In this stage, the operations function begins comparing itself with similar organizations in the outside market. Therefore it is called as 'external neutrality'. By comparing itself against its competitors' performance, operations function tries to implement best practice.

Stage 3: Internally Supportive

However the operations are of the best among the others in the market in Stage 3, they are not the very best. Stage 3 operations are trying to use a clear view of the organization's competitive and strategic goals, and develop appropriate operations resources.

Stage 4: Externally Supportive

In stage 4, operations are seen as the source of the company's competitive success. Operations look to the long term, they forecast the changes in the market and supply, and based upon these future conditions they develop operations-based capabilities. Hayes and Wheelwright are calling this stage as 'externally supportive' because the operations are innovative, creative and proactive, and driving the company's position one step ahead of its competitors (Slack, Chambers, & Johnston, 2013, p. 71-72.)

Perspectives on Operations Strategy

Different authors proposed different perspectives on operations strategy. Between them four perspectives emerge: top-down perspective, bottom-up perspective, market requirements perspective, and operations resources perspective.

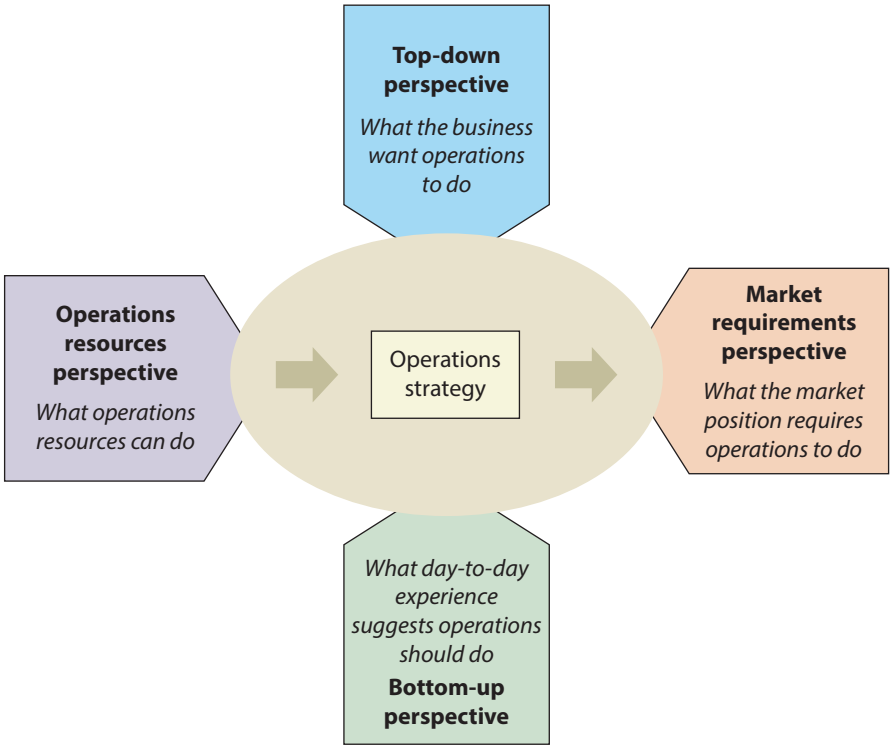


Figure 2.5 The Four Perspectives on Operations Strategy (Slack, Chambers, & Johnston, 2013, p. 73)

Top-down Perspective

According to this perspective operations strategy is developed with regard to the company and its competitive strategy (Gupta & Starr, 2014, p. 44).

This approach supports the organization's business strategy; in other words, the operations strategy is used for realizing the business strategy. This perspective is in line with Stage 3: internally supportive.

For a multi-business organization, the top-down perspective advocates that operations strategy is linked to corporate strategy via the business strategy of each business unit (Barnes, 2008, p. 32). Based upon the top-down perspective, operations strategy need to consider what part each function should play in contributing to the strategic objectives of the business (Slack, Chambers, & Johnston, 2013, p.73).

important

Corporate Strategy ⇒ Business Strategy ⇒ Operations Strategy

'Bottom-up' Perspective

In the 'bottom-up' perspective, the organization learns from its experiences, develop and enhance its operational capabilities (Barnes, 2008, p.32). The organization may also incorporate the ideas which come from daily operations (Slack, Chambers, & Johnston, 2013, p. 74).

important

Operations Strategy ⇒ Business Strategy ⇒ Corporate Strategy

Market Requirements Perspective

In this perspective, operations strategy is developed for responding to the market requirements in which the organization operates. Understanding the market requirements makes it possible to achieve the right priority between the operational performance objectives such as cost, quality, time, flexibility. These objectives are defined as competitive factors or competitive priorities (Slack, Chambers, & Johnston, 2013, p. 77).

important

Market Requirements ⇒ Operations Strategy

The Operations Resources Perspective

In this perspective operations strategy fits with the resource-based view (RBV) of the organization and it is in line with Stage 4: externally supportive (Barnes, 2008 p. 33). In RBV, it is believed that firms with an 'above average' performance gain competitive advantage from their resources. In other words, the operations resources are effective on the organization's strategic success so understanding the importance of developing the capabilities of operations resources will be an important perspective on operations strategy (Slack, Chambers, & Johnston, 2013, p. 82).

important

Operations Resources ⇒ Important operations resources ⇒ Operations Strategy

Learning Outcomes

2 To explain the role of operations strategy in the organizations and the relationship between operations strategy and business strategy

Self Review 2	Relate	Tell/Share
How can the operations strategy contribute to the competitiveness of the business?	Associate operations strategy with business strategy.	Tell Hayes and Wheelwright's four stages of contribution by defining different roles of operations function in an organization.

DEVELOPING AN EFFECTIVE OPERATIONS STRATEGY

Organizations may evaluate the effectiveness of their operations strategy according to the value that is created for their customers. In order to understand the competitive position of the company in its market, operations managers have to develop close relations with marketing and based upon this information they have to decide on competitive priorities which are important for their organization (Reid & Sanders, 2012, p. 37).

Skinner (1969) identified four main competitive priorities. These are cost, quality, delivery, and flexibility.

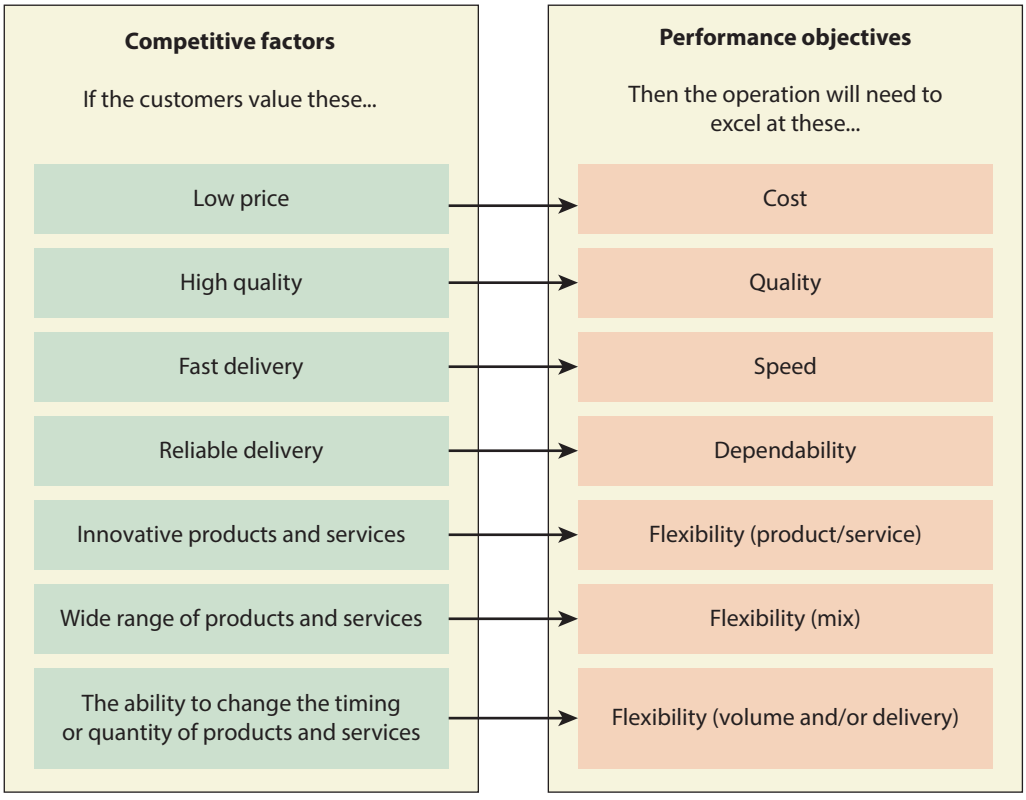


Figure 2.6 Different Competitive Factors Imply Different Performance Objectives (Slack, Chambers, & Johnston, 2013, p. 77)

1. Cost: Competing on cost means delivering a service as a product at the lowest cost when compared with competitors' services or products (Krajewski, Ritzman, & Malhotra, 2015, p. 32; Reid & Sanders, 2012, p. 37). This type of competition emerges from the business strategy. And operations strategy is responsible for developing a plan for the efficient use of resources to support this type of competition. It is important to rate that low cost does not mean high profit and it does not imply low quality. In this type of competition, the operations function must focus on cutting costs such as labor costs, material costs, facilities costs, etc. Also, companies that compete on cost must carefully eliminate the waste in the system. They have to train their employees in order to maximize their productivity and minimize waste. Automation will also be a way for increasing productivity, because in general companies that compete on cost offer a narrow range of products and product features allow for a little customization (Reid & Sanders, 2012, s. 38).

important

Companies that compete based on cost offer a narrow range of products and product features.

2. Quality: As a precondition of competitiveness in global markets, quality can be generally defined as satisfying the requirements of the customers with the launched product, conformance to

specifications and being free of error (Li, 2000; Forker et al., 1996; Krajewski & Ritzman, 2005; Akal, 1998).

Quality as a competitive priority has two dimensions (Reid & Sanders, 2012, p.39). One of them is top quality which means delivering superior product features, close tolerances, greater durability for goods and high level of customer contact, helpfulness, courtesy, and availability of servers for services (Reid & Sanders, 2012, p. 39; Krajewski, Ritzman, & Malhotra, 2015, p. 32). The second dimension is called as consistent quality. It means producing services or products that meet design specifications consistently.

A company that competes on quality needs to implement quality both in product design and processes. Product design involves making sure that the product meets the requirements of the customer. On the other hand, process quality based on designing a process to produce error-free products. In order to provide such a process, the organizations have to focus on equipment, workers, materials and etc. Companies that compete on quality, have to address both of these issues which means that the product must be designed to meet customer expectations, and the process must produce the product exactly as it is designed (Reid & Sanders, 2012 , s.39).

Companies that compete based on quality offer superior product designs consistently.

3. Time: The ability to provide high-quality products in a short time as possible. Time is one of the most important competitive priorities today since today's customers can't wait.

This priority is also emphasized as delivery in the literature. In this type of competition all-time related issues have to be satisfied such as rapid-delivery and on-time delivery. Rapid delivery refers to how quickly an order is received, and on time delivery refers to how often deliveries are made on time. Speed, another time related to competitive priority is the time needed to take an idea to the marketplace. Speed is an important priority for information technology. In order to shorten the time, the task of operations function is analyzing the system and finding the non-value added time, and based upon these findings eliminating or integrating the processes if possible. Another option could be using automation in processes in order to speed up them (Reid & Sanders, 2012, p. 39).

Especially logistics companies compete on time. They are trying to deliver the packages and/or products on time and they are using technologies such as barcode or RFID systems. So they can speed up processing and handling.

Time is a competitive priority that encompasses the production time, delivery time, and time-to-market for new products

4. Flexibility: Flexibility is defined as adapting to the changes occurred in the preferences of the customers easily and quickly (Amoako-Gyompah, 2003). There are two dimensions of flexibility. One is product flexibility which is defined as the ability to offer a wide variety of goods or services and customization of them to the requirements of the customers. Another one is called volume flexibility which means the ability to change the amount of production according to demand changes.

For example, if you consider a custom tailor, he will be more flexible than a retailer. Another example would be going to a fire restaurant and asking for a meal that is made just for you. These examples are examples of flexible companies who accommodate customers' wishes.

Companies that compete based on flexibility should adapt the changes in the market as quick as possible.

As providing customization takes time, companies that compete based on flexibility could not compete based on speed. Also, they do not compete based on cost because it may take more

resources to customize the products or services. Since flexible companies are producing different kinds of products they have to use more general-purpose equipment, and qualified workers (Reid & Sanders, 2012, p. 40).

The Need for Trade-Offs

The companies could not excel simultaneously on all four competitive priorities. Therefore, top management has to decide which priority/priorities is /are critical to the companies' success, and based on this decision resources will be allocated. Here the operations function must place emphasis on the priorities that directly support the business strategy. That means there is a need to make *trade-offs* between the different priorities.

If you consider a company who delivers high quality products, the company could not offer the lowest price for the products. In this case, the company makes a trade -off between quality and cost. Similarly, a company that competes on flexibility may not be able to provide the highest speed. Here, the company makes a trade-off between flexibility and speed (Reid & Sanders, 2012, pp. 40-41).

For large facilities, Skinner (1974) suggested using the "plant-within-a-plant" (PwP) approach. In this approach facilities are divided into plants which have its own facilities and focused on a particular task. Therefore, each plant can concentrate on different priorities for different products.

Trade-off: The need to focus more on one competitive priority than on others.

Learning Outcomes

3 To explain the approaches in developing the operations strategy

Self Review 3	Relate	Tell/Share
How can an effective operations strategy be developed?	Associate the operations strategy with business competitiveness.	Tell which competitive priorities are important for the customers.

PRODUCTIVITY

As mentioned before, an effective business strategy and a supporting operations strategy contribute to the competitiveness of the company in its market. The main questions here could be how to measure competitiveness. One of the most well-known and accepted way is measuring *productivity* (Reid & Sanders, 2012, p. 44).

As a basic measure, productivity is used in evaluating economies, industries, firms and processes. If a company wants to improve its processes and supply chain in order to compete against their competitors, operations managers have to consider improving the productivity (Krajewski, Ritzman, & Malhotra, 2015, p.36). roductive companies are using their resources effectively (Stevenson, 2014, p.56). Productivity is measured by a ratio of outputs (goods and services) divided by the inputs (labor, materials energy, capital, etc.) (Heizer, Render & Munson, 2017, p. 51; Stevenson, 2014, p. 56). It is usually expressed as the ratio:

Productivity=Output/Input

In order to improve productivity, companies can choose one of the two ways. The first one is reducing inputs while keeping the output constant and the second one is increasing the output while keeping the inputs constant (Heizer, Render, & Munson, 2017, p. 51).

With the use of the productivity equation, companies could measure total productivity, single factor productivity or multi-factor productivity.

Further Reading

Tomorrow's Factories Will Need Better Processes, Not Just Better Robots

When people think of the automotive Factory of the Future, the first word that comes to mind is automation. They think of the "lights-out" factory that General Motors Chief Executive Roger Smith fantasized about in 1982 and Elon Musk talks about building today—plants so dominated by robots and machines that they don't need lights to work.

There's no doubt that the auto industry will continue to vigorously pursue automation solutions to lower the cost of producing cars. But the reality is that any major leap forward on cost and efficiency will no longer be possible through automation alone, since most of the tasks that can be automated in an automotive factory have already been tackled.

When a real Factory of the Future arrives, it will not look different because we have automated the processes we use today. It will look different because we will have invented entirely new processes and designs for building cars requiring entirely new manufacturing techniques.

Take the paint shop. Today, in most mature markets, it's more than 90 percent automated, yet it is still one of the most expensive and space-intensive sections of the factory. Robots, instead of humans, perform most tasks—applying protective corrosion coats, sealant, primer, basecoat, and clear coat to achieve the highly polished finishes we like on our cars—but the process itself is not that different than what it was 30 years ago. For instance, in the BMW plant in Spartanburg, South Carolina, processing a car through the paint shop is a 12-hour task, involving more than 100 robots, and requiring a vehicle in the paint assembly line to travel four miles within the factory before the process is complete.

Clearly, there has to be a better way to paint a car, but to make that operation more efficient and take cost out will require the development of a new process. Perhaps it will be the experimental approach of applying a single film over the car and then baking it on, like in a pottery kiln—currently being tested in automotive research labs. Or 3-D printing of the entire car body in the color a customer orders, completely eliminating the need for a traditional paint shop and body shop. Whatever it is, it will have to be more than adding a few more robots into the mix to make a significant difference in the cost of producing an auto.

Today, two-thirds of automotive workers—the human ones—are in the general assembly section. Automating this section has proved more difficult because the customization and complexity of today's autos require the flexibility humans provide. Most factories are producing several models of cars simultaneously, and the mix of those models is often changing depending on demand. It would be expensive, if even possible, to reprogram robots and machines to be able to accommodate daily changes in factory production schedules.

There are also some tasks on the assembly line for which humans are better suited, such as handling all of the intricacies of installing and connecting a car's wire harnesses—the nervous system of a vehicle. With a future market expected to consist of electric and autonomous vehicles,

the electrical systems will need to transmit more data faster and unfailingly, compared to today's car. The consequence to the assembly plant: more wires and connectors leading to longer, heavier wire harnesses. For this operation to be automated would again require a new process—perhaps going wireless, with the electrical systems operating via electronic modules or connecting via the cloud.

A new process will also need to be developed to assemble electric vehicles since they involve the relatively uncomplicated installation of the battery pack and an electric motor. Simpler tasks may lend themselves better to robots, but several steps on the line will also be bypassed. The leap forward will be accomplished through the development of a new process—in this case, electrifying the auto—not automating an old one.

New collaborative robots, or cobots, are also adding a new twist: Instead of threatening the survival of humans on the assembly line by replacing them, cobots enhance their native abilities. Ranging in size from two to four feet high, these automated assistants work with humans to perform tasks that perhaps are slightly dangerous or repetitive, or that require a special agility to work in tight or hard to reach places, such as working underneath autos. For instance, Renault has deployed cobots in a few plants to help build the powertrain—torquing bolts to a certain tolerance, a task that can be tedious for humans to do consistently and efficiently.

Making these small helpers attractive to companies, cobots can be relatively inexpensive, often costing under $50,000 each. They are simple to reprogram—workers on the assembly line can often handle the reprogramming on their own. This allows them to be re-tasked quickly, again adding to their value and versatility.

Unlike much of the current robotic automation that must be kept fenced in, with safety signs warning employees to keep their distance, cobots perform tasks in factories without hurting humans as they are programmed to stop when there is an object in front of them. With their swing arms, they can retrieve certain small parts from bins for their human partners.

Another example of automation that enhances humans' native abilities is the exoskeleton. Workers wear these cyborg-esque contraptions to make them strong enough to lift heavy truck tires or ease the stress on their bodies when performing repetitive overhead assembly tasks. This wearable automation becomes particularly important as the average age of production workers rises above 40 as it has in many industrialized economies, such as the United States, Western Europe, and Japan.

Roger Smith's dream of a lights-out factory has only been realized in a very few operations—robots building robots, for instance—and not in the automotive world. But there are other roads to the automotive Factory of the Future that will likely be paved with human invention, and while robots and automation will be part of the picture, the lights will still be on.

Source: R Harbour, & J Smith, 2018, May 11.

Productivity: A measure of how efficient the organization converts inputs to outputs.

Productivity Measurement

Operations management is responsible for managing the transformation process of all inputs into outputs (goods and services). Productivity is a measure of how efficiently inputs are being converted to outputs, in other words productivity is a measure of how well resources are used (Reid & Sanders, 2012, p. 44).

As a manager, many measures of productivity may be used. For example, the manager can measure the value of output by what the customers pay or simply by the amount of the products or customers served. The value of inputs is measured by cost or by the number of hours worked (Krajewski, Ritzman, & Malhotra, 2015, p.37).

Productivity measures can be based on a single input (*partial productivity*), more than one input (*multifactor productivity*), or on all inputs (*total productivity*) (Stevenson, 2014, p. 57).

The measurement of partial, multifactor, and total productivity examples are at the below.

Total Productivity

When we calculate productivity for all inputs such as labor, machines, and capital, it means we are measuring *total productivity*. For example, let's say that the weekly dollar value of a company's output is $10,200, and the value of all inputs such as labor, materials, and capital is $8,600 then the total productivity of the company is computed as follows (Reid & Sanders, 2012, pp. 44-45).

$$\text{Total Productivity} = \frac{Output}{Input}$$

$$Total\ Productivity = \frac{\$10{,}200}{\$8{,}600} = 1.186$$

Total Productivity: The ratio of output to all inputs.

Partial Productivity

Partial productivity is called as single factor productivity. The main aim of measuring the productivity of a single input is identifying how efficient this factor is being used. Partial productivity is called according to the single factor that is calculated. Following are examples of the partial productivity calculations:

1. If a bakery oven produces 346 pastries in 4 hours, machine productivity is calculated as:

$$Machine\ Productivity = \frac{(No.of\ pastries)}{(Oven\ time)}$$

$$Machine\ Productivity = \frac{346}{4}$$

Machine Productivity=86.5 pastries/hour

2. Two workers are painting tables in a furniture shop. They are painting 22 tables in 8 hours. What will be the productivity? (Reid & Sanders, 2012, p. 45).

Partial Productivity: The ratio of output to only one input.

Multifactor Productivity

Multifactor productivity is a measure of the ratio of output divided into a group of inputs, such as labor and materials. For example let's say output worth $382 and labor and materials costs are $168, and $98 respectively. Multifactor productivity is calculated by (Reid & Sanders, 2012, p. 34):

Table 2.1 Examples of partial productivity measures (Reid & Sanders, 2012, p. 70)

Business Type	Productivity Measure
Restaurant	$\frac{\text{Customers served}}{\text{Labor-hour}}$ *or* $\frac{\text{Customers served}}{\text{Square foot}}$
Hospital	$\frac{\text{Patients}}{\text{Hospital bed}}$ *or* $\frac{\text{Patients}}{\text{Nurse-hour}}$
Amusement park	$\frac{\text{Visitors}}{\text{Square foot}}$ *or* $\frac{\text{Visitors}}{\text{Attraction}}$
Cattle ranch	$\frac{\text{Cattle}}{\text{Pound of feed}}$ *or* $\frac{\text{Cattle}}{\text{Acre of land}}$
Garment manufacturer	$\frac{\text{Sweaters}}{\text{Pound of yarn}}$ *or* $\frac{\text{Sweaters}}{\text{Machine-hour}}$

Multifactor Productivity: The ratio of output to several, but not all, inputs.

Interpreting Productivity Measures

Interpreting the productivity measure means comparing it with a similar productivity measure. For example, if we think of a pizza shop and we know that one worker can produce 17 pizzas in two hours. We can calculate the workers productivity as 8.5 pizzas per hour. This number by itself would not tell us very much. But if we can compare the productivity ratios of this worker with two other workers, let's say one is producing 7.2 pizzas per hour and another 6.8 pizzas per hour, it would be more meaningful. In this case we can say the first worker is much more productive than the other two workers. However in order to know if the productivity of these three workers is reasonable, we need a standard. The standard will also be helpful to measure and compare productivity over time. For example, if we have a chance to get and compare weekly productivity measures for last four weeks, we can get much more information.

Week	1	2	3	4
Productivity (pizzas/labor-hour)	5.4	6.8	7.1	7.5

From the table we can see the productivity improvement easily. It is changed from 5.4 to 7.5 pizzas per labor-hour, which results in an increase of 7.5/5.4=1.39 or an increase of 39 percent. But if we learned that our competitors' worker productivity is 9.5 pizzas per hour, then we can calculate the productivity of our competitor is 26.7 percent (9.5/7.5 =1.267) higher than us in week 4. According to these results we may analyze our processes and increase our productivity in order to compete.

Companies have to consider their competitive priorities in order to evaluate their productivity and set standards for their performance. For example, a company that competes on speed would probably measure productivity in terms of units produced over time. But a company that competes based on cost might measure productivity in terms of costs of inputs (labor, materials, and overhead costs).

In other words, productivity measure provides information on how we are doing relative to the competitive priority of our company (Reid & Sanders, 2012, pp. 47).

important

In order to evaluate their productivity, companies have to consider their competitors' productivity levels and set standards.

Productivity and Competitiveness

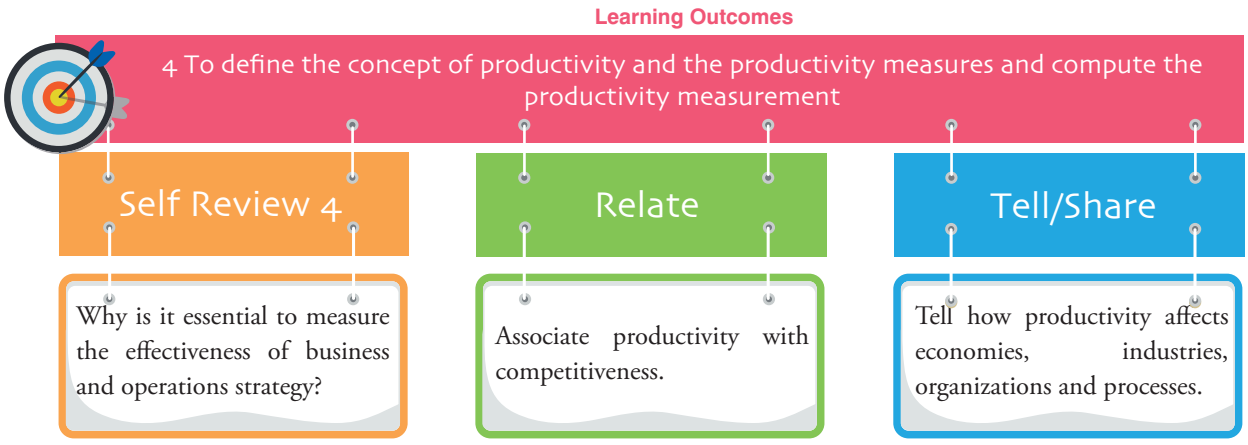
Productivity is a measure used by individuals, department or organizations. Similarly, it can be measured for an entire industry and even a country.

The economic success of a nation and the quality of life of its citizens are related to its competitiveness in the global markets. Increase in productivity brings increase in a nation's standard of living. Therefore, business and government leaders always monitor the productivity at the national level and by industry sectors.

Productivity and the Service Sector

Since service sector companies are producing an intangible product, it makes the productivity measurement difficult. For example, if we consider an emergency room, we can see that there are inputs such as a medical staff, but there may not be an output if no one needs treatment on that day/shift.

If we use traditional productivity measures, the productivity will be zero. In this type of production, in service sector, the real issue has to be the level of readiness and adequate measurement (Reid & Sanders, 2012, pp. 47-48).



LO 1 Define business and operations strategies.

In today's highly global and competitive market environment, companies should have strategic (long-term) plans in order to remain competitive. Business strategy provides a direction for the organizations. Once a business strategy has been developed, functional strategies must be formulated according to this long-range strategy. Operations strategy is defined as a plan for using the resources effectively.

LO 2 Explain the role of operations strategy in the organizations and the relationship between operations strategy and business strategy

Operations strategy will improve the operations performance of the organizations and this improvement will contribute to the competitiveness of the company. In the first step of the contribution, the role of operations function is basically implementing the business strategy. In the second level, operations function supports the business strategy by developing the capabilities. And at the top level, operations function drives the business strategy. As the levels increase, the competitiveness of the company improves. Beyond the contribution levels, there are different perspectives on operations strategy. Between the four perspectives emerge: "top-down perspective", "bottom-up perspective", "market requirements perspective", and "operations resources perspective".

LO 3 Explain the approaches in developing the operations strategy

Organizations may evaluate the effectiveness of their operations strategy according to the value that is created for their customers. In order to understand the competitive position of the company in its market, operations managers have to develop close relations with marketing and based upon this information they have to decide on competitive priorities which are important for their organization. Four main competitive priorities are identified in the operations management literature: cost, quality, delivery, and flexibility.

LO 4 Define the concept of productivity and the productivity measures and compute the productivity measurement

Productivity is expressed as the ratio of output to input. Productive companies are the organizations that are using their resources effectively. Productivity can be measured by a single output. It is called as partial productivity and shows how efficient this factor is used. When all inputs are used while calculating productivity, this type of productivity is called total productivity. And the third measure of productivity is called multifactor productivity which uses a group of inputs such as labor, materials, etc. in the computation of productivity.

Test Yourself

1 Which one of the following could not be considered as a functional strategy?

a. Financial strategy
b. Marketing strategy
c. Human resources strategy
d. Operations strategy
e. Business strategy

2 Which of the following statements is true of mission?

a. It is an ambitious desire for the future.
b. It tends to grow and change in the face of environmental shifts.
c. It defines the company's core values and reason for being.
d. It cannot work together with a company's vision
e. It is the strategy of the company

3 Which one of the following is true?

a. Corporate mission is shaped by functional strategies.
b. Corporate strategy is shaped by functional strategies.
c. Functional strategies are shaped by corporate strategy.
d. External conditions are shaped by corporate mission.
e. Corporate mission is shaped by functional strategies.

4 According to the Hayes and Wheelwright model, the increasing contributions of operations to business strategy are:

a. External neutrality / internal neutrality / externally supportive / internally supportive
b. Internal neutrality / external neutrality / internally supportive / externally supportive
c. Internal neutrality / internally supportive / external neutrality / externally supportive
d. External neutrality / externally supportive / internal neutrality / internally supportive
e. Internal neutrality / externally supportive / internally supportive / external neutrality

5 Which one of the following is suitable for a company as a competitive priority if the company frequently introduces new products/services?

a. Quality b. Cost
c. Speed d. Flexibility
e. Marketing

6 In which perspective operations strategy is developed with regard to the corporate and/or business strategy?

a. Market requirements b. Operations resources
c. Top-down d. Left to right
e. Bottom-up

7 What is the ratio of outputs (goods and services) divided by two or more inputs (such as labor, management or capital)?

a. Production
b. Productivity
c. Multifactor productivity
d. Total factor productivity
e. Single factor productivity

8 When does productivity increase?

a. Inputs increase while outputs remain the same
b. Inputs decrease while outputs remain the same
c. Outputs decrease while inputs remain the same
d. Inputs and outputs increase proportionally
e. Inputs increase more than outputs

9 A firm produces 200 units using 800 labor hours. What is its labor productivity?

a. 0.125 units/hour b. 0.25 units/hour
c. 100 units/hour d. 200 units/hour
e. 800 units/hour

10 Which one of the following does define environmental scanning?

a. protecting the environment around a company
b. watching and recording the environment for the purpose of environment control
c. monitoring the external environment of a company to identify business opportunities and threats
d. copying the environment
e. coping with changes in supply

1. e	If your answer is wrong, please review the "Business Strategy" section.
2. c	If your answer is wrong, please review the "Business Strategy" section.
3. c	If your answer is wrong, please review the "Business Strategy" section.
4. b	If your answer is wrong, please review the "Operations Strategy and the Relationship between Operations Strategy and Business Strategy" section.
5. d	If your answer is wrong, please review the "Developing an Effective Operations Strategy" section.
6. c	If your answer is wrong, please review the "Operations Strategy and the Relationship between Operations Strategy and Business Strategy" section.
7. c	If your answer is wrong, please review the "Productivity" section.
8. b	If your answer is wrong, please review the "Productivity" section.
9. b	If your answer is wrong, please review the "Productivity" section.
10. c	If your answer is wrong, please review the "Business Strategy" section.

self review 1

What is the role of business strategy in defining a company's long term plan?

Business strategy is defined as a long range plan that positions the organization in its environment where it operates. In other words, strategy is the long term decisions that help organizations to achieve their long-term goals. These decisions include defining the mission, making environmental scanning, and identifying the core competencies in order to find out the strengths of the company. A company's mission is the reason or purpose of its existence. The second vital factor for business strategy is environmental scanning. Environmental scanning could be defined as the process of monitoring the environment in which the company operates and the third important factor in business strategy is the understanding of company's strengths. In order to define a long-term plan, good managerial skills are not enough; companies also need to take the advantage of what they do well when compared with their competitors. That is called the organization's core competencies, in other words unique strengths of organizations. Business strategy provides a broad scope for the entire organization and each function in the organization should support the business strategy.

Suggested Answers for "Self Review"

How can the operations strategy contribute to business strategy?

self review 2

Operations strategy could be defined as a plan that is designed for operations function that supports the business strategy (Reid & Sanders, 2012, p.31). The term 'operations strategy' sounds at first like 'operational' which emphasize day-to-day activities while 'strategy' is usually regarded as the opposite of daily routine activities. But operations is not the same as 'operational', operations have a strategic role (Slack, Chambers, & Johnston, 2013, p.70). Operations strategy deals with products, processes, methods, resources, quality, cost, lead time and scheduling. Hayes and Wheelwright proposed a four stage model for the contribution of operations strategy to business strategy. These are internal neutrality, external neutrality, internally supportive, and externally supportive. The progress of this model starts with negative role and ends with being a source of competitive strategy.

How can an effective strategy be developed?

self review 3

Organizations may evaluate the effectiveness of their operations strategy according to the value they create for their customers. In order to understand the competitive position of the company in its market, operations managers have to develop close relations with marketing and have to decide on competitive priorities which are important for their organization. Four main competitive priorities are identified in the operations management literature: cost, quality, delivery, and flexibility. Competing on cost means focusing on cutting costs such as labor costs, material costs, and facilities costs, etc. while eliminating the waste in the system. A company that competes on quality tries to design products that meet customer expectations, and manage the process for producing the product exactly as it is designed. In time based competition, all-time related issues have to be satisfied. Based upon this aim, operations function is responsible for analyzing the system and finding the non-value added time. Flexibility has two dimensions: product flexibility and volume flexibility. Product flexibility is is defined as the ability to offer a wide variety of goods or services and customization of them to the requirements of the customers whereas volume flexibility means the ability to change the amount of production according to demand changes.

Why is it essential to measure the effectiveness of business and operations strategy?

self review 4

An effective business strategy and a supporting operations strategy contribute to the competitiveness of the company in its market. The main question is how to measure the competitiveness. One of the most well-known and accepted ways is measuring productivity. Productivity is used in evaluating economies, industries, firms and processes. If a company wants to improve its processes and supply chain in order to compete against their competitors, operations managers have to consider improving productivity. Productivity is a measure that is used by individuals, organizations, for an industry and even a country. The main point in evaluating productivity, is interpreting the measure by comparing it with similar measures. The standards will be helpful while comparing the productivity levels over time.

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Chapter 3

Product Design and Selection of Production Process

After completing this chapter you will be able to:

Learning Outcomes

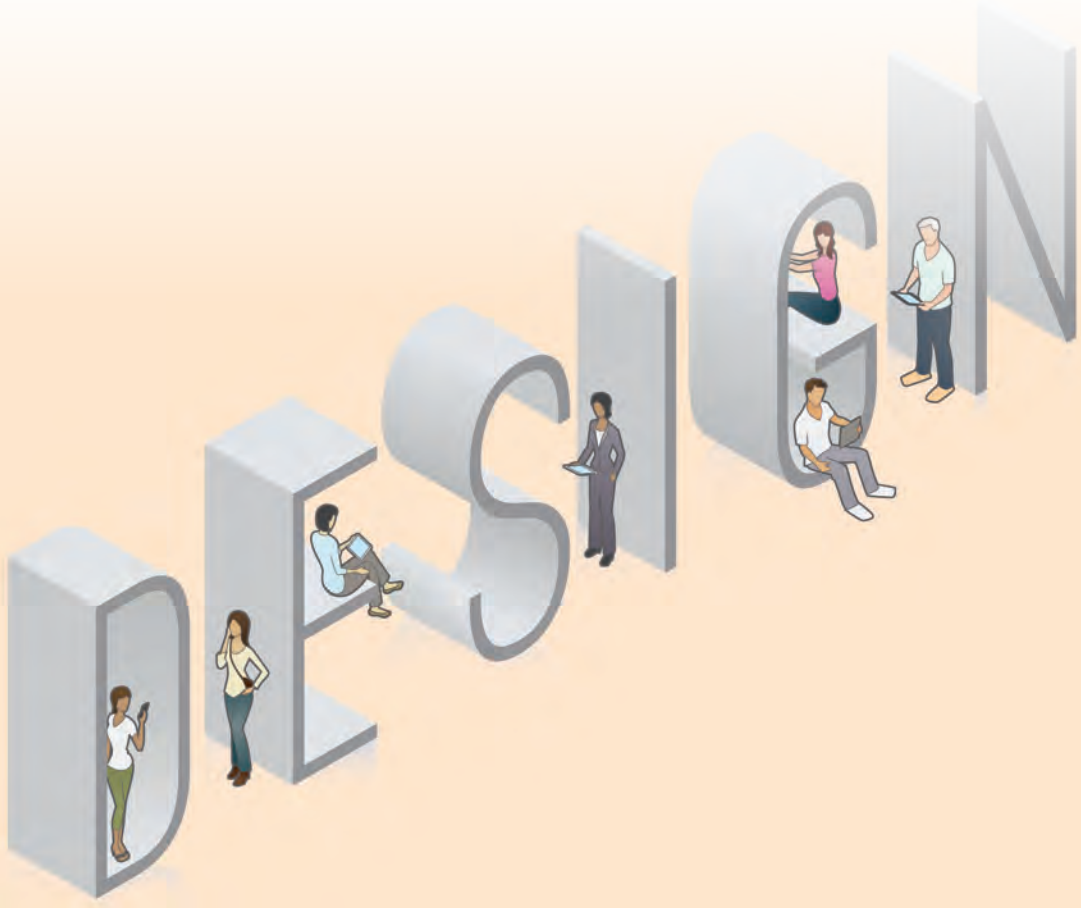
1. Define the product selection
2. Explain the product development and design process
3. Explain the product design tools
4. Analyze the selection of the production process

Chapter Outline

Introduction
Product Selection
Product Development and Design Process
Product Design Tools
Selection of the Production Process

Key Terms

Product
Product Development
Design Process
Product Design Tools
Selection of the Production Process
Production Process Types
Product-Process Matrix



INTRODUCTION

Products are the main and critical elements of a company to survive. Product design can bring many opportunities to the company in the competitive market such as increasing market share, new customers and new products. Product design is the process of deciding on the characteristics and features of the company's product based on customer's needs and requirements. It is a critical process for a company and uses company's core competencies and tries to find out the other competencies that must be developed. Moreover, product design causes changes by new products and markets for the rejuvenation of the company. New products and markets encourage the company to widen the boundaries and lead it to think differently, to break down the barriers. Successful product designs are the keys to the existence of a company. Another important issue for the companies is that products' life cycles are limited and they are even getting shorter. Because of that, companies need to design, produce and deliver new products to the competitive market. Communication among customers, products, processes and suppliers is very important for the competition of the products in the market.

Although it is important for the companies to introduce new products to the market, it shouldn't be overestimated, since many of the sales of the companies are coming from the current products. It is not so easy to introduce new products and have large volumes of sales in the market, immediately. Moreover, many new products are not so successful in the market in spite of a lot of efforts made for them.

An effective product strategy connects decisions about product with investment, market share and product life cycle and identifies the scope of the product line. The purpose of the product decision is to develop and implement a product strategy that meets the demands of the market with a competitive advantage. The focus of the product strategy for a competitive advantage can be differentiation, low cost, fast response or a combination of them (Heizer, Render, & Munson, 2017, p. 201).

Selection of the production process is one of the most important strategic decisions in operations management. Right decisions give the company an opportunity of being successful in operations and market, but wrong decisions cause the company to go bankrupt. That is why this decision is vital for the company. Moreover, selection of the production process indicates the efficiency and effectiveness of the operations in the company. The product type, volume of production, facility size, demand type, market characteristics, suppliers and competitors are some of the important factors affecting this decision.

PRODUCT SELECTION

Many global companies are aware of having products that satisfy the needs and requirements of the customers. Otherwise, the existence and survival of the company are in danger. A good product is one of the essential factors of a company to be successful in the market. It can be a disaster for a company if the product strategy is not set according to the company's overall strategy and the market structure. In order to maximize the success of potential products, companies focus on only a narrow range of products and then concentrate on those products. The core competences of those products are the key factors for the success of the company.

Since all the products have a lifespan, the companies must continuously select and develop new products to survive in the market. For the success of new products, communication among customers, products, suppliers and functions such as marketing and operations of the company are very important factors. The need for new products can arise from the changes in the market or new technological improvements. Although many new products come to the market, a few of them are successful and become popular. Many efforts are made for the selection, definition and design of the products in the company. Sometimes hundreds of times these efforts are made to find the financially successful product. Many ideas are evaluated in the selection and development of products to determine the marketable product. The company along with its functions should take the new product risk and tolerate the failures of this effort. While the company adapts many new product ideas and works on them, it has to continue operations to which it is already committed. A new product decision is a very critical decision for a company and meets the demand of the market

and expectations of the company at the same time. Some of the important expectations of a company can be low cost, high profit and a huge volume of sales in the targeted market.

important

While right product selection decision increases the success of the company in the market, wrong decisions lead to catastrophe of the company.

Depending on the new product characteristics, new customers and markets emerge. For example, if an automobile manufacturer produces small cars in a market, the products they produced are mostly for single living customers. However, if they decided to produce large size cars, the market is changing and these products are mostly for families. The company can differentiate itself by providing unique, high-quality and high-technology products. While companies produce their current products in their existing operations system, new product selection may need new operations and new operations system. So, new product selection can affect the entire operations system. While some companies can choose to produce products with low cost and the selection and design of the product are done according to these constraints, some companies select products that can be designed and produced for fast response to changing customer demand (Heizer, Render, & Munson, 2017, p. 202).

Decisions about the product are fundamental for an organization's strategy and have a great effect on the operations function. For example, some features of a product that is newly designed can increase the efficiency and quality of the current production. Or, a newly designed product can decrease the operations time and the resources used for the production of this product. These type of improvements definitely affect the strategy of the company in the market.

The Product Life Cycle

As it is said at the beginning, every product has a life span and they are born then they live and die. Every product goes out of the market by changes in the market sooner or later. The lives of products are changing from one product to another, from a few months to several decades. However, the structure of product life cycles are the same for all the products regardless of the length of the cycle. The phases of the products in the product life cycle are birth or introduction, growth, maturity and decline as it is shown in Figure 3.1.

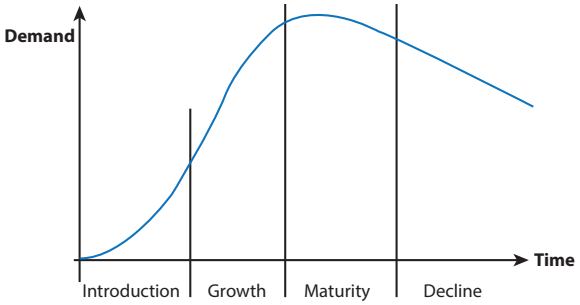


Figure 3.1 Product Life-Cycle Curve

Introduction (Birth): This phase is the beginning of the product life cycle. In the introduction phase, the market for the product is developing. Generally, not only the production and distribution costs are high but also research and development, customer testing and the marketing needed to launch the product costs are high and the competition is not a problem. In the introduction phase, the market is too small, which means sales are low. Products and the market in this phase are not very well defined and the customers are uncertain about the products. The purpose of the company is to build product awareness in the market.

Growth: The main purpose of the company is to establish the product as firmly as possible in the market. In this phase, the sales and the profit are rapidly growing. Since the potential of market growth is high, more money is invested in the promotional activities to use this potential. Although some changes can be made to the product and operations, the companies usually prefer to make minor changes not to disrupt the operations system. As the volume of sales increases, the operations system should make improvements and standardizations. Besides, flexibility and modularization of the operations system are required in order to meet this increasing demand. Moreover, upward trend in sales increases the market share of the company in the market. In the growth phase, the product takes hold and both product and market continue to be refined.

Maturity: When the product is mature, competition is high in the market. Although many changes are made during the introduction and growth phases, some minor changes can be made in the product design if necessary and costs are low and productivity is high in this phase. During this phase, the objective of the company should be to maintain and improve the brand loyalty that is provided in the growth phase while maximizing profit. The company has the chance of increasing market share through competitive pricing. Improved production control and product distribution can decrease the cost of production. Because of new competitors and saturation in the market, the rate of growth is slowing down. However, the volume of sales in this phase is almost at the top level.

Decline: Most of the main operations are automated, the production process is standardized and few manufacturing innovations are introduced in the last phase of the product life cycle. Market of the product starts to shrink and sales go down. The reason for this shrinkage could be the saturation of the market or the switch of the customers to other substitute products. Although the decline in sales is unavoidable, companies can find some cheap production methods and cheaper markets to make some profit. In this phase, some decisions must be made on whether to finish the production of the product and replace it with new ones or try to find new uses of it or new markets for the current product.

There are many products in different stages of the product life cycle in the market. The followings are some examples for them.

- 3D TVs in the introduction phase
- Blu Ray discs in the growth phase
- DVD and flash disks in the maturity phase
- Video cassette and floppy disc in the decline phase

It is important for the companies to manage products throughout their life cycle and apply the appropriate resources and sales and marketing strategies based on what stage products are at in the cycle in order to be successful in the market.

Since companies know that products they sell have a limited lifespan, most of them invest heavily in new product development in order to make sure that their businesses continue to grow.

Product Strategy

Many options are available for the selection, definition and design of products. Product selection is to choose the goods for the satisfaction of the customer. For example, restaurants specialize in different types of meals. Restaurant management can decide on providing Italian food or various steaks or Chinese food to its customers. Restaurant owners choose their products when they decide on the type of the restaurant. Many other options are also available for restaurants such as kebap or ciborek. Some restaurants are specialized at cooking some foods such as cookies and bread.

Some fast food restaurants have developed and executed a low-cost strategy through their product design. They design and produce the products in a way that they have a low cost and high value for the customers. The design and the way of its production allow the company to be competitive in the market.

Strategies of some automobile companies are rapid response to changing customer needs and requirements. By designing the products fast they can catch the changing needs and requirements of their customers rapidly before their competitors and decrease the duration of product development process as a competitive weapon.

As it is indicated by given examples above, product decisions are very effective to an organization's strategy and support the operations functions. Product designs play an effective role in the development of high quality and efficiency. Besides, some designs are so successful in the market that the organization is forced to change its strategy in order to maintain the position in the market among competitors. These product designs lead the organization to have different strategies than they have in the past.

Product strategy defines the direction of the product and what the company wants to achieve.

Strategically, a product design defines a company's customers and competitors, at the same time. It uses the core competencies of a company and tries to determine what new competencies are needed for the development of new products and competition.

While companies try to construct strategies for the products in order to be successful in the competitive markets they need to know the activities and responsibilities of product design. So, they become conscious of the value of product design for their customers and themselves. The followings are some of the essential activities and responsibilities of a product design (Stevenson, 2009, p. 132):

- Reflect customer needs and requirements to product requirements
- Refine or modify current products
- Develop new products
- Formulate quality goals and cost targets
- Construct and test prototypes
- Document specifications
- Translate product specifications into process specifications.

Product design activity has typically strategic effects for the success and wealth of an organization. Moreover, this activity definitely affects its future plans. Therefore, decisions about design activities must be given by mid or high level managers. Organizations are involved in product design or redesign for different reasons. One of the most important reasons for product design or redesign is to have market opportunities and threats. The factors that give rise to market opportunities and threats can be one or more changes in economy, society and demographic structure of it, policies or liabilities of government, competition, cost structure and technology.

important

Product strategy helps the company decide the target market.

Learning Outcomes

1 To define the product selection

Self Review 1	Relate	Tell/Share
What are the most important elements of an effective product strategy?	Associate product selection with product strategy.	Tell some of the products you use according to the product life cycle phases.

PRODUCT DEVELOPMENT AND DESIGN PROCESS

Since products die because of many reasons such as loss of profit or unfashionable products, companies need to develop products for their customers on a continuing basis. Therefore, many decisions about product such as product selection, definition and design, are taken in the companies. Moreover, companies should know how to find and develop new products for the sustainability of the company in the competitive market.

An effective product strategy connects decisions about the product to other business functions such as research and development, operations, marketing and finance. A company needs financial support, understanding of the marketplace and human skills for successful product development. Success of the product development process can determine not only successful products but also future of the company. For the success of the product development process, support of other business functions is not sufficient and integration of these functional units is also very important and vital. Identifying products that appear likely to capture market share, be cost-effective and be profitable but are, in fact very difficult to produce may lead to failure rather than success (Heizer, Render, & Munson, 2017, p. 204).

Product Development Process

A product development process is a group of activities required to bring a new concept to a state of market readiness. These activities involve everything from the initial inspiring new product vision, to business case analysis activities, marketing efforts, technical engineering design activities, development of manufacturing plans, and the validation of the product design to conform to these plans. Moreover, it even concludes development of the distribution channels for strategically marketing and introducing the new product (Otto & Wood, 2001, p. 5).

Design process is in the product development process that tries to meet the needs and requirements of marketing and business. It is actually a set of technical activities. Some of the main activities are the refinement of the product vision into technical specifications, new concept development, and embodiment engineering of the new product. They do not cover business and financial management activities of product development and marketing and distribution development activities, as well. Besides, manufacturing process activities are included neither in product development process nor in the design process. However, product design process and the design of the manufacturing process must be performed simultaneously for effective and efficient product development.

Although some companies still consider the research and development as part of the product development process, today, many companies separate research and development process from the product development process. Ideally, the research and development unit tries to create new technologies and these new technologies are adopted to new systems and products by product development teams, as it is done for outsourcing subsystems. This situation makes the product development process fast and efficient for the adoption of new technologies in new products that meet the changing needs and requirements of customers.

Product development does not mean just product management, instead it is a broad process for bringing products to market which involves many teams across a company, such as product management, marketing, design, testing and distribution.

Although successful new products exist in the market, many of the new coming products do not survive in the market due to wrong transfers of technology derived from research and development functional unit. The new technology cannot function well in the product as it is supposed to do. Miscommunication of specifications and forms among different functional units is the main source of error. Even people working in the same organization can misunderstand the same written descriptions and conversations. All the preliminary product development activities that happen before a product developed is referred as the fuzzy front-end. This fuzzy front-end involves decisions such as what products to develop, company strategies, customers needs and requirements, current technological improvements and competitors. Moreover, it includes development decisions on what type of product portfolio can be suitable for the current market. Design engineers are the top contributors of these teams in front-end decisions. Nevertheless, there is not classification scheme for development activities that fits all organizations. These activities change from one organization to another because of many factors such as varying purposes, structures, markets and competitors. The most important factor is to be aware of how a design process fits within a product development process of an organization and how a product development process fits within an organization's business environment.

In the product development process, creativity, understanding, communication, testing and persuasion activities are essential for the success.

Product development process is separated into three phases as it is shown in Figure 3.2 (Otto & Wood, 2001, p. 14).

1. Understand the opportunity
2. Develop a concept
3. Implement a concept.

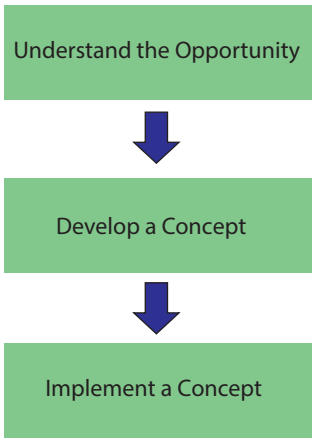


Figure 3.2 Phases of a Product Development Process

1. **Understand the opportunity:** The first step in this phase is to develop a vision for a new product. Every worker in an organization has an idea or a vision for a new product. However, the point is whether any vision can be transformed into a successful realization, or it can be developed and implemented into a product at a reasonable profit. In order to respond to this situation, a market analysis must be made and opportunities and threats must be determined. Information about potential customer behaviours, competitor's products, market price, forecasted volume of sales are collected. Moreover, the development team tries to understand the requirements of the potential customers and how they are satisfied by competitors. Therefore, the development team has a lot of idea about the state of the competitive market, customer profile and available technologies. By depending on this evaluation, it is decided on whether to proceed in the development of a new concept.
2. **Develop a concept:** After having all the information given in the first phase, the team's first effort is to design general market specifications for the product. While the product is tried to be developed, complementary set of products that will be offered by the company must not be forgotten. It is about product positioning in the market and portfolio planning and development. For new concept generation it is determined what the product must do to fulfill customer satisfaction and it is about functional modeling. Design team generates concepts for the implementation of functional specifications. Many functional models and alternative product architectures are synthesized and one is selected as a concept for implementation.
3. **Implement a concept:** The selected concept takes a form through purchased components, manufactured parts and assembled as a product. This is called embodiment engineering. Embodiment involves modeling and testing of the physical construction. Modeling is not only the physical representation of the concept but also satisfaction of the customer and profit for the company. Modeling is a type of product development process that indicates how it supports design decision making. When the physical models are not sufficient or difficult to make for effective decision making mathematical models are developed for customer needs and requirements. Then a design configuration can be selected based on customer needs. Besides, the team has the ability to design the product according to different Design-for-X methods. This X can be manufacturing, assembly or environment (design for manufacturing and assembly). Finally, a prototype is prepared for production. Production planning and manufacturing process design show the finish line of the product development and most of the time production of the developed product is initiated.

The Design Process

One of the most important mistakes of the organizations is to consider the design as a single event or activity rather than an extended process. Design is a set of activities that need to be followed and managed one by one for the success of the company in the market.

Design activity is one of the major activities of business either for the service company or manufacturing company. While some companies design credit cards or cars for their customers, some non-profit organizations use design to get their message across to the public such as state universities used web and print design to help student recruitment or registration. Many design decisions are made about the features of the product such as the shape, form, color, smell, functions and materials. Generally, the design is the activity of conception, planning and implementation. Moreover, it is primarily about problem solving. Changing consumption and taste behaviours and commercial imperatives are the drivers of the design. In order to be competitive in the market, companies create competitive products that have driven the diversity of design. Design is not only related to manufacturing but also a strong tool for conveying persuasive ideas, attitudes and values. It is used both for tangible items such as car, chair, biscuits and intangible items such as a holiday or a well-served meal.

Design is not a random combination of elements, but it is the output of some planned activity to create some new things for a specific purpose. The value of this output is important, as well and it is not so easy to assess the value of this output objectively, when the output is evaluated aesthetically, since it is a matter of taste and highly subjective. Although design is intrinsically linked with taste, it has an economic role. The design process is not the combination of function with materials to have efficient production. However, it is the combination of style and appearance that products attract customers.

Designs can be classified as good or bad design by different measures in terms of fitness for use, quality, performance and functionality. Good designs are designs that have high market share, open new fields or have a long lasting impact and have strategic advantage. Bad designs are designs that have poor targeting or execution and cannot find widespread acceptance or sustained use in the market. Introduction of new designed products to the market is a risky business, especially if the company is not very experienced.

Design is about creativity but it is not a monopoly of some people who are designers or research scientists or any other creative specialists. For the execution of a design, inputs from different disciplines and functions within the organization need to come together. In an effective management of a design process cross-functional and shared involvement is critical. During the design process structures, systems and behaviours produce designs that satisfy the customer at low cost, that are easy to make and that appear in a short time. Walsh et al. (1992) identify four "Cs" of design:

- **Creativity:** Creation of something that has not previously existed.
- **Complexity:** Design includes many decisions for a wide variety of parameters and elements such as shape, texture and color to materials.
- **Compromise:** It is a type of trade-off between some elements and features such as performance and cost or weight and ease of use.
- **Choice:** It is about coming to decisions on the concept solution to color or form.

Creativity is another important and essential factor in design process. Creativity is not a province of a few gifted people, but it is something that most people are capable of. Although there are many famous painters, composer or scientists who are very creative, you do not need to be a Leonardo da Vinci in order to come up with new creative solutions for problems. *Creativity* can be defined as "the generation of novel ideas". This novelty can be looking at things in a different way (Bruce & Bessant, 2002, p. 27). Managers in the companies must be careful not to block the creative ideas coming from the workers by fast evaluation. Therefore, management of creativity is a serious task and comes with *innovation* that involves bringing something new into widespread use, not just inventing it. It starts as a flash at the beginning, and many problems are solved by creative inputs then finishes by the input of many different people over a sustained period of time. These are

the combination of creative endeavour of many people. Many Japanese companies in automobile or electronics sector, are successful in the market by the systematic application of creative solving. Moreover, many suggestions come from their workforce and the company tries to implement many of them. So, employee involvement in problem solving helps the company keep improving continuously.

Another major feature of creativity is that it is not a totally conscious or rational process. According to psychologists and others creative behaviour follows a pattern. This pattern involves first insight, preparation, incubation, illumination and verification. On the other hand, instead of individual creativity group creativity can be a valuable asset within the organization. When a group of people from different backgrounds, experience and personality focus on the same problem, total creativity can find easy and fast ways to solve the problem.

Creative and innovative ideas do not just come within the boundaries of a company. Working with customers and suppliers can yield original ideas. When a design company works with a manufacturer, this can result in a stream of commercially viable products.

In design process creativity, design and innovation terms are used extensively and synonymously. Many countries encourage their own local manufacturers to design new products in order to help companies compete in the global market. Such attempts discover the value of design and promote it as an engine of innovation in products and business processes. Design takes new improved technologies out of research and development and into the market as original and usable products.

Design can be at the heart of innovation and integral to innovation. Designers can both create innovative products and translate innovative ideas to the market. By extending the designer's role beyond the product design process, design sensibilities can be integrated with other functions and so widen their impact. Design skills and knowledge can help many activities of a business such as marketing, cost reduction and operations. The success of the companies come from the response of these companies to the changing needs and requirements of customers by developing skills and knowledge. New challenges need new ways of thinking and creativity and companies learn to improve and innovate in all aspects of a business.

Creativity is the ability to combine ideas in new ways to solve problems and exploit opportunities.

Innovation is the successful application of new ideas in practice in the form of new or improved products, processes.

Good design does not emerge by accident but as the result of a well managed process. Many companies have tried to prepare and use their own variations of the basic road map for the design process. Therefore, it is important to keep in mind that each type of business has its own version and the names and quantities of these stages can vary widely.

Although product development process is shortly described in three phases, it will be useful to describe the main stages of design process separately as shown below (Rothwell, 1983, p. 621).

- **Stimulus/trigger:** This is the first stage of design process and also called idea generation. It is something that starts the process. This can be a new idea coming from a variety of sources. These sources can be supply-chain based, competitor based and research based. Customers, suppliers, distributors, employees

and maintenance and repair personnel are the sources of the ideas in a supply chain. Competitors' products and services and how the competitor operates (pricing policy, return policy, warranty policy, etc) can give many ideas. Research and development department effort is another source of ideas for new or improved products.

Perceptual maps, benchmarking and reverse engineering can help companies learn from their competitors. Perceptual maps compare customer perceptions of a company's products with competitors' products. Benchmarking refers to finding the best-in-class product or process, measuring the performance of your product or process against it, and making recommendations for improvement based on the results. Reverse engineering refers to carefully dismantling and inspecting a competitor's product to look for design features that can be incorporated into your own product (Russell & Taylor, 2009, p. 152).

- **Concept development:** In this stage, the idea is evaluated in terms of viability for the company, based on its strengths, capabilities and market demands. Feasibility study needs to be made in terms of production capability, quality and costs, too.
- **Project planning:** If the company decides to continue and investigate the idea further, then a product plan should be prepared for the explanation of objectives, allocation of resources and planning of timescales and budgets.
- **Design brief:** Preparation of a design brief is not an easy job and requires information from different units such as operation, finance, marketing and design units. Designers prepare reports for the project including objectives, work schedule, task list and budget.
- **Sourcing design skills:** The design team that will work in the design process can be an in-house team, or solely an external team or a combination of external and in-house designers. The company management needs to understand the design competences needed for the proposed project and decides according to it.
- **Concept design:** After having an outline of the design idea, sketches and simple models of it are made for sharing it with others. Therefore, clear and focused concept is discussed with others in terms of strategic decisions.
- **Design specification:** Drawings and models of the actual design are made and details of the design are decided on these drawings and models. Purchased components and parts are discussed and company gets in contact with the suppliers for the supply of them.
- **Concept development:** The concept is elaborated and missing and incomplete information is collected. The design team explores the key strategic questions based on collected information.
- **Prototype and testing:** Mock-up, model or some other preliminary version of the final design is made. Then, this model is explored, tested, evaluated and used for discussion and development.
- **Detailed design:** After discussions about the final design, agreed design is converted into detailed specifications. Some prototypes of the agreed design are produced and tested.
- **Market development:** Problems about the design are found in terms of market and design team tries to solve these problems such as the nature of demand or changes to an original concept on market side.
- **Technical development:** In this stage, if there are some technical problems these problems are found and solved. Some examples of these technical problems are feasibility, debugging and design for ease of manufacturing.
- **Launch:** This stage shows the end of the design phase. The designed product is introduced to the market after its production in the company. The design phase is a part of a total product development process. In textiles, the design phase typically takes two to four weeks of the total product development process which is about nine months.

- **Evaluation:** This stage is about the analysis of the process and the project outcome. The management of the design process needs to be examined and reviewed in order to be certain if the goals are achieved or not. Besides, the project needs to be evaluated in terms of time budget and performance such as the volume of sales or customer complaints.
- **Support and extension:** After the launch of the product, close relation with users and access to their feedback about the product is easy to achieve. Retention of the customer and the development of relationship depends on after sales services or supports. This support can be more demanded when the product is complex or expensive.
- **Re-innovation:** This stage is neglected by many companies. However, the information and experiences gained from this stage after the launch stage are very important for the improvement of the designed product. Every feedback is a lesson for the company and an input for further innovation.

In the design process, many decisions are made and many factors are effective in these decisions. Figure 3.3 shows the variety of knowledge needed in the design of products and the important factors to be considered in design decision making (Bruce & Bessant, 2002, p. 47).

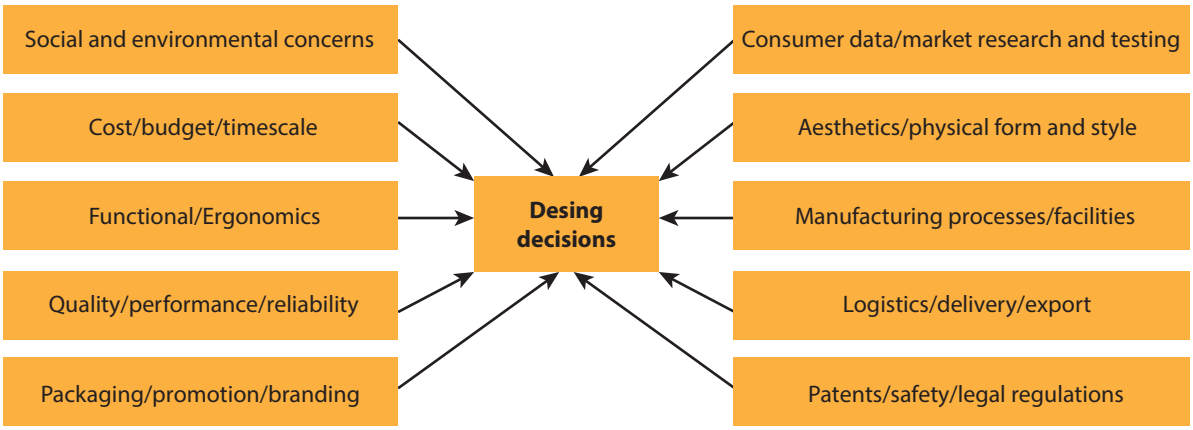


Figure 3.3 Design Decisions

There is no guarantee of success in design, however there are some success factors that summarized as shown below, to enhance the management of process (Bruce & Bessant, 2002, p. 49):

- Commitment of top management
- Clear explanation of the concept
- Take into consideration the voice of the customer
- Unique features of the product
- Early detection of problems
- Close monitoring of each design stage
- Parallel working of design and operations
- Multi-disciplinary team working in design
- Usage of advanced support tools such as CAD, prototyping, etc.
- Continuous improvement

important

Good design is to use the most appropriate technology and procedure for being successful in the market with low cost and high quality.

The followings are the design principles to simplify the products and processes (Martinich, 1997, p. 219):

1. Minimize the number of parts used
2. Use common components and processes
3. Use standard components and tools
4. Simplify assembly
5. Use modularity to obtain variety
6. Make product specifications and tolerances reasonable
7. Design products to be robust

Minimize the number of parts used: Minimizing the number of parts, subassemblies and features of the product used is a way of design simplification. A simple product is easy to make with high quality and low cost. When the components or parts are eliminated they are neither designed nor bought. Moreover, no part number is assigned and less part variety is in the inventory. Simplification also means that fewer tools, separate fasteners and adjustments are used. While trying to minimize the number of parts used, the team must be careful if the eliminated part or component is really redundant or not. Otherwise, it can cost a lot of money to the company while expecting cost savings. For the reduction of parts used, the designer analyses the parts one by one for their necessity and functionality. Parts can be eliminated either since there is no functionality of them or since some parts can be combined by other part.

Use common components and processes: In order to reduce the number of parts used, the design team can use parts that are common across several products or used in several processes. For example, a company manufactures 100 different types of refrigerators but do not use 100 different motors. Instead, they can use 5 to 10 different motors for all these 100 different refrigerators. When they design a brand new product they prefer to use one of these motors is applicable, so they do not need new jigs, tools, fixtures and machinery to produce and assemble them. Besides, common components or parts are manufactured or bought in large quantities and minimize the cost to the company. Another important advantage of using common components is to improve the quality in different ways. Since the components are produced in large quantities, they have more consistent quality. Using common components reduce the number of parts used so the chance of using the wrong components in an assembly or any other operation is reduced. Finally, assembly tools and methods do not need to be changed for production of different products.

Use standard components and tools: Using standard components gives the company an opportunity of cost saving, high quality and good performance. When a company uses unique and special components, they need to be specially manufactured and cost many times more than standard components. Moreover, assembly or other operations of these components require special tools and equipments. Suppliers producing many different components help the companies identify the standard components that can be used in product design. Using standard parts in a product also saves design time, tooling costs and production worries. *Standardization* is another issue that arises in both product design and process design. Standardization gives the possibility of using interchangeable parts among products. This results in high volume of production, low inventory, easy material handling, less quality inspection and fewer difficulties in production.

Standardization refers to the extent to which there is an absence of variety in a product, service, or process.

Simplify assembly: When the process is simple whether the production is automated or manual, the product will be cheap and reliable. Assembly simplification can be made easily by using preliminary production documents such as assembly drawings and *assembly charts*. While some computer softwares are used to simulate the production process in order to simplify the process, sometimes using more expensive components in the assembly can simplify the process and decrease the total cost and increase the quality of the product.

Assembly chart is a schematic diagram of how and in what sequence the components of the product will be assembled.

Four product design characteristics especially affect the ease and quality of assembly:

1. **Fasteners:** Many of the activities of assembly labor is to fasten one component to another by bolts, screws or snaps. Since the type, shape and size of the fastener affect the cost and quality of the operation, it is important to use the convenient fasteners for the assembly operations.
2. **Orientation and accessibility in assembly:** The sequence of assembly and the orientation of components in an assembly task are crucial. If there are several components to be aligned and held together, a simple task, such as fastening a bolt and nut, becomes very difficult. If the product needs to be repositioned frequently assembly becomes very difficult and time consuming. All the parts and components of a product can be assembled from one side if the planning and design are made carefully.
3. **Design for testing:** Most of the products with complex structure require testing after the assembly. The cost of testing and the quality of the product can be improved by designing the components in a way that testing can be made one or more stages before final assembly. Discovering and correcting the defects early in the process avoids time and money spending. Early testing makes diagnosis of a problem easier and less costly than testing the final product.
4. **Mistake-proof assembly:** One way of simplifying the assembly process is to design the product and components so that it is difficult or impossible to make mistakes. It is called *mistake-proof* assembly or *Poka-Yoke*. Some bolts used in one stage are designed to fit just one special hole, and cannot be used in other stages to prevent the mistakes. So, this is a proactive activity that increases quality and decreases total cost.

Mistake proofing, or **Poka-Yoke** is the use of any automatic device or method that either makes it impossible for an error to occur or makes the error immediately obvious once it has occurred.

Use modularity to obtain product variety: Companies produce a variety of model options for a product in order to satisfy a wide array of customers. If each model is produced separately then the model is very expensive because of its inefficiency. Producing variety of products at low cost is to use modularity. Modularity is dividing the product into modules and then determining which variations of each module would be desirable from a marketing and manufacturing viewpoint. Modular designs gives flexibility to both production and marketing. Moreover, modularity allows the customers to mix and match according to their own taste. This is called customization. Modular design is used in some sectors such as electronics, automobiles and furniture. Some automobile companies use the same body chassis for different models and in some computer companies customers can build their own computer by using the standard modules.

important

Modular design consists of combining standardized modules in a variety of ways to create unique finished products.

Make product specifications and tolerances reasonable: When the specification of a component is very demanding, the cost of it is high. So, physical properties of the components should not be more demanding than needed even under extreme conditions. If some components of a product are unnecessarily demanding, the cost of the product will be high without increasing product quality. Another important point is to make the product specifications and tolerances consistent with technical capabilities. Otherwise, the cost of production is unnecessarily high.

Design for robustness: Because of the variations in materials, wear on equipment and fatigue of the worker variations can emerge in the production. So, the quality of production reduces. In order to prevent this, a procedure called robust design has been introduced. By this procedure, normal variations in product attributes are reduced and product performance is less sensitive to the variations. For reducing the attribute variations, Taguchi method is used and this method uses physical experiments to determine the most effective product and process characteristics in the attribute variations of a product. So, designer can select the best fitting attribute values of the product to minimize these variations. Another important point of robust design is to accommodate the attribute variations for minimizing their effects on product performance and quality such as thickness or weight of a component.

Learning Outcomes

2 To explain the product development and design process

Self Review 2	Relate	Tell/Share
What is stage-gate model as a new product development process model?	Associate the product design by the basic principles of designing products for production.	Tell some of the companies products that use common components in their product portfolio.

Further Reading

The Story Behind BMW, Rolls-Royce And MINI's Exciting Future Product Strategy

Basic Principles of Designing Products for Production

The BMW Group is responsible for an impressive portfolio of products. Through Rolls-Royce, BMW and MINI, the company offers cars for very different scenarios - from the ultimate in luxurious travel, to premium performance cars and fun urban run-arounds.

Then there is the i sub-brand, one of the first dedicated teams within a traditional car company to create solely electric production vehicles with a unique visual language. Lately, the company has also been busy exploring the future – the new sustainable, autonomous era through the Vision Next cars. The recent Vision iNext shows the ways in which autonomous driving will change life on-board cars, whilst the upcoming Vision M Next concept demonstrates how technology can enhance driving pleasure.

Behind all this complex creative thinking is Adrian van Hooydonk, senior vice president BMW Group design. I caught up with the designer to understand his vision for the future of the three brands.

Design teams need to be careful in product design and take into consideration design principles and tools to guide their thinking and to help them evaluate alternative product designs. The most important principle of product design is "Make it Simple". Simplicity of design and product often makes it easy to produce and consume. Mostly simple designs require fewer parts, simpler tooling and machining and less and simpler assembly. Thus, production cost is low and product is easy to use and reliable. Good design does not mean using the latest

technology and procedures, rather it uses the most appropriate technology and procedures to accomplish the purpose of the product with low cost and reliably.

Nargess Banks: The traditional auto world is facing a very big challenge: how to evolve and remain relevant in the new, sustainable age of mobility. Yours is a tough job of navigating this transition for three very different car brands, each with a unique identity rooted in rich history. BMW seems the toughest, for it is a marquee with the promise of performance and driving pleasure. How do you take this into the future?

Adrian van Hooydonk: Yes, BMW is rooted in performance and it is about the thrill and the emotion of driving. On the one hand, it is about speed, yet the thrill is also about the vehicle's direct response to your input. Then there is the technology that works well and the design which speaks on an emotional level. So, BMW is a combination of something that is highly emotional but delivers on a rational level. This can be motorized in any possible way. You know from your experience that the thrill and the speed and responsiveness can be had with electric driving too - perhaps even more since these cars are nimble, the steering is lighter and more direct.

NB: The electric i3 and i8 have a very strong visual identity. Do you see the electric drive opening-up great possibilities for design?

AvH: Absolutely. Since the electric car layout is so different you open-up a new chapter in design. Some of these brands are over 100 years old, so maybe this is just what we need as designers. Yet, it takes effort to re-invent and transform a brand.

NB: Are the mainstream BMW products learning from the progressive visual language of the i cars?

AvH: Our latest cars show a new design language that is cleaner and simpler. This was an idea that started with the i3 and i8, with designs that have very few lines, to look cleaner and express the zero-emission. This has naturally transformed the look and feel of our new models. The i started as a sub-brand, but it is now a very integral part of what we do. We want the i cars to push and stretch the mother brand in terms of technology and design.

NB: We've had marathon discussions on electric vehicle design. But how far can you push design with electric cars without losing sight of your brand values?

AvH: We're at a stage when finding a unique visual language for electric vehicles is no longer necessary. People now understand electric cars and see it as another engine choice. Saying that the whole advent of electric mobility has been a catalyst for us for the design change.

NB: What about Rolls-Royce – a brand with such a history of traditional luxury?

AvH: One day we will electrify this brand too. We haven't put a date to this as it is not urgent since Rolls-Royce is about silent mobility anyway.

NB: With the Vision Next concept study cars you have been exploring how the three brands could potentially take on technology in the future. Will the level of tech differ according to each brand?

AvH: I don't see a difference in technology for the three brands. They will all go electric ultimately so it is about creating vehicle intelligence that would lead to cars being able to drive autonomously. All our cars will have to become intelligent and be connected as they can then enjoy the intelligence of other vehicles.

NB: The MINI Vision Next concept looked at the possibility of shared ownership. How do you see this developing?

AvH: Sharing mobility will happen in urban environments. If you have a customer profile with our company then the car would adjust to your settings seamlessly. There will be a top layer of premium and luxury mobility that one would subscribe to, much like the systems that exist now for sharing private jets.

NB: You mentioned to me in the past that you see the BMW Group as evolving from being a car company to a technology firm. What are your thoughts now?

AvH: We are transforming into a luxury tech brand because we develop complex technology as it takes tremendous effort to make autonomous drive happen. In the end, the customer is buying a mobility service with a certain accent - and this will have a lot to do with design.

NB: Do you see your team expanding its work to include the design of other elements which support mobility?

AvH: This is one of the things we are exploring now. In a big company likes ours each customer touch-point is taken care of by a separate department. These areas are now merging and the move is rapid. As a creativity tank, our design department will be involved in the thinking behind all sorts of services that we can offer, to include their look and feel.

NB: You're trained as an industrial designer and have worked at the marque's Californian studio Designworks on non-automotive products. Has this impacted on your design approach?

AvH: Yes, I can put myself in a customer's shoes. I learned never to start designing from technology or a problem. Instead to start from what the customer has right now, what they would like to have and what they will need in the future?

NB: But how do you envisage the needs and wants of your future customers given much of the data suggests the next generation are less and less likely to be interested in cars and especially car ownership?

AvH: Our design team stays informed of where the world is going towards through Designworks and our personal connections to the design world at large. You see patterns and see things appearing. And although you never know how fast they will play a key role, you can tell what you need to work on next. I always believe if you can imagine something, it will happen.

NB: You've been working with MINI Living, an interesting initiative creating living concepts with architects. You have also lately worked with the designer Patricia Urquiola at BMW Welt on another non-car project. And of course there are the art projects. How do these impact on your work?

AvH: They are about a brand looking beyond the actual product. And they are great projects as they help you not drift off into your own bubble of mobility – so to speak. It gives creative input and context on what people are doing in other fields. You need to then bring the vision back to our own products.

NB: Will MINI be making city dwellings?

AvH: It is hard to tell at this stage. The latest Shanghai project is setting up MINI to be more than a mobility brand, to be an urban lifestyle brand and a natural part of people's lives.

NB: Sustainability is about a bigger picture than a clean engine. You have often discussed your excitement at finding materials that speak the language of modern luxury, yet there remains an awful lot of traditional leather and wood in your cars.

AvH: That's true but we are not the only industry struggling with this. When we started the i3 we began assessing what happens after the product's life. BMW Group is making products that can be 90% recycled. We use a fairly high percentage of recycled materials in our products too. But I agree there is still a lot to do. My vision is to get to a stage where when you point your telephone to elements in the car, it tells you what material it is, how it is made, where it is made and the whole supply chain story. In the past, we didn't know the detail of our supply chain. Now we are finding out everything so we can offer complete transparency. This has to be our ethos.

NB: BMW as a company has an ever-expanding family. Surely this goes against the concept of sustainability where cars become disposable items?

AvH: That's a difficult question. Ultimately by that logic the best company will be one that stops business. We cannot do that of course. We try to provide a change from within. The approach we're taking is to produce cars that bring back what has been disconnected and this is what people need and want. I believe this is possible through design. For example, when I presented the i8 in Abu Dhabi the customers liked a sports car but had no idea they wanted a hybrid one as there is no need for electric cars there. But when they saw the i8 they loved it and bought it. Through strong design, creating emotionally attractive and yet sensible and rational products, you can influence people's behavior in a good way - and maybe make some changes in the world.

Source: N Banks, 2019, June 18.

PRODUCT DESIGN TOOLS

Many different kinds of design tools and methods have been developed to help product designers and teams develop products with high quality, low cost and decreased product development time. Depending on the conditions of the companies and inner and outer factors affecting the company, the company uses one or more of these tools and methods. The followings are some of the important product design tools that tried to be explained briefly.

Quality Function Deployment

One of the important product design tools is quality function deployment (QFD). It is first used in Japan in the late 1960s as a form of cause-and-effect analysis, and it was brought to the United States in the early 1980s. Most of its popularity comes as a result of numerous successes in the automotive industry. *QFD* is transferring the voice of the customer to the design specifications of a product. During the implementation of this method multi-disciplinary teams from marketing, design, engineering and manufacturing are used in the organizations. QFD process starts by determining the requirements of the customer then finishes by translating these customer desires into the target design. The idea of QFD is to understand the desires of customers and to identify alternative process solutions. This information is then integrated into the evolving product design. QFD is used early in the design process to determine the needs and requirements of the customer and where to deploy quality efforts.

QFD is a process and set of tools used to effectively define customer requirements and convert them into detailed engineering specifications and plans to produce the products that fulfill those requirements

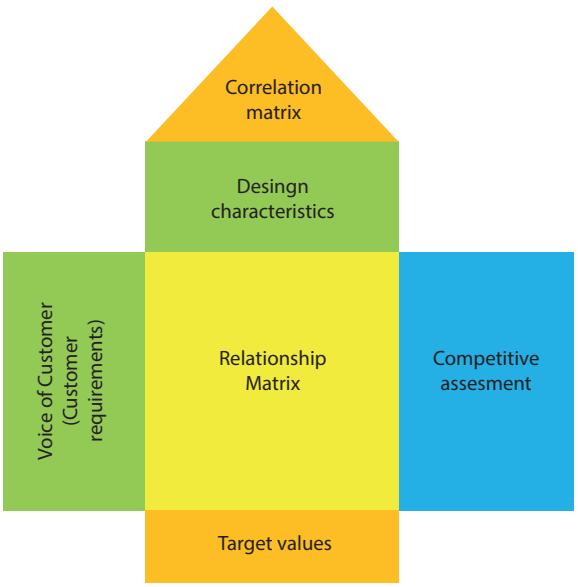


Figure 3.4 House of Quality

important

House of quality matrix relates to the customer's requirements to the technical attributes of the product.

One of the essential tools of QFD is the house of quality which is a matrix for defining the relationship between customer desires and product as shown in Figure 3.4. The design team uses customer feedback in a house of quality matrix to make many decisions about marketing, engineering and design. The matrix assists the team to translate customer desires into solid operating goals. The house of quality matrix shows the important product characteristics and goals for improvement and they are jointly determined and detailed in the matrix. This process encourages team working which includes people from different

departments and results in understanding other departments' goals and issues. Moreover, the most effective and important benefit of house of quality is to help the organization to focus on building a product that satisfies customers.

Defining the relationship is the first step in building a world-class production system. To build the house of quality, the following seven basic steps need to be followed (Heizer, Render, & Munson, 2017, p. 205):

1. Identify customer needs and requirements
2. Identify how the goods will satisfy customer needs and requirements.
3. Relate customer needs and requirements to product hows by building a matrix.
4. Identify relationships between the company's hows.
5. Determine importance ratings.
6. Evaluate competing products.
7. Determine the desirable technical attributes, company's attributes, and the competitor's performance against these attributes.

House of quality allows for direct comparison of how your design or product stacks up to the competition in satisfying the customer requirements This quick analysis can be useful in making design decisions that could result in improvement. QFD decreases the probability of late design changes by focusing on product features and improvements based on customer requirements. Effective QFD methodology decreases product development time and avoids resources from being wasted on development of non-value added features or functions.

Another important usage of QFD is to show how the quality effort will be deployed. Figure 3.5 shows house of quality sequence. House of quality sequence shows how to deploy resources to achieve customer requirements. Design characteristics of the first house are the inputs to the second house, which are satisfied by specific components of the product. In the third house, specific components of a product are to be satisfied through particular production processes. After production processes are defined, they are the inputs of the fourth house to be satisfied by a quality plan that will ensure conformance of those processes. The quality plan includes tolerances, procedures, methods and sampling techniques in order to meet the customer requirements.

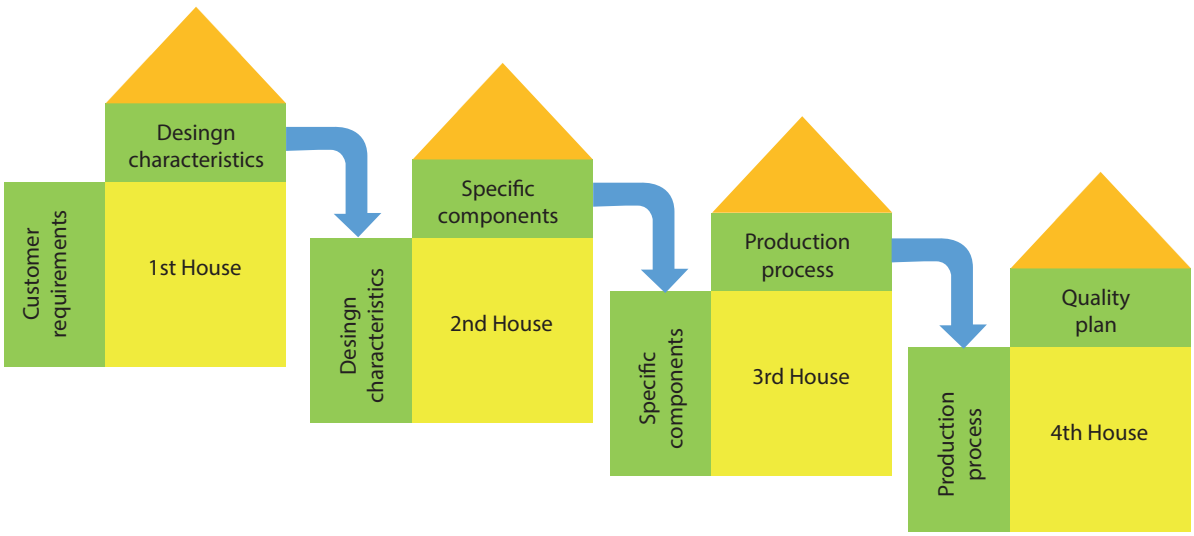


Figure 3.5 House of Quality Sequence

Companies in a highly competitive market must introduce new and improved products to the market that meet the customer's needs and requirements while reducing development time and total production cost. QFD methodology is for organizations committed to listening to the voice of the customer and satisfying their needs and requirements.

Value Analysis

Another way of thinking the customer in product design is to analyze the "value" that the customers see in the finished product. Value can be defined as the ratio of usefulness to cost. The cost can be defined as the amount of resources used for the production of a product. On the other hand, usefulness is the functionality that the customer assigns to the product. Usefulness covers some terms such as product features, performance or reliability of the product. *Value analysis* is a method for improving the usefulness of a product with no increase in cost or decrease the cost with no decrease in the usefulness of the product. The result of value analysis is great cost savings or a better product for the customer.

Value analysis is also known as value engineering, is a design methodology developed by General Electric in 1947 that focuses on the function of the product, rather than on its structure or form. This methodology's effort is to maximize the economic value of a product or component relative to its cost. The purpose of value analysis is to simplify products and processes in order to achieve equivalent or better performance at a lower cost while maintaining all functional requirements defined by the customer (Chase, Jacobs, & Aquilano, 2006, p. 121).

Value analysis starts by analyzing the product totally. After it is completed, subassemblies and then each components are analyzed. During this analysis, unnecessary parts and functions are determined and eliminated for the reduction of the total product cost. Unnecessary parts or components or functions are those that do not give any value to the customer.

Three most important points of this methodology are:

- Usage of multi-disciplinary teams
- A systematic approach to the comparison of product functionality and value
- Concentration on the simplification of the product

Explanation of the function of the product and the characteristics of the product that have value for the customer are the activities included in the first step of the implementation. "What is the product or what is its function" are some questions that could be asked in the first step. After the specification of the function of the product and identification of the product characteristics, contribution of the product characteristics and components to the product value and functionality are determined and are compared by its cost. The final step is the creative phase of this method. The product is redesigned by the team to decrease its cost or improve its value. On the other hand, redesign of the product includes the simplification of the design, as well.

Value analysis a methodology which ensures the necessary functions for the minimum cost without reducing quality, reliability, performance and appearance of the product.

The followings are some of the most important benefits of value analysis:

- It is a powerful tool for cost reduction since its objective is to identify and eliminate unnecessary costs.
- It increases the productivity of the company by efficient use of all kinds of resources.
- It helps the company follow the latest technology and other improvements.
- It promotes creativity and innovation
- It can be applied at every step of the production of a product either in initial design or final step of its packing and dispatch.
- Customer satisfaction is high.
- Management effectiveness can be measured easily.

The Taguchi Method

Dr. Genichi Taguchi is a Japanese quality guru known with his work in the field of product design. According to his research, almost 80 percent of all defective items are caused by poor products design. Taguchi emphasizes the design phase of the product for the quality of it and remarks that it is much easier and cheaper if the changes are made on the design phase instead of production process. Taguchi is known for applying a method called design of experiment to product design. This method is based on robust design which is a design that results in products that can perform over a wide range of conditions. The idea behind this is that it is easier and cheaper to design a product that can perform at every type of environmental conditions than it is to control the environmental conditions (Reid & Sanders, 2013, p. 160).

The Taguchi method is one of the best known methods used in robust design. The followings are the three basic principles of this method (Martinich, 1997, p. 232).

1. When the value of a product attribute such as width, temperature, length, deviates from its target value, the cost to society (customers and producers) in terms of lower quality increases more than linearly.
2. Variation of the product attributes is determined by both the design features of the product and the production process.
3. Product and process characteristics that affect product attributes can be determined by experimentation and products can be designed to decrease attribute variations by manipulating these characteristics that result from normal production variations.

Taguchi determines the quantity of customer preferences toward on-target quality in the quality loss function. The quadratic function which is shown in Figure 3.6, shows that a customer's dissatisfaction (quality loss) increases geometrically as the actual value deviates from the target value. In traditional quality loss, the cost increases if the product dimensions fall outside of the specified limits. The Taguchi's quality loss function is used to emphasize that customer preferences are strongly oriented toward consistently meeting quality expectations (Russell & Taylor, 2009, p. 175).

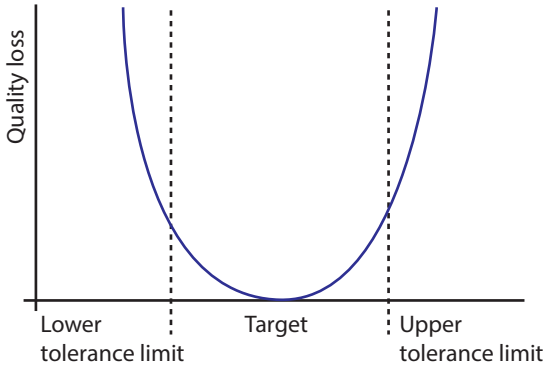


Figure 3.6 Taguchi's Quality Loss Function

The reason for poorly operated product can be distinguished from controllable and uncontrollable factors. From a designer's point of view, the controllable factors are the design parameters such as material used, dimensions that the designer makes decisions about it. Uncontrollable factors are under the user's control (length of use, maintenance, settings, etc.). The designer must decide on the value of the controllable factor that reacts in a robust fashion to the possible occurrences of uncontrollable factors. In order to achieve this, the products with different controllable factor values are tested under different operating conditions specified in the design of experiments. The experiment is repeated many times. What is tried to be done by this method is to determine the level values of the controllable factors in a way that the product becomes insensitive to variations in uncontrollable factors. The average performance of an experimental configuration over a number of trials is called the signal. The standard deviation of performance is referred to as noise. The most robust design shows the highest signal-to-noise ratio.

important

Taguchi method uses parameter design which is an engineering method for product or process design that focuses on determining the parameter (controllable factor) settings giving the best levels of a quality characteristic (performance measure) with minimum variation.

Taguchi method identifies proper control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments. These standard arrays provide the way of managing the minimal number of experiments that could give all the information of all the factors that affect the performance parameter. Results of these experiments are used to analyze the data and predict the quality of components produced. The most important and critical part of orthogonal arrays method is to select the level combinations of the input design variables for each experiment. However, since the results of this method in many sectors are tremendous, many companies try to implement this method in their design and processes. This method has helped the companies reduce development time and cost more than expected.

Concurrent Engineering

Concurrent engineering is a method that takes many people from different disciplines together in the early stage of product design in order to simultaneously design the product and the process. To achieve a smooth transition from the design stage to actual production and to have a shorter product development time with improved quality results, concurrent engineering is used. It brings together multidisciplinary teams involving systems engineers, mechanical engineers, electrical engineers, quality managers, and so on to work together and in parallel from the start of the project to the end.

Today, while competition is very high, customers' needs and requirements are rapidly changing. For the success of the companies, satisfaction of the customers is a must and companies frequently need to present new products to the market for the changing desires of the customers. So, they must be fast in the presentation of new products to the market in order to be competitive in the market. Unfortunately, many companies are not very well and are inefficient in getting new products to the market. Problems in converting ideas to finished products are mostly due to poor design. Design decisions affect sales strategies, efficiency of production, speed of repair and product cost. In concurrent engineering, design and development of the product run simultaneously rather than consecutively. It decreases product development time and the time to market and also leads to improved productivity and reduced cost of production.

In the old approach of product and process design, the designers come up with the exact product characteristics. After the design was finished, it is passed on to operations and the design of the production that will produce the product is made. This approach is called "over-the-wall" since the designs are finished separately then pass to the operations unit. Then this becomes a great problem for this unit how to produce it. It is a sequential design with walls between functional areas. This old approach is very inefficient, time-consuming and costly. For example, some features of the product that are not very important for the designers of the product, can cause a lot of problems in the design of the production process. The cost of the production can increase unexpectedly or it can be very difficult for the operations unit to manufacture it. Since there is no cooperation and communication between these two business units (design and operations), unnecessary costs that pass to the customers emerge or it takes too long time to make some changes in the design of the product. Concurrent engineering allows everyone in the organization to work together, therefore the company faces no such type of problems.

Over-the-wall relies on tasks being performed sequentially and with very little or no need for communication or collaboration.

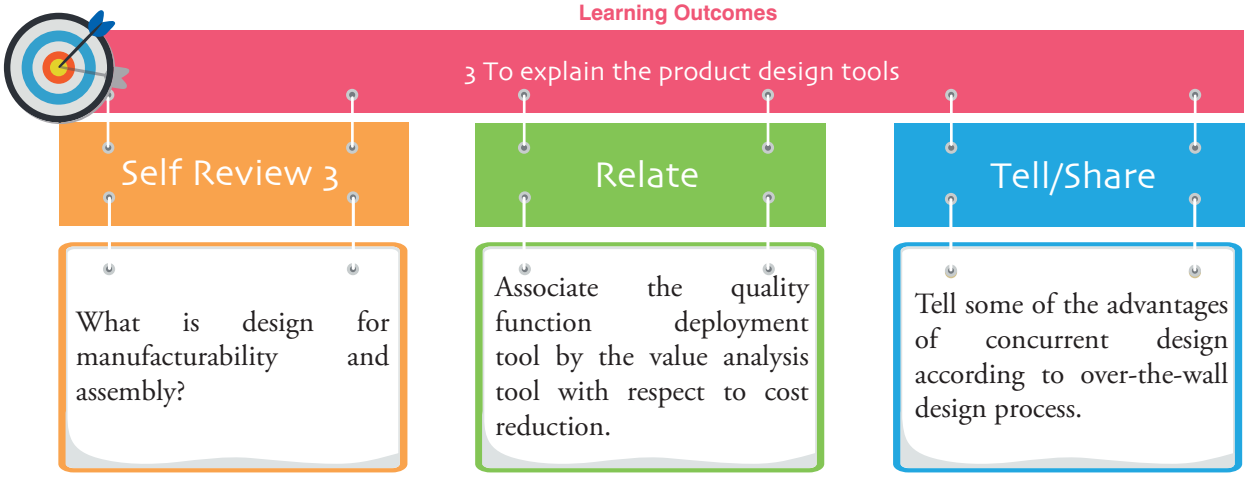
Another problem of the old approach is that it takes a longer amount of time since the work is done in sequence. However, when the product and process design are done concurrently, new product introductions occurres faster. In highly competitive markets, companies do not have the chance or time to follow a sequential approach. Moreover, in old approach everyone works alone, no team work is done and there is no synergy. Concurrent engineering creates a team atmosphere that everyone is responsible for designing and getting the product to market. Everyone in the team continues working together to resolve problems with the product and improve the process.

Concurrent engineering cannot be applied easily and fast to improve the performance of the company. It's a business strategy that tries to allocate important company resources. The major objective of this business strategy is to improve product development performance. It is a long-term strategy, and in order to be successful in this method, it requires major organizational and cultural change.

Concurrent engineering is a method of simultaneously designing products, and the processes for manufacturing those products, through the use of cross functional teams to assure manufacturability, lowest lifecycle costs, and to reduce overall development cycle time.

The implementation of this method focuses on three areas: people, process, and technology. Because of the necessity of integration of people, business methods and technology, it requires major organizational changes. Formation of teams is very important for collaboration rather than individual effort, and shared information is the key to success. The team leader must supply the basic foundation and support for change, rather than telling the other team members what to do, and training the people to work together in teams is an important factor in the success of implementation of concurrent engineering.

All the necessary information related to products, parts and processes must be available when it is needed for the success of its implementation. The smooth flow of information under tightly controlled conditions allows the users to access, distribute, store, and retrieve the information from a variety of sources. In order to achieve the required results in the organization, concurrent engineering must be well managed and controlled.



SELECTION OF THE PRODUCTION PROCESS

After the issue discussed about the design of the product, it is also very important how to produce this designed product in order to be successful in the competitive market. Product design cannot be considered separately from the selection of the production process. In this section process design is to be discussed and then the relation of product design to process selection is analyzed.

Selection of the right production process requires the consideration of many factors. Some of the most important ones are the volume and the variety of products to be produced, trade-offs between the cost of the production and the flexibility of it, compatibility with the organization's product portfolio, company's order-winning dimensions, and the relative costs and risks.

Production Process Types

Production processes are classified in Chapter 1 and described in a detailed way. In this topic, before discussing the selection of the production process, a brief explanation of the classification of the production processes is given for reminding them.

The classification of the production processes can be made according to the demand of the customer. In this classification there are three types of processes: make-to-stock, make-to-order and assemble-to-order.

Make-to-stock process: Make-to stock process is a traditional production strategy that is used by the companies to match the inventory with expected customer demand. Since products are produced according to the demand forecast, the accuracy of the forecasts is very important for the company. The accuracy of the forecasts prevents excess inventory and opportunity loss due to stockout. So, when the demand is accurately forecasted to some extent then there is no problem for the company. Otherwise, company faces with many problems such as excess inventory, loss of cash gains. In a make-to stock production, business processes can remain stable and unchanged. However, due to the uncertainty of demand in the market and products are produced before customer orders are received, it is a risky production strategy. Companies applying this process have competitive advantages like meeting customer demand immediately, meeting unexpected demand, increasing efficiency and minimizing cost, but on the other hand there are some disadvantages of this process such as high inventory costs and standard and inflexible products.

Make-to-order process: In make-to-order processes, the production is activated only in response to an actual demand or orders from customers. After receiving the order, the design must be completed, and materials are ordered that are not on hand from the suppliers then materials and labor are added for the processes and the process for the order is completed. After the order is delivered to the customer, the cycle is completed. The critical and important performance measure of this process is the lead time which is the length of time to design and produce the product. Another one is the percentage of orders completed on time. In this process, products are produced according to the customers' desires, so they are customized products. Some of the advantages of this process are more flexible customized products, less inventory and higher customer satisfaction. Some of the disadvantages of this process are expensive products, inefficient processes and long lead times.

Assemble-to-order process: Assemble-to-order process is a business production strategy where products ordered by customers are produced quickly and are customizable to a certain extent. It is a hybrid process between make-to-stock where products are fully produced in advance and make-to-order where the products are produced after the order is received. It tries to combine the benefits of both processes. It provides products into customers' hand fast while allowing for the product to be customized. In this process, the basic parts of the product are already produced but not yet assembled. When the orders come, the parts are assembled quickly and delivered to the customer. Assemble-to-order provides flexibility, speed and helps reduce waste. It is said that this process is agile and lean at the same time. This process has the capability of generating a production order to assemble the finished product right out of the sales order. It is beneficial for companies where a great number of customers demand for customized products and keep inventory costs in low levels.

Another classification of the production processes can be made according to physical configuration, material and product flow, product variation and volume expectation. In this textbook processes are classified according to product flow and volume expectations into the following four categories:

1. Flow processes
2. Job-shop processes
3. Cellular processes
4. Project processes

Flow processes: In this process, products are produced following the same process in the same sequence. Generally high volumes of standardized products are produced efficiently. The production process is separated into tasks or operations and then loaded to sequentially arranged work stations. Each workstation is distinct from the next, and value is added at each workstation until the product is finished. It is usually difficult to introduce new products to this type of production process. Although flexibility is low, efficiency is very high. Therefore the cost of production is low. Initial investment of this type of production process is high due to the usage of specialized tools and equipment. Balance of the workstations is

very important for the efficiency of it and work in process inventories are too low or none. Besides, most of the time automation is high in this process. There are three types of flow processes which are continuous flow processes, repetitive or discrete flow processes and disconnected or batch flow processes.

Job-shop processes: Generally job shop operates on a relatively small scale. In job-shop processes a high variety products in small batches with different processing requirements are produced. Since different products need different processing, the route of the production is not standard. Each work includes small jobs with somewhat different processing requirements. Therefore, operations tend to be labor intensive rather than capital intensive. General purpose equipment are used for the production of different products and semiskilled or highly skilled workers are needed in this process because workers need to be flexible to perform different operations. Since wide variety of products are produced in different routes, it is not an efficient process and the cost of the production is high. The production is usually started by the order of the customer and the products are customized.

Cellular processes: Cellular processes are the combination of flow processes and job-shop processes. It is a hybrid production process that tries to take the opportunity of the efficiency of flow processes and the flexibility of job-shop processes. When there are some problems in flow processes or job-shop processes, manufacturer tries to convert its processes into a cellular design. In cellular processes machines are grouped together according to the families of parts produced. It provides a clear advantage by the improved material flow and reduces the traveling distance by materials, inventory, people which increases the overall lead times. Since the goal of this process is to minimize the travel distance between each step and cycles starting point of the process must be close to the finish of the process. Most of the cells are designed as U-shaped for taking the advantage of minimizing the travel distance. A cell can be small and clearly-defined production unit within a larger factory. In this unit a family of like parts or a product is produced. Since all necessary machines and manpower are in this cell, it gives a degree of operational autonomy. The workers must be fully skilled for systematic job rotation and training. Training of the workers is necessary conditions for effective cell development and efficiency of it.

Project processes: In project processes, generally large scale, complex and unique products are produced. The lead time of the production is long and requires a large investment of funds and resources and usually one product at a time is produced according to the customer's desire. This process is used when there is high customization and low volume of product. Customer is usually involved in the design of the product before the production. Materials, labor and equipment are brought to the place where the production is made and it is usually stationary. Since the production of one of a kind product takes long time to produce, it is considered as a project and the production cost is high for this process.

When the company tries to select the suitable production process for achievement of the company goals, many factors are important. Some of the most important factors that are critical for this selection are product variety and the volume of production. When a wide variety of products are required to be produced in small quantities, the flexibility of the process must be high so job-shop processes can be selected and used for this production. By contrast, when a narrow range of products with high volume is required to be produced, selection of the flow processes for the production has many advantages as it is stated in the description of the flow process.

The variety and volume of products to be produced in the company are affected by whether the company sells the products that are made to stock or made to order. Since, when the make-to-stock products are presented to the market, they are generally produced in large quantities. However, when the company presents make-to-order products to the market, the variety of the products are wide and the production process must be flexible.

Another important point for the selection of the process is that some companies can use different processes for different kinds of products and the best fitting process may change over time when new products are introduced and the current ones mature and die. After the introduction of the product to the market, it passes through different phases of product life cycle and the order-

winning dimensions of the product can change by time because of changing customer requirements and competition. In the introduction phase of the product, the design of the product can change frequently, demand can be relatively low and the price of it can be not so much important. However, the selection of the best production process for the product can change when the product is in the mature phase, the design of it is not changed and the product is produced at high volumes and price is very important for the competition. In order to be competitive in the market, the production process of the companies for individual products in their life cycles must be flexible to the changes and the company must adapt their production systems to the overall mix of products produced by the process. For the selection of the best process, the company must take into consideration production of the mix of products rather than single product (Martinich, 1997, p. 350).

Product-Process Matrix

Product-process matrix, shown in Figure 3.7, is very helpful for analyzing the relationships between the production process, product mix and product life cycle phases. While the horizontal dimension of the matrix shows production volume, product variety and the degree of product standardization, the vertical dimension of the matrix shows the types of processes which absolutely specify the condition of being connected to each other, specialization/flexibility, automation and production volume.

It is important to be close to the diagonal of the matrix when the company matches its products and processes. For example, if a company such as producer of customized carpets produces wide variety of products in small quantities, the production process must be job-shop process with high flexibility and it does not need specialized process with high volumes of production. But when the company produces standard products such as automobile tires in high volumes, it is beneficial for the company to use flow processes for the production. Companies within the same sector can be successful in the market although they are at different points of the matrix as long as they are close to the diagonal of the matrix. For example, while some small dairy farm companies producing a wide variety of special white cheeses are located close to the upper left corner of the matrix, large dairy farm companies producing standard white cheeses in huge volumes are located close to the lower right corner of the matrix.

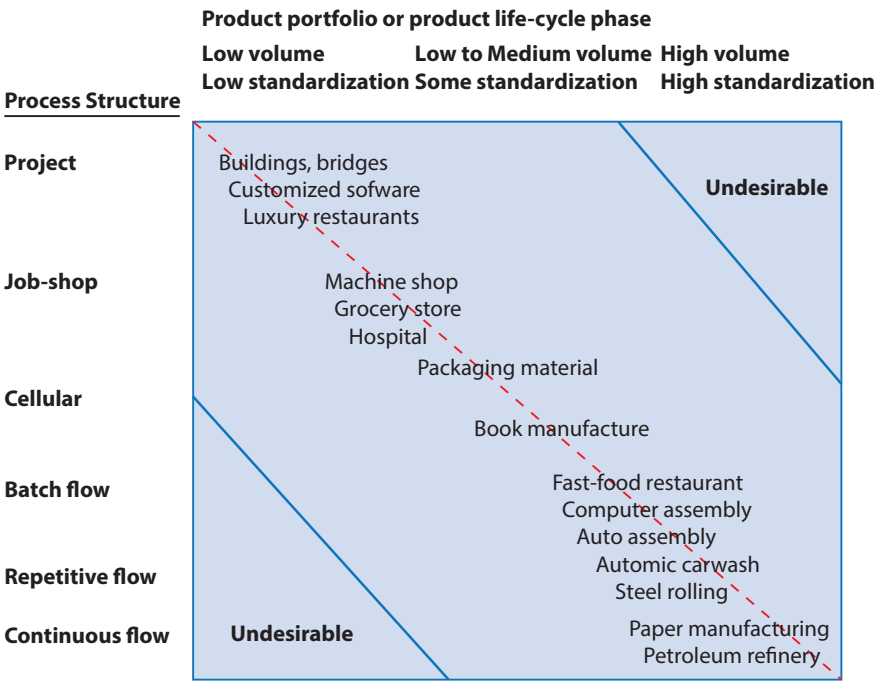


Figure 3.7 Product-Process Matrix

Source: Martinich, J.S., 1997.

The product-process matrix can provide a company to perceive its marketing and operations strategies together. If a company is not located at the diagonal it shows the inconsistency of the strategy. When a company uses an automated flow process for a high volume of production of a certain product with low cost, the competitors cannot compete with this low cost and price and they can use job-shop production with a wide variety of products or customized products in order not to lose their market share. In this situation, the first company can try to produce products with more variety. This forces the company to move to the left on the matrix. So the company uses flow processes to produce a wide range of products in small quantities with specialized equipment. Therefore, its product and process do not match and its marketing and operations strategies become inconsistent. In this case, the company either reduces its product variation or builds a separate different process for low volume production. The opposite of this situation can also happen. A company that is very successful with customized products can lose its market share to a company which has inflexible but efficient production processes that compete on price.

The product-process matrix helps companies in selecting technologies and products,as well. When the company knows the place of itself on the matrix, its competitive advantages and phases of its products on the life cycle, the company can easily make decisions about adding or dropping a product, expanding capacity, creating special processes or increasing process flexibility. Another important help of this matrix is to see the exact position of the production structure of the company on the matrix and prevent product proliferation by showing the effects of adding or dropping products to the production process.

A company can be seen in a particular region on the matrix. This region is determined by the company's stage in the product life cycle and the firm's selection of production process. At the upper left extreme, companies are characterized as process oriented or focused while the lower right extreme holds companies that are said to be product focused. The decision of where a company locates on the matrix is determined by whether the production system is organized by grouping resources around the process or the product.

Read more: https://www.referenceforbusiness.com/management/Or-Pr/Product-Process-Matrix.html#ixzz5rfs48hxy

As it is seen in Figure 3.7, both project and job-shop processes have low volumes and offer customization. However, project processes are more customized in very low volumes compared to job-shop processes. Also, note that both repetitive and continuous flow processes produce standardized products in large volumes. But continuous flow processes are more extreme cases of high volume and product standardization than are repetitive flow processes. In Figure 3.7 the diagonal line shows the best process strategies for these processes relative to product volume and product variety. Companies whose process strategies do not fall along this diagonal may select the wrong process type as the best fitting one. But, keep in mind that not all companies fit into only one of these process types. Due to the structure and condition of the market, the company may use both job-shop and batch flow processes. Moreover, as it is seen in Figure 3.7, cellular processes are located between job-shop and flow processes to take advantage of both of these processes.

Learning Outcomes

4 To analyze the selection of the production process

Self Review 4	Relate	Tell/Share
How can breakeven analysis be applied to process selection?	Associate the selection of technology by the selection of the production process.	Tell some of the advantages of cellular processes according to job-shop processes.

Summary

LO 1 Define the product selection

Good product is one of the essential factors of a company to be successful in the market. It can be disaster for a company if the product strategy is not set according to the company's overall strategy and the market structure. In order to maximize the success of potential products, companies focus on only a narrow range of products and then concentrate on those products. The core competences of those products are the key factors for the success of the company. Since all the products have a lifespan, the companies must continuously select and develop new products to survive in the market. For the success of new products, communication among customers, products, suppliers and functions such as marketing and operations of the company are very important factors.

Every product has life span and they are born then they live and die. Every product goes out of the market by changes in the market sooner or later. The lives of products are changing from one product to another, from a few months to several decades. However, the structure of product life cycles is the same for all the products regardless of the length of the cycle. The phases of the products in the product life cycle are birth or introduction, growth, maturity and decline.

Strategically, a product design defines a company's customers and competitors, at the same time. It uses the core competencies of a company and tries to determine what new competencies are needed for the development of new products and competition. While companies try to construct strategies for the products in order to be successful in the competitive market, they need to know the activities and responsibilities of product design. So, they become conscious of the value of product design for their customers and themselves.

LO 2 Explain the product development and design process

Companies need to develop products for their customers on a continuing basis. Therefore, many decisions about product such as product selection, definition and design, are taken in the companies. Moreover, companies should know how to find and develop new products for the sustainability of the company in the competitive market. An effective product strategy connects decisions about the product to other business functions such as research and development, operations, marketing and finance. A company needs financial support, understanding of the marketplace and human skills for the successful product development. Success of the product development process can determine not only successful products but also future of the company. Design process is in the product development process that tries to meet the needs and requirements of marketing and business. It is actually a set of technical activities. Some of the main activities are refinement of the product vision into technical specifications, new concept development, and embodiment engineering of the new product. They do not cover business and financial management activities of product development and marketing and distribution development activities, as well.

In product development process creativity, understanding, communication, testing and persuasion activities are essential for the success of it. Product development process is separated into three phases: Understand the opportunity, develop a concept and implement a concept.

Design is not a random combination of elements, but it is the output of some planned activity to create some new things for a specific purpose. The value of this output is important, as well and it is not so easy to assess the value of this output objectively, when the output is evaluated aesthetically, since it is a matter of taste and highly subjective. Although design is intrinsically linked with taste, it has an economic role. The design process is not the combination of function with materials to have efficient production. However, it is the combination of style and appearance that products attract customers. Well design does not emerge by accident but as the result of a well managed process. Many companies have tried to prepare and use their own variations of the basic road map for the design process. Therefore, it is important to keep in mind that each type of business has its own version and the names and quantities of these stages can vary widely.

LO 3 Explain the product design tools

Many different kinds of design tools and methods have been developed to help product designers and teams develop products with high quality, low cost and decreased product development time. Depending on the conditions of the companies and inner and outer factors affecting the company, the company uses one or more of these tools and methods.

One of the important product design tools is quality function deployment (QFD) which is first used in Japan in the late 1960s as a form of cause-and-effect analysis, and it was brought to the United States in the early 1980s. Most of its popularity comes as a result of numerous successes in the automotive industry. QFD is transfering the voice of the customer to the design specifications of a product. During the implementation of this method multi-disciplinary teams from marketing, design, engineering and manufacturing are used in the organizations. One of the essential tools of QFD is house of quality which is a matrix for defining the relationship between customer desires and product. The design team uses customer feedback in a house of quality matrix to make many decisions about marketing, engineering and design. The matrix assists the team to translate customer desires into solid operating goals. The house of quality matrix shows the important product characteristics and goals for improvement and they are jointly determined and detailed in the matrix.

Value analysis is also known as value engineering, is a design methodology developed by General Electric in 1947 that focuses on the function of the product, rather than on its structure or form. This methodology's effort is to maximize the economic value of a product or component relative to its cost. The purpose of value analysis is to simplify products and processes in order to achieve equivalent or better performance at a lower cost while maintaining all functional requirements defined by the customer.

The Taguchi method is one of the best known methods used in robust design. Taguchi emphasizes the design phase of the product for the quality of it and remarks that it is much easier and cheaper if the changes are made on the design phase instead of production process. Taguchi is known for applying a method called design of experiment to product design. This method is based on robust design which is a design that results in products that can perform over a wide range of conditions. Taguchi determines the number of customer preferences toward on-target quality in the quality loss function. The quadratic function shows that a customer's dissatisfaction (quality loss) increases geometrically as the actual value deviates from the target value.

Concurrent engineering is a method that takes many people from different disciplines together in the early stage of product design in order to simultaneously design the product and the process. To achieve a smooth transition from the design stage to actual production and to have a shorter product development time with improved quality results, concurrent engineering is used. It brings together multidisciplinary teams involving systems engineers, mechanical engineers, electrical engineers, quality managers, and so on to work together and in parallel from the start of the project to the end.

Summary

LO 4 Analyze the selection of the production process.

Selection of the right production process requires the consideration of many factors. Some of the most important ones are the volume and the variety of products to be produced, trade-offs between cost of the production and the flexibility of it, compatibility with the organization's product portfolio, company's order-winning dimensions, and the relative costs and risks.

The classification of the production processes can be made according to the demand of the customer. In this classification there are three types of processes: make-to-stock, make-to-order and assemble-to-order. Another classification of the production processes can be made according to physical configuration, material and product flow, product variation and volume expectation. In this textbook processes are classified according to product flow and volume expectations into the following four categories: Flow processes, job-shop processes, cellular processes and project processes.

Product-process matrix is very helpful for analyzing the relationships between the production process, product mix and product life cycle phases. While the horizontal dimension of the matrix shows production volume, product variety and the degree of product standardization, the vertical dimension of the matrix shows the types of processes which absolutely specify the condition of being connected to each other, specialization/flexibility, automation and production volume. It is important to be close to the diagonal of the matrix when the company matches its products and processes. For example, if a company such as producer of customized carpets produces wide variety of products in small quantities, the production process must be job-shop process with high flexibility and it does not need specialized process with high volumes of production. But when the company produces standard products such as automobile tires in high volumes, it is beneficial for the company to use flow processes for the production. Companies within the same sector can be successful in the market although they are at different points of the matrix as long as they are close to the diagonal of the matrix.

The matrix has two dimensions that help to illustrate the linkage between the type of product produced and the production process. The first being product structure/product life cycle and the second is process structure/process life cycle. The organization can identify the type of production approach necessary for a particular product with these two dimensions.

1 In which one of the product life cycle phases is the sales low because the market is too small?

a. Introduction
b. Growth
c. Maturity
d. Decline
e. Push

2 Which one of the followings is not a characteristic of maturity phase?

a. Competition is high.
b. Major changes related to product are required.
c. Brand loyalty must be company objective.
d. Competitive pricing is important to increase market share.
e. Saturation in the market means the growth is slowing down.

3 I- Product strategy should include a design to define company's customers and competitors.

II- Even if design becomes so successful in the market, companies should not change their strategy to maintain their position in the market.

III- Documenting specifications is one of the essential activities of product design.

Which of the above statements related to product strategy is/are correct?

a. Only I
b. Only III
c. I and II
d. I and III
e. II and III

4 A _ _ _ _ _ _ _ is a group of activities required to bring a new concept to a state of market readiness. Which of the following completes the sentences above?

a. design process
b. product development process
c. product selection
d. value analysis
e. make-to-order process

5 When considered phases of a product development process, which one of the following activities is required at "implementing a concept" phase?

a. Developing a vision
b. Determining threats
c. Modeling and testing of the physical construction
d. Designing general market specifications for the product
e. Portfolio planning

6 Creation of something that has not previously existed refers to_ _ _ _ _ _ _. Which one of the following completes the sentences above?

a. choice
b. compromise
c. complexity
d. creativity
e. trade-off

7 Using standard components and tools_____ Which one of the following completes the sentences above?

a. creates an opportunity of cost saving
b. increases the number of parts used
c. makes the production automated
d. creates inefficiency because of dividing the product into modules
e. is costly because it requires experiment of design

8 Which one of the followings is a design methodology that relates customer requirements to the technical attributes of the product?

a. Quality function deployment (QFD)
b. Value analysis
c. Simplicity
d. Taguchi method
e. Concurrent Engineering

Test Yourself

9 According to which one of the following design tools, does customer's dissatisfaction mean quality loss?

a. Concurrent Engineering
b. Taguchi method
c. Quality function deployment (QFD)
d. Value analysis
e. Simplicity

10 When considered a company producing customized curtains, which one of the following production process types is beneficial for the company?

a. Make-to-stock process
b. Project processes
c. Job-shop processes
d. Flow processes
e. Mistake-proof assembly

1. a	If your answer is wrong, please review the "Product Selection" section.	6. d	If your answer is wrong, please review the "Product Development and Design Process" section.
2. b	If your answer is wrong, please review the "Product Selection" section.	7. a	If your answer is wrong, please review the "Product Development and Design Process" section.
3. d	If your answer is wrong, please review the "Product Selection" section.	8. a	If your answer is wrong, please review the "Product Design Tools" section.
4. b	If your answer is wrong, please review the "Product Development and Design Process" section.	9. b	If your answer is wrong, please review the "Product Design Tools" section.
5. c	If your answer is wrong, please review the "Product Development and Design Process" section.	10. c	If your answer is wrong, please review the "Selection of the Production Process" section.

self review 1

What are the most important elements of an effective product strategy?

The most important elements of an effective product strategy are market and needs, key features and differentiators and business goals. The market explains the target customers and users of the product. The need involves the main problem the company's product solves or the main benefit it gives. Key features and the differentiators of the product are crucial to address the main problem or create the main benefit and make customers select it among competitors' products. Company must focus on a few key aspects that make customers buy and use it. The business goals take the control of how the company's product will benefit the company such as generate revenue, help sell other products, decrease cost or increase the brand equity.

self review 2

What is stage-gate model as a new product development process model?

It is project management approach that divides up the process of developing new products into a funnel system. However, separating out the key stages in the design process such as sourcing appropriate design skills, preparing briefs, project management and evaluation, the management aspects of the process can be more understandable. At the end of each stage, many activities pass through a management approved gate before moving onto the next stage. Business functions such as marketing, operations, or purchasing need to feed into the design management process to evaluate its viability at each stage and be prepared to abort the project if it is not appropriate for the business goals. One of the most important stages of the process is design brief that defines the purpose and objectives of the design project, timescales and costs, concept development, detailed design and assessment of the final outcome. In some implementations stages are processed simultaneously and by this model companies cut the cost by filtering out the inappropriate concepts and ideas through the funnel.

Suggested Answers for "Self Review"

self review 3

What is design for manufacturing and assembly?

Design for manufacturing is the method of design for ease of manufacturing of the collection of parts that will form the product after assembly. It is a tool used to determine the most cost effective material and process to be used in the production in the early stages of the product design. It is concerned with decreasing the whole production cost by minimizing the complexity of operations and using common data features and primary axes. Design for assembly can be defined briefly as the method of design of the product for ease of assembly. It is a tool used to help the designers in the design of the products that will transition to productions at a minimum cost, focusing on the number of parts used, handling and ease of assembly. It is concerned only with decreasing product assembly cost by minimizing the number of assembly operations. However, individual parts tend to be more complex in design.

self review 4

How can breakeven analysis be applied to process selection?

Many quantitative methods can be used for selecting a process. One of them is the process selection which is based on cost tradeoffs associated with demand volume. Breakeven analysis allows manufacturing managers to visually present alternative profits (and losses) based on the number of units produced or sold. Specific equipment follows the selection of the general type of process structure in an organization. The components of this analysis are volume which is the level of production, mostly expressed as the number of units produced, cost which is divided into two: fixed and variable, revenue which is the price of the item times volume sold and the profit which is the difference between revenue and total cost. In selecting a process volume of sales and production expected must be determined to earn a profit. It is required that the cost of producing a product does not exceed the revenue received from the sale of the product. By equating total revenue with total cost, the volume at which profit is zero can be found. This is called breakeven point. The profit is made above this breakeven point. The best process depends on the anticipated volume of demand for the product and the tradeoffs between fixed and variable costs.

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Chapter 4 Facility Layout and Capacity Planning

After completing this chapter, you will be able to;

Learning Outcomes

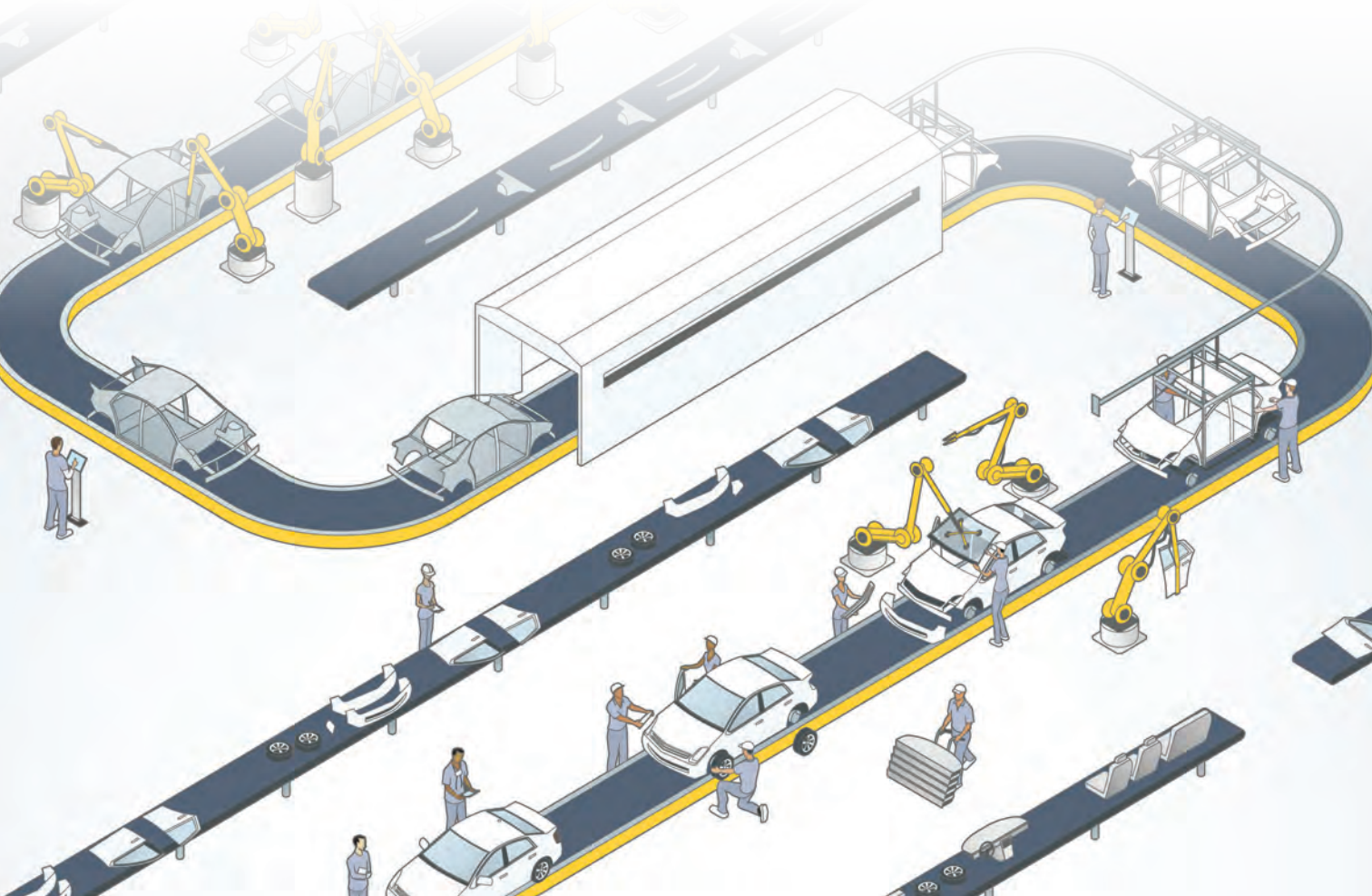
1. Define facility layout planning and basic objectives.
2. Explain facility layout types and characteristics.
3. Sort the solution methods applied in the facility layout design.
4. Define the concept and types of capacity.

Chapter Outline

Introduction
Facility Layout
Types of Facility Layouts
Designing Facility Layouts
Capacity Planning

Key Terms

Facility Layout
Line Balancing
Capacity Planning
Theoretical Capacity
Effective Capacity
Decision Tree



INTRODUCTION

Facility layout planning refers to the process of designing the physical layout of resources in a production system. The decision of the facility layout of an enterprise is usually made during the installation phase. However, in an existing production system, the facility layout can be rearranged for various reasons such as capacity change requirements and productivity problems. The production process, production volume and product variety are of great importance in deciding the layout of the facilities. After the layout decision is made, detailed facility planning is made for the best positioning and arrangement of production resources. In this process, different problems should be solved according to the type of layout that will optimize the performance of the system.

Designing and constructing or establishing production facilities means that production resources are in some way fixed. For this reason, enterprises should make long-term demand forecasts before deciding the size and layout of the facility. In this way, the capacity that the facilities should have in the long term can be determined and it will be possible to supply and establish the production resources that will constitute this capacity.

Capacity planning is closely related to the competitiveness of enterprises. The delicate balance between capacity and demand will positively affect the success of an enterprise in a competitive environment. Facility layout and capacity planning are important issues in operations management.

FACILITY LAYOUT

Facility layout is one of the key decisions that affect the success of an organization. According to the business processes and objectives of the facilities, many facility layouts can be applied. For example, the proximity of employees in an office environment, customer satisfaction in the retail sector, minimizing the amount of material transport in a warehouse layout plays an important role in determining the layout. Facility layout refers to the arrangement of the location of production resources, workstations, stock areas within an existing or proposed facility in an enterprise that produces products or services.

Facility Layout decisions are very important for organizations. Although there are many reasons for this, three main reasons are as follows:

- Large expenditure of money and effort for the construction of facilities and no compensation for this.
- The result of layout decisions covers a long period. Therefore, it is very difficult to overcome the mistakes to be made.
- The decision about facility layout significantly affects production efficiency and production cost.

Facility layout planning: These are all decisions made to determine the appropriate physical placement of production resources.

Facility layout planning is to decide how to place the physical production resources used in the transformation process such as labor, machinery, raw material, product, intermediate product and personnel. Although the layout is usually carried out during the establishment of a production or service facility, existing facilities may also need to be re-planned for different reasons and changes. The main purpose of planning the layout of the production resources in a production system is to maximize the benefit.

Although the targets in the facility layout may differ according to the strategic plans of the enterprises, there are basic targets that apply to all systems in the efficient and safe execution of the production process.

- ***Safety:*** It is necessary to prevent unauthorized access to all processes and places that may pose a danger to the customer and personnel.
- ***Flow of movement:*** Material, information and customer movement areas in the production process should be designed appropriately. While aiming to minimize material flow in a manufacturing facility, it may be desirable to maximize the customer navigation route in a shopping mall.
- ***Comfort of employees:*** In the production process, it is necessary to ensure that the working conditions of the personnel are appropriate. Ergonomic factors such as noise, temperature and lighting should be considered in the layout planning.

- ***Ease of communication:*** *Ensuring communication within the facility is an important issue. Access to devices such as telephones and monitors should be provided for personnel to communicate during the production process.*
- ***Access:*** All machinery and equipment must be placed in an accessible manner for cleaning, maintenance and repair.
- ***Space usage:*** *Designing spaces in facilities is also an important decision. While it is aimed to minimize the spaces in a manufacturing facility, the areas designed for a luxury hotel may need to be large.*
- ***Flexibility:*** Innovations in technology, improvements in product design and similar changes may require a reorganization of the plant layout. Therefore, good plant layout should anticipate any future changes and be designed to adapt to these changes.
- ***Bottlenecks:*** Variables such as production process, capacity planning, machine utilization rates, and semi-finished stock quantities should be taken into consideration in the layout planning of the facility. Therefore, bottlenecks can be prevented.

The facility layout features specified here are the criteria that apply to almost all businesses or organizations. Many business environments need different facility layouts due to their characteristics. Office activities, services requiring face-to-face interaction, manufacturing sector where machine-human interaction is intense, retail sales processes may need different layout plans.

How can one say that the facility layout of an enterprise is well designed? Of course, except for the above-mentioned general objectives, the answer to this question differs according to the nature of the service or product produced and the type of production process. It is necessary to design the best layout in order to ensure efficient production of the plant layouts applied in different production process types. Optimization problems and simulation applications that can be solved can be used in the design of the plant layout. Therefore, in this section, firstly the types of facility layout will be listed and then the design details of these layout types will be given.

Learning Outcomes

1 To define facility layout planning and basic objectives.

Self Review 1

In a hospital, the baby birth department and the radiology department should not be designed to be close to each other.

What is the subject of this issue which should be considered in facility layout planning?

Relate

Associate facility layout planning with occupational safety processes.

Tell/Share

Explain the possible negative effects that a facility layout with faulty design may cause to employees and entrepreneurs.

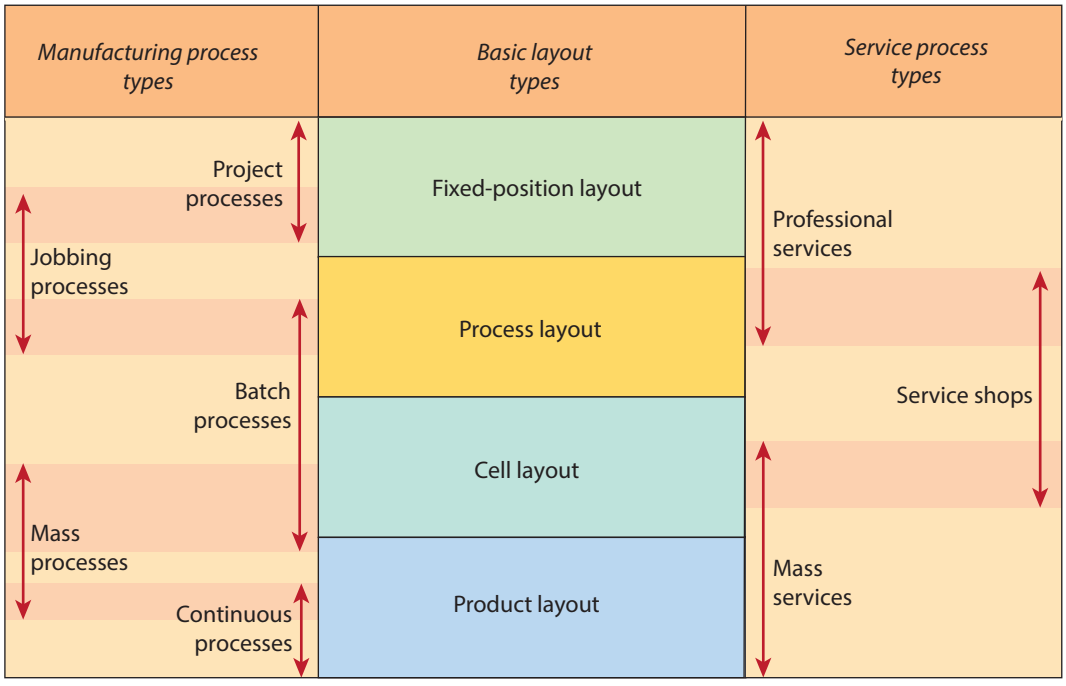
TYPES OF FACILITY LAYOUTS

Facility layout planning is the decision to determine the location of machines in a manufacturing facility, the location of tables and office machines in an office, and the locations of polyclinics in a hospital. An effective layout plan means the best flow of materials, people and information between departments. In order to achieve this aim, different approaches have been developed according to production processes and characteristics. Four basic approaches in this chapter are discussed.

- Fixed-position layouts
- Process Layouts
- Product Layouts
- Cell layouts

The main feature that distinguishes the facility layout types is the differences in the activities and processes of the organizations. Although process characteristics are decisive in choosing the layout, in some cases there may be intersections between the process type and the layout types. Table 4.1 shows the relationship between basic facility layout types and manufacturing and service processes.

Table 4.1 The relationship between process types and basic layout types (Slack, p. 94)



Fixed-Position Layouts

Fixed-position layout is also called project-type layout. While the product or the basic raw material is fixed in the fixed arrangement, the machinery, equipment, labor and other materials that perform the production are moved to the fixed position. The main reason for this is that the product or service produced is too large to carry. Construction of dams and buildings, ship and airplane manufacturing, highway construction, oil and mineral extraction, production processes in which agricultural production resources are transferred to products or services.

important

In a fixed--position facility, the product is not moved due to its structure and size. Instead, production resources are moved around the product.

Figure 4.1 Fixed—Position Layout Example

Process Layouts

Process layout is a group of production resources based on similar processes and functions. Process layout, also called functional layout, is a suitable layout for workshop and batch production processes. In workshop and batch production, where the number of parts is high and production volume is low, it is advantageous to group and place the production resources according to their functions. Figure 4.2. shows the layout of five workstations where similar machines are positioned together according to their functions.

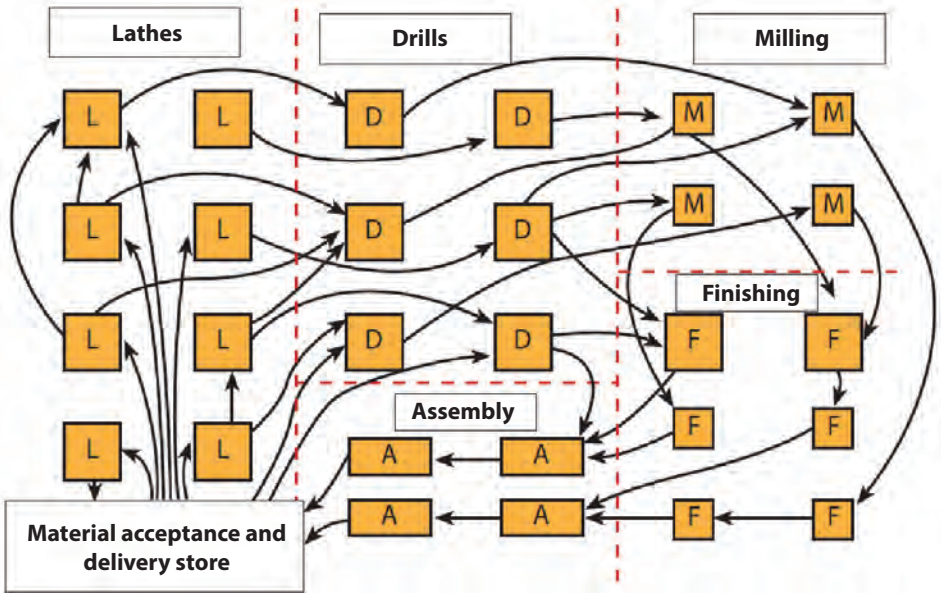


Figure 4.2 In the Process Layout, Machines with the Same Function are Located in the Same Workshop

In the process layout, parts are transported between workshops by flexible transport methods such as forklifts. Hospitals in the service sector can be given as examples of facilities where the process layout is applied. The units in the hospitals are grouped according to the characteristics of the services provided (cardiology, radiology, oncology).

The facility layout where production resources are located together in the production systems with more product diversity and low production volume is called **process layout.**

Universities are service institutions with the same layout. The advantages and limitations of the process layout are listed below.

Advantages:

- Machine utilization rates are high and require fewer machines.
- Flexible use of production resources is possible.
- It requires lower investment costs.
- High utilization rate of its production facilities.
- The level of flexibility in the distribution of work is high.
- The satisfaction of the staff is higher.

Limitations:

- Long routes increase the amount of transport.
- The automation of the transport system is not possible.
- High setup times of the machines result in low productivity.
- Production time is higher than other facility layout types.
- Excess stocks in the production area cause a waste of space and capital.

The high transportation costs in the process layout planning highlighted the effort to minimize transport distances between the production departments. Mathematical models where production routes, production size and machine numbers as parameters are used to determine the locations of production units.

Product Layouts

In contrast to the functional layout, in the product layout, production resources are based on the product rather than the process. The machines and processes used in production are ordered according to the processes carried out from the processing of the raw material to the final product. In the facilities that produce services, departments are positioned according to the order of operations of the customers. The layout of the product is also called the production line because of its structure. In production lines, products flow through production resources. The product layout is designed for high-speed production of standard products or services. This type of layout is applied in the production of automobile assembly lines, self-service restaurants and electronic products.

important

In the product layout, production resources are sorted in the order in which the product is processed.

Figure 4.3 The First Assembly Line in the Automobile Industry was Implemented by Henry Ford.

The general characteristics of the product layout are summarized below.

- Production resources are designed for the purpose of high-speed production.
- Automation systems used to improve production speed and performance result in high installation costs.
- The process rate is faster as all the resources are ordered for efficient production.
- The arrangement of production resources according to the product, the proximity of the production lines to each other leads to lower material transportation costs compared to the process layout.
- The warehouse requirement for inventory is lower.
- Since all facilities and resources are customized for the production of certain products, there is no flexibility when a new product is added to the system or when substantial changes to the product are required.

Failure of a machine in the product layout can cause all production to pause. The speed of the production line depends on the machine or workstations with the lowest speed in the production system. Therefore, it is necessary to avoid bottlenecks while waiting for the capacity of the workstations and machines. The basic features of the product layout are compared with the process layout in Table 4.2.

Table 4.2 Comparison of Process Layout and Product Layout Features

Process Layout	Characteristics	Product Layout
High	Product variety	Low
General purpose	Resource usage	Specialized
Labor intensive	Resources feature	Technology intensive
High	Product flexibility	Low
Low	Production speed	High
High	Material handling cost	Low
Low	Stock area	Low

Cell Layouts

The *cell layout*, also called hybrid layout, is the layout that applies the advantages of both product layout and process layout together. In the cell layout, it is possible to process product groups formed by similar geometry or similar methods in the same section. Machines with different functions are used to produce a group of products together in a cell. In this way, each cell benefits from the advantages of the product layout when forming a production line. The simultaneous operation of more than one cell also means the flexibility of the process layout. Figure 4.4 shows the sample layout of the cell layout and the process layout.

Cell layout is the layout that allows similar parts to be grouped and processed at the same workstations. It is also called cellular manufacturing.

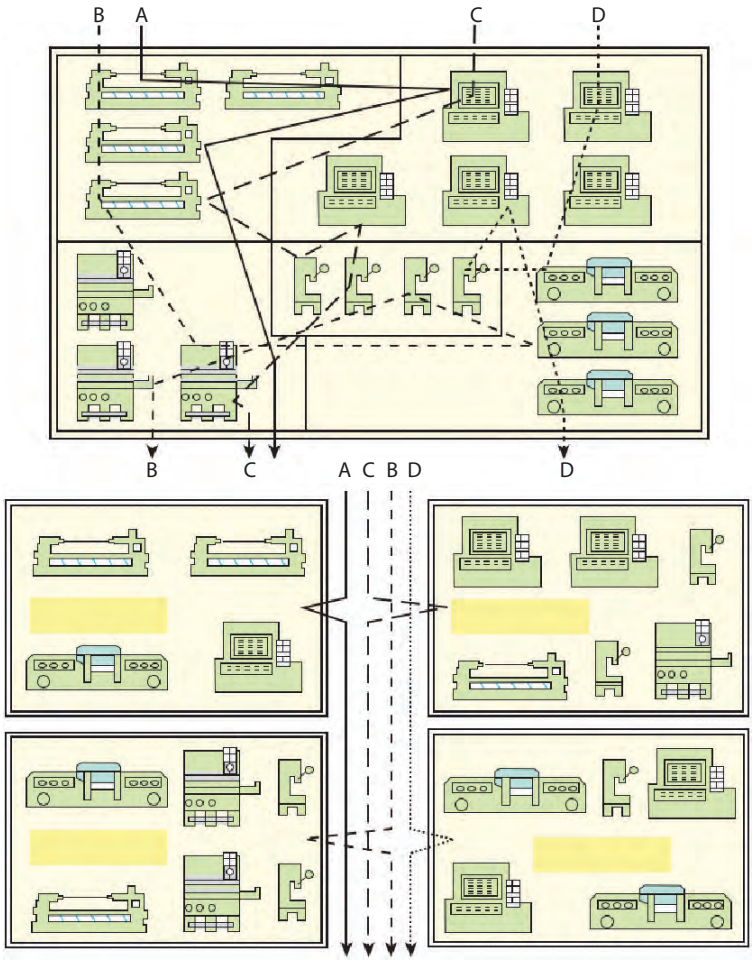


Figure 4.4 In the Cell Layout, the Pieces are Grouped for Processing in Cells Similar to the Figure.

The processing of similar parts in the same cells in the cell layout enables a reduction in machine setup times, especially in machining workshops. In this way, the number of parts in the process is reduced by increasing the machine utilization rate, shortening production time and reducing temporary stocks. The specialization of the personnel in the cell layout also affects the quality positively and the job satisfaction of the personnel increases. It is very important to assign the resources used in production to the cells. The cells that cannot be used efficiently can increase the investment cost.

Learning Outcomes

2 To explain facility layout types and characteristics.

Self Review 2	Relate	Tell/Share
Compare process layout with product layout in terms of installation cost?	Associate a hospital with a layout considering the departments and functions.	Explain to the product the general characteristics of the layout.

DESIGNING FACILITY LAYOUTS

The path followed by the raw material until it becomes a product is the most important factor in determining the facility layout. This movement, also known as flow, is defined as a material movement in manufacturing facilities and customer movement in service producing facilities. The performance of the facility where the flows are well planned is also high. Production volume and product variety are important in planning the flows in the facility layout.

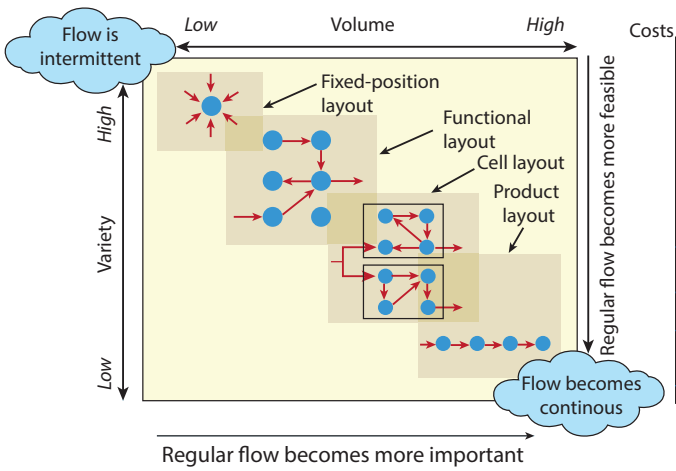
Flow cannot be mentioned in a production where production volume is low and product variety is high. For example, the reason why a facility that manufactures luxury yachts applies a fixed-location layout is that each product is ordered and has differences and is not easy to move because of the product's characteristics. It is not possible to mention an arrangement in which this facility will minimize the amount of flow in the layout design.

important

The number of products produced (volume) and the number of different products (variety) are important criteria for the selection of facility layout type.

Product flow in a production system with a high volume and low product variety is the main problem. However, in a production system with high product volume and high product variety, it is quite difficult to design a completely flow-based facility layout. Since different flow patterns will occur in these production systems, process layout may be an appropriate option. If the product variety can be divided into categories according to the similarities of the products, the cell layout can be a suitable layout.

a) The relationship between production volume and variety with the choice of basic facility layout desing



b) Basic layout types and costs

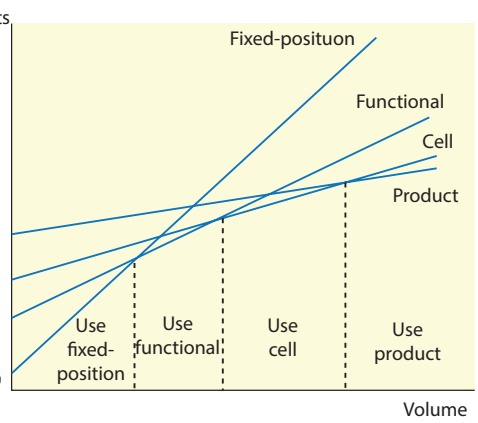


Figure 4.5 Production Process and Cost of Facility Layout Types (Slacks, p. 187)

Figure 4.5 (a) shows how production volume and product variety can be effective in determining the type of layout of a production facility. The volume and diversity characteristics of the production system can give an idea of which layout type will be more effective. However, making the right decision is possible by understanding the superiority and limitations of the basic layout types. Another important criterion in determining the type of layout is cost. In Figure 4.5 (b), the costs of the four main types of layouts are compared in terms of production volumes. The left vertical axis of this graph shows the fixed costs of placement types. According to the figure, the lowest fixed cost is the fixed location layout, whereas the product layout where automation systems are used is the highest fixed cost layout. If the production volume increases, the total costs of facility layout types are reversed. Theoretically, although the limits of preference seem very clear, it is not possible to determine these costs precisely during the installation phase. Therefore, it can be said that the limits of preference are not very clear.

The detail of the layout plan is designed after the basic layout of the facility is decided. Models are

available to help determine the best placement in accordance with the nature of each layout type. The models and solution techniques used in designing the detailed layout are briefly listed below in the following titles.

Fixed Position Layout Design

Due to the large size of the product in a fixed position arrangement, it is more convenient for the production resources to move to the product. The purpose of this type of layout is to ensure that the resources are arranged to provide the highest contribution. The design of a fixed-location layout is less complex than that of other types of layout.

Process Layout Design

The determination of the location of the workstations in the process layout or functional layout is the main decision of the layout design. In a facility with two workstations, it will not be difficult to determine the locations, because there are two possibilities. However, in a facility with five workstations similar to the one in Figure 4.2, 120 (5x4x3x2x1) different layouts can be created. The number of placement options calculated by factorial can be quite large when the number of workstations is large. There may also be workstations that must be close or distant to each other. An example of this is that the plastic product warehouse, which may be damaged by heat, should be away from the furnace or that the obstetrics department and the X-ray or tomography sections that are in danger of radiation should be distant. Close positioning of the two workstations, which may have an intensive material transfer between each other, will reduce the transportation cost.

important

The number of options in the process layout is calculated by the factorial of the number of workstations. For example, 5! = 1x2x3x4x5 = 120 different options can be created in a plant with five workstations.

The first step in designing the process layout is to compile the information required for the design. The information to be collected is listed below:

- Determining the amount of space required for each workstation,
- Determining the constraints of the building or area where the workstations will be placed,
- List possible workflow type and quantity among workstations,
- Obligations of the workstations to be close to a fixed point, listing the constraints of work centers to be close or distant with each other

LOADS

	Dep. A	Dep. B	Dep. C	Dep. D	Dep. E
Dep. A		10	20	18	-
Dep. B	5		5	-	-
Dep. C	-	25		-	15
Dep. D	12	5	10		2
Dep. E	10	-	5	-	

Unit Distance or Cost of Layout

	Dep. A	Dep. B	Dep. C	Dep. D	Dep. E
Dep. A		2	3	3	2
Dep. B	2		5	1	4
Dep. C	3	5		3	3
Dep. D	3	2	2		5
Dep. E	5	3	7	1	

Cost of Layout

	Dep. A	Dep. B	Dep. C	Dep. D	Dep. E
Dep. A		20	60	54	-
Dep. B	10		25	-	-
Dep. C	-	125		-	45
Dep. D	36	10	20		10
Dep. E	50	-	35	-	

Total Cost of Layout: 500

Figure 4.6 Process Layout Data and Calculate

In order to determine the best option in the process layout, it is necessary to measure how successful a layout is. The cost of material transportation between units in manufacturing facilities is used as the purpose of designing the best layout. Since the material transport cost is directly related to the transport distance, the total material transport distance is taken into consideration in determining the best layout. Figure 4.6 shows information to be collected in the process layout design.

The cost for the prefix layout in Figure 4.6 can be calculated by the following formula.

$$\text{Effectiveness of layout} = \Sigma F_{ij} D_{ij} \text{ for all } i \neq j$$

where F_{ij} = the flow in loads or journeys per period of time from work centre i to work centre j

D_{ij} = the distance between work centre i and work centre j.

The layout cost in the example is 500, but in different layouts, this value can be calculated lower. In addition, it should be considered in the departments that should be close or distant when determining the layout.

The best layout for four workstations can be calculated manually, but it will not be easy to locate a plant with a large number of workstations. Therefore, step by step heuristic methods have been developed to achieve a good solution. Computer programs that apply the heuristic methods developed can be widely used in large-scale layout design. CRAFT (computerized relative allocation of facilities technique) and ALDEP (automated lay-out design software) are two important computer software used as decision support tools in facility layout design.

Product Layout Design

Production resources such as equipment, machinery and labor used in operations in the product layout are arranged on a line for the product to proceed in one direction without return. Assembly lines are a type of product layout in which the products move along one line. Conveyors or cranes can be used to ensure product flow in assembly lines. Formal structure of assembly lines where manpower, machinery or robots are used in joining the parts to the product can be U type, straight and branching structure.

In order to achieve the targeted production speed in product layout design, operations must be appropriately assigned to workstations. In this planning activity called assembly line balancing, it is aimed to minimize the workload differences between the workstations. The operations carried out in assembly lines are carried out by nature in order. Although some operations are performed simultaneously, the classification of the transactions according to the workstations is performed in the order of operations. The steps to be followed for balancing an assembly line are listed below.

1. The order of relations between tasks is determined using the precedence diagram. The diagram consists of circles representing tasks and arrows showing the ordering between tasks.
2. Calculate for a day the cycle time of the required workstations using the following formula

$$C = \frac{\textit{Production time}}{\textit{Required output}}$$

3. Using the following formula, the minimum number of workstations sufficient for cycle time is theoretically determined. (The calculated value is rounded to an upper integer)

$$N_t = \frac{T(\textit{sum of task times})}{C(\textit{cycle time})}$$

4. The primary and secondary rules are used for assigning tasks to the workstation. The primary rule allows the workstation to decide which task to start with and the second rule to decide which task to select first among multiple tasks. By applying these rules, a task is assigned to the workstation.
5. Tasks are assigned to the workstation so that the total duration of the tasks on the workstation does not exceed the cycle time. Repeat step 4 until all tasks are assigned to the workstations.

6. The assembly line balancing efficiency is calculated by the following formula.

$$Efficiency = \frac{T(sum\ of\ task\ times)}{N_a(Number\ of\ workstations)C\ (Cyle\ time)}$$

Where C: cycle time

T: Sum of task times

N_a: *Number of workstations* after assignment

7. If the calculated efficiency is not sufficient after the stabilization, the new rules are rebalanced.

For a better understanding of the process steps above, all steps were performed on an example.

Example

The tasks and details of an assembly line are given in Table 4.3. The tasks in the assembly line, which is intended to produce 500 products in 420 minutes, should be shared among the workstations.

Table 4.3 An Assembly Line and Task List

Task Code	Task Time (sec)	Task Descriptions	Tasks that must be completed before
A	40	Fit the part to the main body and secure it with 4 bolts	-
B	10	Connect and check the wiring between main body and part	A
C	50	Secure the fasteners by inserting the gasket of the cover	-
D	15	Weld right-connected element to cover	C
E	15	Weld left-connected element to cover	C
F	9	Connect part and main body (right 2 bolts)	B
G	9	Connect part and main body (left 2 bolts)	B
H	12	Place the buttons on the cover and bolt	D,E
I	7	Check the compatibility of the part with the main body	F,G
J	12	Check the cover for body mounting	H
K	10	Secure the cover to the main body with 4 bolts	I,J
	189		

The main purpose of the line balancing problems is to balance the tasks to be performed simultaneously on the workstations in order to realize the production at the desired capacity. This is because the workstation on which the largest time is spent is equal to the time it takes to produce a product. Thus, the cycle time is calculated while balancing, and the tasks are assigned to the workstations step by step, considering the order in which the tasks are performed. Below are the solution steps.

1. Draw a precedence diagram for tasks.

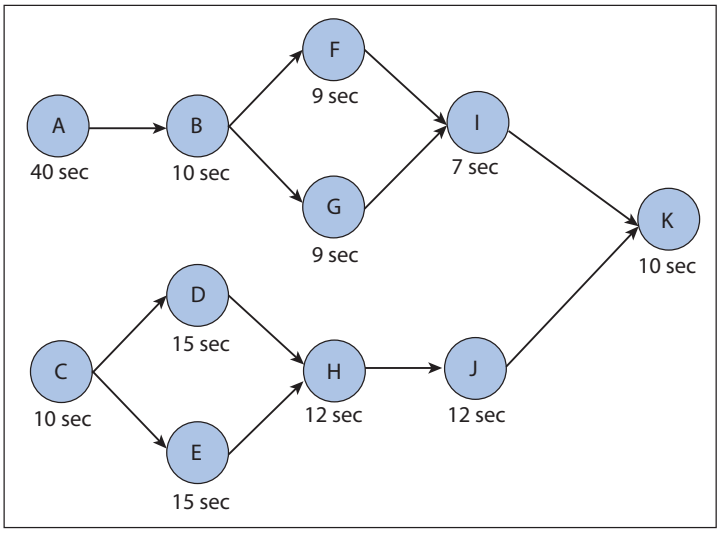


Figure 4.7 Precedence diagram for tasks

2. Calculate for a day the cycle time. Since the task times are in seconds, the cycle time is also calculated in seconds.

$$C = \frac{Production\ time}{Required\ output} = \frac{420\ minutes * 60\ seconds}{500\ products} = 50.4\ seconds$$

3. Calculate the theoretical minimum number of workstations

$$N_t = N_t = \frac{T(sum\ of\ task\ times)}{C\ (Cyle\ time)} = \frac{185}{50{,}4} = 3.67 \cong 4\ \text{workstations}$$

4. After determining the smallest number of workstations, it is time to assign tasks to the workstations. In determining which task is assigned to which station, some rules are set in order to prioritize tasks. The first rule to be applied in this line balancing problem is to give priority to the tasks with a high number of following tasks. If there are multiple tasks matching the first rule, then the second rule, the task with the maximum processing time, is given priority. For the implementation of the first rule, all tasks are listed as follows, decreasing by the number of following tasks.

Task	Number of Following Task
A, C	5
B,D,E	4
FiG,H	2
I,J	1
K	0

5. For all tasks, the tasks are assigned to the workstations in sequence until the assignment is complete. Assignments are performed for line balancing using the rules specified in step four. Table 4.4 provides an overview of how tasks are assigned to workstations. In the first assignment, one of the tasks A or C, which has the maximum number of successive jobs as a rule, must be assigned to the first workstation. Task C is assigned to the first workstation because the processing time of C is longer than A. After selecting the first task to be assigned, task C is written to the first row of the table. In the table, the duration of the C task and the remaining time of the workstation are written respectively. The remaining time for the first workstation is 0.4 (50.4-50) seconds, and since there is no task with a duration less than this time, the subsequent columns are left blank and the workstation assignment is switched. When assigning workstations, due to the nature of the assembly process, the priorities of the operations are taken into consideration. For this purpose, the following tasks are entered in the "Feasible Task" column. In the following columns, the number of subsequent jobs and processing times are written. These values are used as criteria for the next assignment. In this way, the rules continue until the last task is set. The line balancing result in which 11 tasks are assigned to 4 stations is shown in Figure 4.8.

Tablo 4.4 Line Balancing Steps

Workstation Number	Task	Task Time	Remaining time for the station	Feasible Tasks	The Task with Most Followers	Longest Operation Time
W1	C	50	0.4 (idle)	-		
W2	A	40	10.4	B		
	B	10	0,4 (idle)	-		
W3	D	15	35.4	E,F,G	E	
	E	15	20,4	F,G,H	F,G	F,G
	F	9	11.4	G		
	G	9	2,4 (idle)	-		
W4	H	12	38.04	I,J	I,J	J
	J	12	26.04	I		
	I	7	19.4	K		
	K	10	9.4 (idle)			

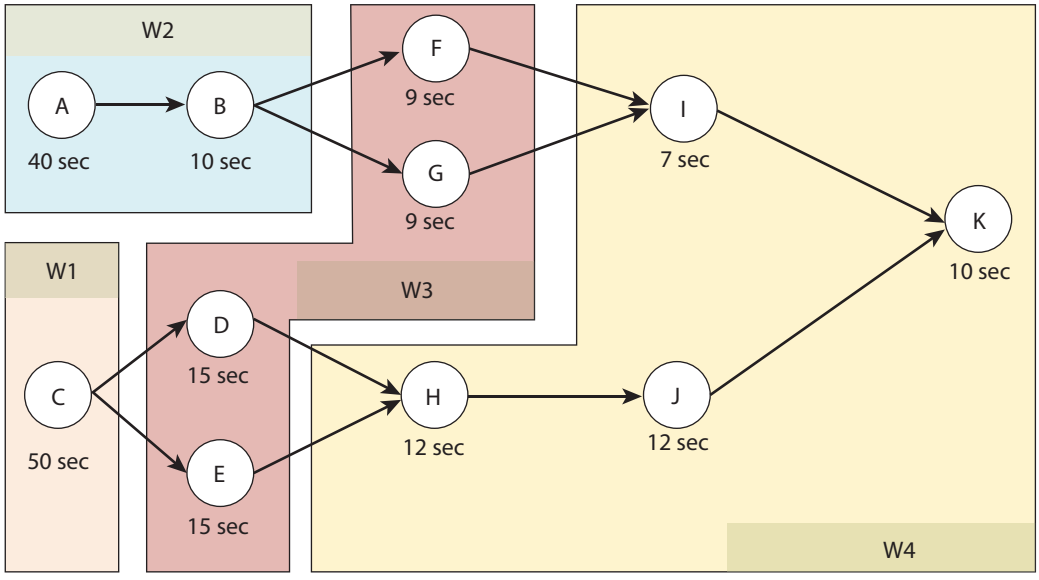


Figure 4.8 Workstations and Tasks

6. The efficiency of the line balancing obtained by the rules applied is calculated.

$$Efficiency = \frac{T(sum\ of\ task\ times)}{N_a(Number\ of\ workstations)C\ (Cyle\ time)} = \frac{185}{(4)\ (50,4)} = \%93,75$$

7. The efficiency of the assembly line was calculated as 93.75%. In other words, 6.25% of the total work time on the workstations is empty. Table 4.4 shows that all workstations have a total of 12.6 seconds of free time. The rules applied in this example may not have achieved the best solution for the current problem. For better balancing, the efficiency value obtained by applying different rules can be compared. Combining works for balancing times and dividing them into parallel machines are among the methods used in line balancing.

Cell Layout Design

Figure 4.5 shows how the production resources in the process layout are divided into four cells according to the families of parts processed. In the design of the cell layout, it is necessary to determine how many cells will be formed, which production sources will be located in the cell and which part will be produced in which cell. The most common method used to make these decisions is *production flow analysis*. The production flow analysis examines both the process and the product simultaneously, positioning the product or product families and machines in the cells.

In Figure 4.9, the first table shows the machine-part relationship of a workshop that produces workshops, and the second table shows the grouped product and machine table after the production flow analysis.

Production flow analysis allows the parts to be analyzed and grouped to similarities.

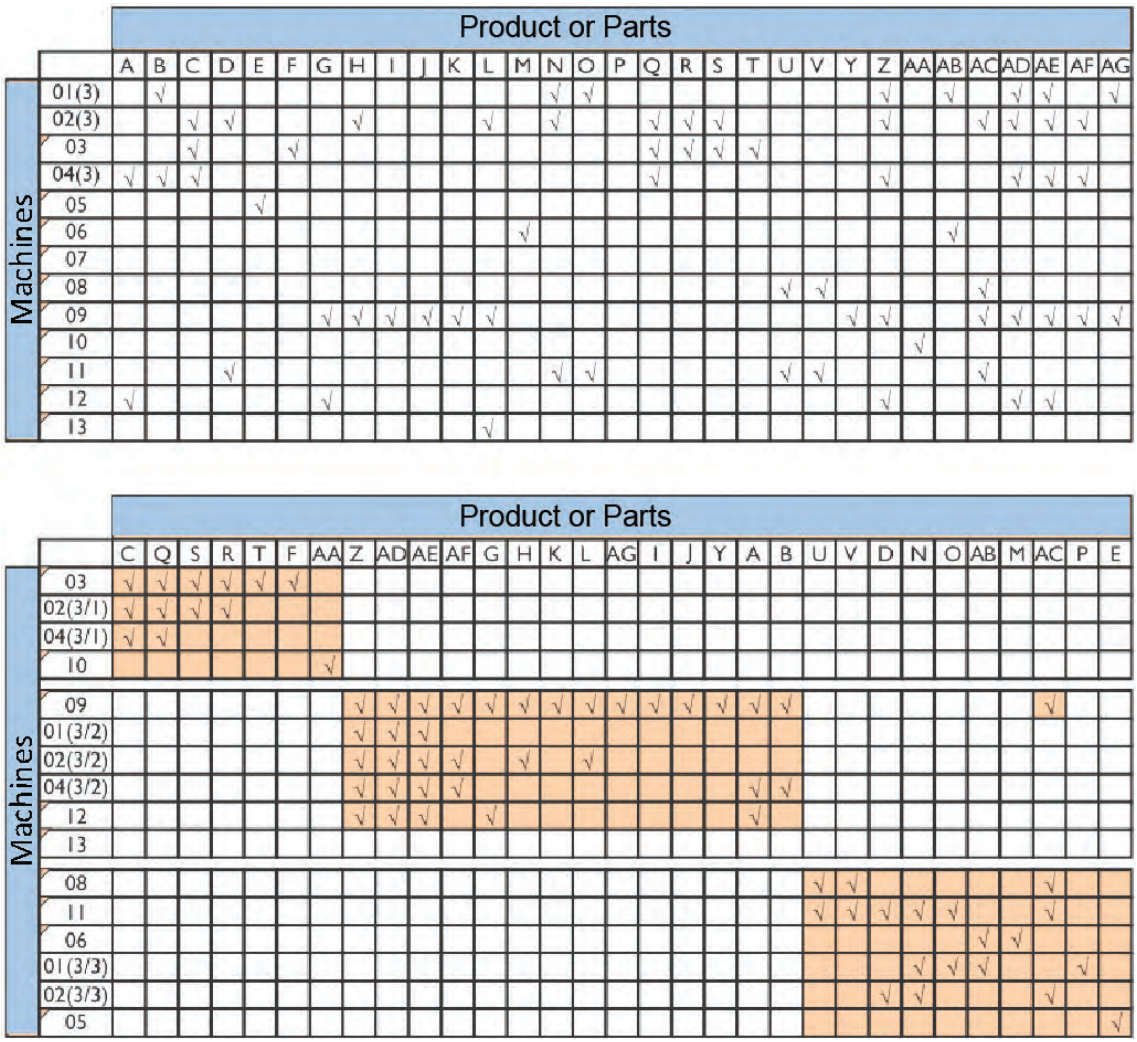


Figure 4.9 Grouping the Products and Parts According to the Machines After Processing Flow Analysis

Learning Outcomes

3 To sort the solution methods applied in the facility layout design.

Self Review 3	Relate	Tell/Share
How should the facility layout of an automobile manufacturer producing automobiles for a middle-class family be?	Calculating cycle time in line balancing problems is the starting point of the cause process. Associate with process steps.	Describe the impact of production volume and cost on the choice of layout type.

CAPACITY PLANNING

The main purpose of a production system is to provide production to meet the current and future demand in its market. The production systems that provide the right balance between capacity and demand are able to offer products at an affordable cost to their customers. Systems that are unable to achieve this balance may be unable to meet demand or reflect large idle capacity costs to their customers. In this case, the global competition is intense today, which can lead to the failure of enterprises.

important

The capacity of a production system is defined as the maximum output rate that can be achieved in a given period of time.

The term capacity in daily life is used to indicate the number of objects that can be in a limited space. Examples of capacity are the number of beds in a hospital, the number of runways at an airport, or the number of products a warehouse can store. As the capacity expression in production systems refers to the largest output amount of a process, it should be emphasized how long the process produces this output. Expressions such as 21 million barrels of oil production per day, 100,000 vehicles per year, and 10,000 tons of cement per month are used to express the capacity of production systems. In systems producing services, capacity is usually expressed as the number of customers serving at the same time or the maximum number of customers serving in a given period of time. The number of beds for a hospital or hotel, the number of tables or chairs for a restaurant, the number of subscribers for a GSM service provider can be given as examples of capacity measures in service enterprises.

Most businesses operate at a production speed below their maximum capacity. This is because they cannot work at full capacity due to inadequate demand or they maintain their idle capacity to respond quickly to a new demand.

Capacity planning is the process of determining the production volume to meet the demand by considering the future expansion and growth plans of an enterprise. In fact, this process is to plan how production should respond to fluctuations in demand. Capacity planning in organizations is carried out at two levels. First level planning involves long-term strategic decisions. The purpose of long-term capacity planning is to provide an approach to determine the holistic capacity level of capital-intensive resources such as facilities, equipment, and workforce size that will support the company's long-term competition strategy. Long-term capacity planning is closely related to predicting developments in technology and society that may lead to demand change.

important

Strategic capacity plans are related to the generation of production capacity that will meet long-term customer demands.

The second level focuses on the short and medium term. It is decided how long-term capacity plans will be reflected in the mid-term. This usually involves evaluating demand forecasts for a period of 2 to 18 months. In short and medium term capacity planning, basic capacity cannot be changed much. Instead, the fluctuations in demand are tried to be overcome with more tactical capacity decisions including labor, inventory and daily machine use plans.

The decisions made in capacity planning are important decisions that may affect the performance of the system. These decisions are closely related to cost, revenue, capital, quality, speed of meeting customer demand, dependability of supply and flexibility.

- Costs are affected by the balance between capacity and demand. If the capacity is higher than demand, the unit cost of the product increases.
- Revenues are also affected by the balance between capacity and demand. If the capacity level is equal to or greater than the demand, it prevents loss of income.
- Making a production decision on stock to meet high demand will adversely affect working capital. This decision will ensure that the demand is met but there will be no income inflow until the products are sold.
- A capacity plan that meets fluctuations in demand through the use of temporary personnel may adversely affect product or service quality. Employing inexperienced personnel increases error rates.
- Quick response to customer demands can be made by overproduction. Many customers want to get ready for the product instead of waiting for the product.
- Dependability of supply is also affected by the close proximity of capacity and demand levels. This proximity makes it difficult to remedy disruptions in product or service deliveries.
- Flexibility, in particular volume flexibility, is closely related to excess capacity. The balance between demand and capacity may make it impossible to respond to unexpected increases in demand.

Measuring Capacity

Although the term capacity can be easily defined, measuring capacity requires different approaches. Table 4.5 shows the measures that different types of enterprises use for capacity measurement. In the middle column of the table is the input capacity measure and in the right column is the output capacity measure. It is preferred in enterprises with more product diversity because it is easier to calculate input criteria instead of output criteria. For example, the capacity of a patisserie is difficult to measure relative to the products it produces. Sorting the quantities of dozens of products produced in one day will yield a meaningless value when compared to the effort and material spent. Instead, the expression of capacity as a spent raw material becomes more understandable

Table 4.5 Examples of Capacity Measurements by Input and Output

Type of Business	Input measures	Output measures
Hospital	Number of beds	Number of patients treated per week
Cinema	Number of seats	Number of customers watching movies per week
Car manufacturer	Labor time per shift	Number of cars produced per shift
Power plant	Generator size	Produced electric megawatts
Beverage manufacturer	Production tank capacity	Liters produced per week

Different capacity measurements are used to measure the capacity of a production system. The most commonly used capacity type is design capacity and effective capacity definitions.

Design Capacity: Design capacity, also called **theoretical capacity**, is the maximum output rate or service capacity that a process or facility can achieve under ideal conditions in a given time. The design capacity is calculated on the assumption that all production resources are used with 100% loss-free efficiency.

But in practice it is almost impossible to reach. The reasons such as machine failure, human errors in machine loading, shift changes, staff breaks, periodic maintenances, planning errors make practically impossible to reach the design capacity.

Effective Capacity: The amount of capacity that can be obtained under normal conditions. Maintenance activities in the production processes, machine setup times, waiting due to parts routes are normally encountered. Therefore, effective capacity will be lower than the theoretical capacity. It is also called **practical capacity**.

It is possible for enterprises to achieve effective capacity, but there are other factors that prevent this production rate. Different reasons such as machine failure, quality problems, personnel health problems, decrease in demand cause production output to be lower than effective capacity. An assessment of the production of the enterprise in terms of capacity can be made by calculating the utilization and efficiency. **Utilization** is calculated by the ratio of the actual output to the design capacity and **efficiency** is calculated by the ratio of the actual output to the effective capacity.

$$Utilization = \frac{Actual\ output}{Design\ capacity}$$

$$Efficiency = \frac{Actual\ output}{Effective\ capacity}$$

We can explain the above-mentioned capacity measurements and concepts by an example. Suppose a production line that produces four products per hour operates 24 hours a day and 7 days a week. The design capacity of the production line is calculated as 4x24x7 = 672. The lost production times of the production line running for one week are given in Table 4.6.

Table 4.6 Lost Production Time List

No	Reason for the Lost Production Time	Time (hour)
1	Machine setup times	15
2	Scheduled maintenance	15
3	No scheduled work	4
4	Quality Sampling control	8
5	Shift change times	8
6	Machine breakdown	22
7	Product defect review	6
8	Discard due to machine error	5
9	Lack of staff	3
10	Delay in yarn supply	12

It is possible to measure the capacity of the production system in time units. When the loss time list in Table 4.6 is examined, it is seen that the first five reasons cause a total of 50 hours (15 + 15 + 4 + 8 + 8) lost time due to the nature of the work that cannot be prevented. The last five reasons on the list are 48 hours (22 + 6 + 5 + 3 + 12) lost time caused by avoidable errors such as deterioration and planning error. Since the system operates 24/7, the weekly design capacity is calculated as 168 hours (7x24). Effective capacity is calculated as 118 hours (168-50) by subtracting the expectations that are impossible to avoid theoretical capacity and the nature of the work. The production time or actual output in the system is 70 hours (168-50-48), which is beyond all expectations. Accordingly, utilization and efficiency are calculated as follows

$$Utilization = \frac{Actual\ output}{Design\ capacity} = \frac{168 - 50 - 48}{168} = 0.42 = 42\%$$

$$Efficiency = \frac{Actual\ output}{Effective\ capacity} = \frac{168 - 50 - 48}{168 - 50} = 0.59 = 59\%$$

Capacity Planning Decisions

Capacity planning is about identifying short term and long-term capacity needs and how to meet these needs. Decisions in capacity planning are based on the combination of customer demands and the human, material and financial resources of the enterprise. Short term capacity planning is considered within the scope of resource requirement planning of the production system. Detailed information on resource planning requirements can be found in Chapter 6 "Production and Resource Planning" in the book.

important

Short-term demand fluctuations can be solved by production to stock, labor balancing, and external capacity utilization.

In **short term capacity planning**, the main production facilities cannot be changed radically and the basic capacity is considered constant. However, it is possible to reduce or increase the capacity with some arrangements that can be made during the production transformation process. Capacity increase can be realized by capital intensive methods such as purchase of new equipment and machinery, recruitment of additional personnel or storage of products in warehouses to the extent permitted by facility building and layout. Short- and medium-term capacity strategies are listed below:

- **Stock:** Production to stock is used for periods when capacity is insufficient and demand is at the highest level. This production is performed when the capacity is empty,
- **Delay:** To produce later for customers willing to wait for product delivery in periods of insufficient capacity,
- **Labor level**: Hiring additional labor in the period of high demand, dismissing in the period of low demand (using the seasonal labor strategy),
- **Employee training:** To provide additional training for staff to meet different skills (rotation),
- **Subcontractor use:** Temporary rental of the capacity of other companies for the production of products or components during periods of high demand (use of external capacity),
- **Process design:** Increasing the capacity by redesigning the business process.

In making **long-term capacity** decisions, firstly capacity requirements are defined, then capacity alternatives are derived and alternatives are evaluated.

Identify Capacity Requirements

Determination of long term capacity needs is based on forecast of future demand. When companies need to make long-term forecasts, they examine patterns of long-term variability, such as trends. It may take as long as five years to plan, build and start up new facilities. Considering the long-term use of the facilities to be built, it can be said that the decisions to be made will affect a lot of years. It is clear that there will be many changes in government regulation and policies in this period as well as economy, consumer habits, competition, technology, demographic factors.

The most important process in determining capacity needs is to determine future demand based on forecast. In addition to quantitative methods, qualitative methods can be used to forecast demand in the future. Qualitative methods such as Delphi method, executive opinion based on expert or customer opinions are used especially in the absence of historical data or making long term decisions. Quantitative forecasting models define future data as a function of historical data. Time series analysis methods, regression analysis, artificial intelligence methods, data mining, machine learning, simulation are some of the quantitative methods used in forecasting future data.

Companies often add *cushion capacity* on regular capacity forecasting. Cushion capacities provide businesses with greater flexibility when demand exceeds expectations or when customers need to meet different product needs.

Capacity cushion: Additional capacity added to regular capacity requirements to provide greater flexibility.

Further Reading

Turkey's Capacity Usage Rises in April

The Turkish manufacturing industry's capacity utilization rate rose in April from the previous month, the country's Central Bank said on April 24.

The rate climbed 0.7 percentage points month-on-month to reach 75 percent in April, the Central Bank survey showed.

The capacity utilization rate (CUR) figures are based on responses to the bank's business tendency survey by local units operating in the manufacturing industry, according to the bank.

Out of over 20 sectors, the highest CUR in April was seen among manufacturers of tobacco products, with 85.13 percent. The lowest was from among manufacturers of leather and related products, with 60.5 percent.

In the six main industrial groups, the highest capacity usage was 74.7 percent for intermediate goods, while the lowest CUR was 71.4 percent for durable consumer goods.

The usage rate in the consumer goods industry inched up to 73.6 percent in April from 73.3 percent in the previous month, while in the investment goods manufacturing industry the CUR rose to 74.2 percent from 73.5 percent in March.

The bank also reported that the seasonally-adjusted capacity utilization in the manufacturing industry increased to 75 percent in April from 74.7 percent in March.

The Central Bank said the monthly data, gathered from some 1,745 companies in April, does not reflect its own views or predictions.

Source: Hürriyet Daily News, 2019, April 24.

Development and Evaluation of Capacity Options

Companies are developing options to regulate their capacity after determining their future capacity needs. One of these options is to make no changes. Current capacity is to be re-evaluated in the future. Other options may be the purchase or expansion of a new facility. At this stage, the options for the size and characteristics of the new plant or the expansion of the existing plant should be evaluated.

There are many techniques and methods used in the evaluation of alternatives in decision-making processes. In this section, *decision trees* that are commonly used and capacity alternatives will be evaluated.

Decision tree is a modeling tool used to evaluate independent decisions that must be made in sequence.

Decision trees are a decision model that can be used in the decision-making process among the options and the expected values are calculated based on the probabilities as a result of the decision. The four elements of the decision trees are given below:

- **Decision points:** The node that represents the moment when the decision is made. For example, a decision in which the growth decision of the enterprise evaluated is indicated by the square figure in the diagram.

- **Decision options:** Provides two possible options in the decision tree, such as the purchase of a large or small plant. It is shown as arrows or lines separated from the decision point.
- **Random events:** Events that may affect the value of a decision. There is a possibility for each event to occur. For example, it can be predicted that an enterprise's demand for a particular product will fall by 40% in the coming year, with an increase of 60%. Random events are shown in decision trees as two or more branches separated from a circle.
- **Outputs:** The decision tree lists the output for each possible option. Depending on the resolution resolved, this value can be attributed to revenue, cost, and so on. It consists of numerical values.

It will be useful to examine the issue of decision tree creation and solution options on a simple example. A business manager recognized the need for expansion of the facility and reviewed possible decisions. Accordingly, an additional building will be placed under a large investment burden or a small renovation decision will be possible to miss the demand. As a result of the analyzes, it is estimated that the high demand will be 65% and the low demand will be 35%. In order to capture the opportunity created by high demand, it is possible to increase the capacity with additional building construction or renovation of the existing system. He calculated that the large expansion option would yield a profit of ₺250,000 in high demand and ₺75,000 in low demand. In case of high demand with small expansion, ₺180,000 profit and low demand will be ₺100,000 profit.

In the first stage, the decision tree of the problem is created for the evaluation of capacity options. The decision tree starts from left to the right by first forming the square shape showing the decision and then the round shapes symbolizing the random event. The probability values and return values of each random event are also written on the branches resulting from the events. Figure 4.10 shows the decision tree created for this problem.

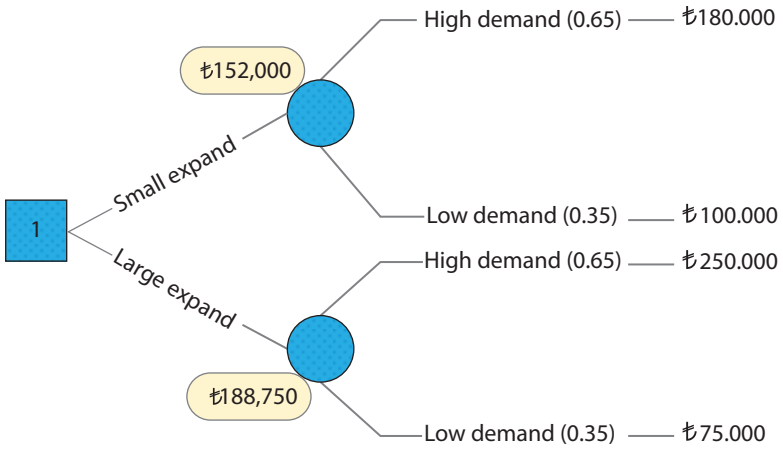


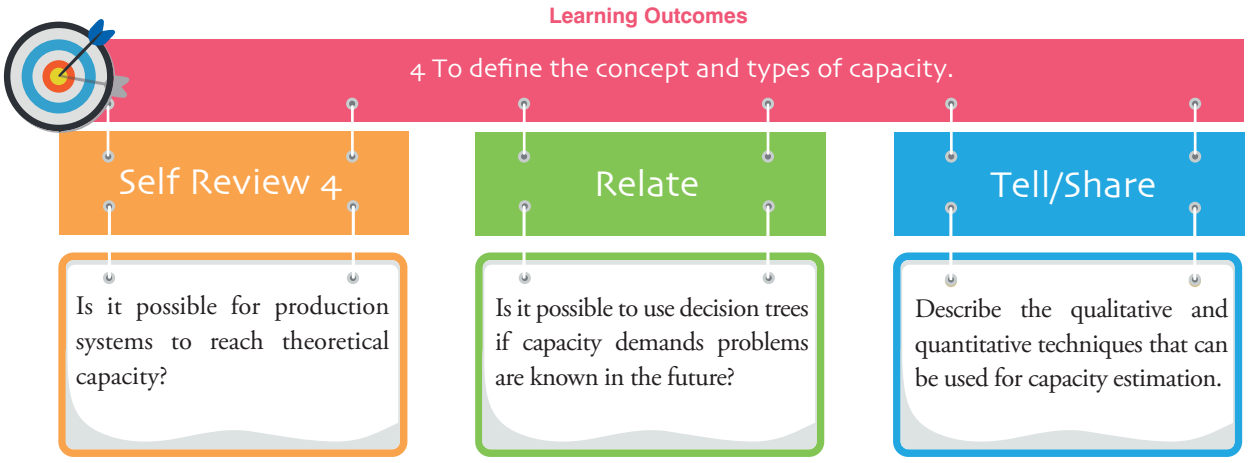
Figure 4.10 Decision Tree for Expansion Options

The expected value is the weighted average of random events. Therefore, the income that can be obtained from each option is weighted with probabilities.

$(\text{Expected Value})_{\text{Small Expand}} = (0{,}65 \times 180{,}000) + (0{,}35 \times 100{,}000) = ₺152{,}000$

$(\text{Expected Value})_{\text{Large Expand}} = (0{,}65 \times 250{,}000) + (0{,}35 \times 75{,}000) = ₺188{,}750$

When the expected profit values of the options are calculated, it is seen that the large expansion option is calculated higher than the small expansion expected value. Thus, the decision to make additional buildings will be correct. In this example, a simple decision tree was created in which a single-stage decision was made. In more complex decision trees where there are many stages, the decision values drawn from left to the right are calculated by making the right values from the right to the left.



Summary

LO 1 Define facility layout planning and basic objectives.

Facility or workplace layout is a decision problem not only at the stage of establishment of organizations, but also at the rearrangement of existing facilities for various reasons. Facility layout planning is a set of decisions to ensure proper placement of all physical production resources. Great effort and capital are spent on the construction and installation of the facilities. Moreover, the fact that the errors related to the layout of the facilities because high costs increase the importance of these decisions. There are many issues that need to be considered in determining the layout of enterprises in different sectors. Safety, flow, comfort, coordination, access, space utilization, flexibility, bottlenecks are common issues that are considered in almost all installations.

LO 2 Explain facility layout types and characteristics.

It is possible to classify Facility layout in four basic types. Fixed-position layout is the layout used when the product is too large to move. The layout is suitable as long as it is suitable for the plants producing high product variety, low production speed and high flexibility. In the process layout, production resources are grouped according to their functions and positioned together. The enterprises with mass production requirements where production volume is very high applying the product layout. The product layout is the layout in which the production resources are positioned in succession according to the processes to be performed on the product. Cell layout, which is the mix of product layout and process layout, is an efficient facility layout where group technology is applied.

LO 3 Sort the solution methods applied in the facility layout design.

The amount of production and the number of different products is two important criteria for selecting the type of facility layout. As a product volume increases in a production facility, the product flow becomes continuous. In a facility where there is no product flow, fixed position placement is applied. Product layout is preferred in a facility with high product volume and product flow. If we list the layouts in terms of production volume and cost in an increasing way, they are fixed-location layouts, process layouts, cellular layouts and product layouts.

After deciding on the basic layout of the plant producing the product or service, the detail of the layout plan is designed. Due to the nature of each layout type, models are identified to help determine the best layout. In the process layout design, it is decided how the workshops will be positioned relative to each other. The aim of the process layout design in manufacturing facilities is to minimize the total transportation cost. In designing the product layout, the tasks are assigned to the workstations according to the desired production speed. There are many algorithms and optimization methods for solving these problems. Today, many computer software developed for the purpose of creating the right layout can be used.

LO 4 Define the concept and types of capacity.

Summary

The capacity of a production system is defined as the maximum output rate that can be achieved in a given period of time. The main purpose of a production system is to provide production to meet the current and future demand in its market. The production systems that provide the right balance between capacity and demand are able to offer products at an affordable cost to their customers. Therefore, methods for measuring and evaluating capacity have been determined. **Design capacity**, also called theoretical capacity, is the maximum output rate or service capacity that a process or facility can achieve under ideal conditions in a given time. **Effective capacity is** the amount of capacity that can be obtained under normal conditions.

Decision trees are a decision model that can be used in the decision-making process among the options and the expected values are calculated based on the probabilities as a result of the decision. Decision trees where decisions and their possible results are represented by a tree-like graph or model are drawn from left to right, and the solution is made by moving from right to left.

Test Yourself

1 Which of the following is the main objective of the facility layout regarding the working conditions of the personnel?

a. Flow of movement
b. Space usage
c. Flexibility
d. Comfort
e. Access

2 Which one of the following **is not** a type of facility layout?

a. Fixed position
b. Mass
c. Cell
d. Product
e. Process

3 Which one of the following is a **disadvantage** of a process layout?

a. Flexible use of production resources is possible
b. Machine utilization rates are high and require fewer machines
c. High utilization rate of its production facilities
d. The satisfaction of the staff is higher
e. High setup times of the machines

4 Which one of the following facility layouts does the assembly lines relate to?

a. Process Layout
b. Cell Layout
c. Product Layout
d. Functional Layout
e. Fixed-position Layout

5 Which one of the following is the facility with the highest fixed cost?

a. Process Layout
b. Cell Layout
c. Fixed-position Layout
d. Product Layout
e. Hybrid Layout

6 How many different settlements can be made in the process layout of a facility with six departments?

a. 6
b. 12
c. 36
d. 120
e. 720

7 It is aimed to produce 1000 products in an assembly line that works 8 hours a day.

According to this information, how many seconds is the cycle time of the assembly line calculated?

a. 5.6
b. 10.0
c. 28.8
d. 56.9
e. 120.4

8 Which one of the following capacity measures is the output measure?

a. Patisserie - used flour
b. Hospital -number of beds
c. Beverage manufacturer- tank capacity
d. Furniture factory - number of sofas
e. Refrigerator factory Labor time per shift

9 Which one of the following **is not** a short-term capacity planning option?

a. New facility
b. Delay
c. Subcontractor use
d. Labor level
e. Stock

10 What is the weighted average of random events in a decision tree?

a. Decision point
b. Expected value
c. Output
d. Standard deviation
e. Index

Answer Key for "Test Yourself"

1. d	If your answer is wrong, please review the "Facility Layout" section.
2. b	If your answer is wrong, please review the "Types of Facility Layout" section.
3. e	If your answer is wrong, please review the "Types of Facility Layout" section.
4. c	If your answer is wrong, please review the "Types of Facility Layout" section.
5. d	If your answer is wrong, please review the "Designing Facility Layout" section.
6. e	If your answer is wrong, please review the "Designing Facility Layout" section.
7. c	If your answer is wrong, please review the "Designing Facility Layout" section.
8. d	If your answer is wrong, please review the "Capacity Planning" section.
9. a	If your answer is wrong, please review the "Capacity Planning" section.
10. b	If your answer is wrong, please review the "Capacity Planning" section.

Suggested Answers for "Self Review"

In a hospital, the baby birth department and the radiology department should not be designed to be close to each other.
What is the subject of this issue which should be considered in facility layout planning?

self review 1

Safety is one of the most important criteria to be considered in the facility layout of the enterprises in the service and manufacturing sector. If they are close to each other, the sections that may cause danger or damage should not be located close. It is a situation that may be encountered in the manufacturing facility that the high temperature casting workshop and the plastic product warehouse that will be affected by heat are not positioned side by side. Security is the reason why the relevant departments are positioned away from each other in order to keep pregnant women away from radiation in hospitals which are a service producing facility.

Compare process layout with product layout in terms of installation cost?

self review 2

In the process layout, machines with the same function are located in the same workshop. The products move between this machine and the sections so that it can produce more varieties with fewer machines and provide flexibility. On the other hand, in the product layout arrangement, the production resources are listed in line with the production process. A large number of machines and labor with a large number of productions. However, the cost of the institution is quite high compared to other layouts.

Suggested Answers for "Self Review"

How should the facility layout of an automobile manufacturer producing automobiles for a middle-class family be?

self review 3

When the customer profile of the automobile manufacturer is taken into consideration, the costs of the product produced by the company should be low. When the product variety of a production system is decreased and production amount increases, it is seen that the cellular layout and product layout types provide superiority to the enterprise. It is known that the initial costs are high due to the fact that production resources are sorted by product and use intensive technology. However, if the amount of production is high, the unit cost of the product will decrease. For this reason, the company, which aims to produce automobiles for middle-income families, will have to establish its production policies on the product layout where mass production can be realized.

Is it possible for production systems to reach theoretical capacity?

self review 4

Theoretical capacity is defined as the amount of capacity achieved when the resources in the production system operate at 100 percent efficiency. However, almost no system works with 100 percent performance. Although the problems to be encountered in bringing together the production resources such as machinery, people and materials in the production system are minimized, they are not completely eliminated. Mandatory waiting due to machine failure, decreases in production number due to machine calibration, lack of manpower due to various reasons or disruptions caused by human errors, delays in supply of raw materials and planning errors make it impossible to reach the theoretical capacity of production systems. Because of these reasons it is impossible to reach the theoretical capacity of production systems.

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Chapter 5 Inventory Management

After completing this chapter, you will be able to;

Learning Outcomes

1. Express inventory and inventory management key terms.
2. Define the different types of inventory control systems and the roles they play.
3. Apply the knowledge and skills of basic inventory models.
4. Use ABC analysis to determine the items deserving the most attention.

Chapter Outline

Introduction
Inventory Management
Inventory Control Systems
Inventory Models
Abc Analysis

Key Terms

Inventory
Inventory Control Systems
Inventory Costs
Lot Size
Inventory Models
Economic Order Quantity

INTRODUCTION

In order to meet future demands or requirements in production, the materials that are required to be kept in various ways before or after the requirement are named as inventory. In all of the organizations producing goods or services, inventory is available in various forms. However, due to the number of materials and their differences in manufacturing many various applications can be encountered.

Inventory management is the planning, organizing and controlling procedures that are carried out in order to achieve a balance between the items that must be available to meet the requirements. In case of inventory shortage, loss of customer, risk of stopping in production and loss of image may occur.

For these reasons, the inventory is controlled to keep production at the desired level at all times. Inventory control systems are the ordering and monitoring methods used to control the quantity and timing of inventory transactions. Inventory control provides systematic methods regarding the time and quantity of supply and ensures that these are complied with. The methods used in inventory control systems change from simple counting, visual inspection and two-bin methods to electronic data processing systems.

Traditional inventory control systems can be examined under two groups as "continuous" and "periodic" review systems. However, there are several hybrid systems that use the features of both of these systems. Today, various production systems such as "material requirements planning" and "just in time" which are integrated with inventory control systems have become widespread.

In the following chapters, detailed information will be given for the concepts that are mentioned here.

INVENTORY MANAGEMENT

Inventory management is the planning, organizing and control procedures that are carried out in order to achieve a balance between the items that must be available to meet the requirements. The most important aim of inventory management is to efficiently ensure quantity and timing of the inventory that is needed for operations of the enterprise.

Inventory can be in the form of materials in the production systems such as; raw materials, parts, components, work in process or finished goods. However, wholesale or retail companies only have finished goods in their inventories. Inventory, in the most general sense, is the goods or merchandise kept on the premises of a business or warehouse and available for use in businesses.

All physical materials that are directly or indirectly involved in the produced product and the product itself can be considered in the inventory concept. These include the management of raw materials, components, and finished products as well as warehousing and processing such items. Inventory is one of the most important cost items of enterprises. According to the area of activity, inventory types or weights in total inventories can vary. Since inventory is the largest item in the current assets category for many companies , inventory problems can and do contribute to losses or even business failures.

Inventory management refers to the process of ordering, storing, and using a company's inventory.

We can list the reasons that lead companies to maintain inventory as follows:

- To be able to respond sudden and seasonal changes in demand.
- To provide protection against problems arising from suppliers.
- To provide stability in employment by stabilizing production.
- To be able to tolerate failures and postures that may occur in the system.
- To ensure that different products can be produced in the same facility.
- To take advantage of the price advantages by taking the materials into economic size parties.
- To protect the enterprise against price and delivery uncertainties such as strike, price changes and inflation.
- To have the desire of looking strong with an image of delivery from inventory.

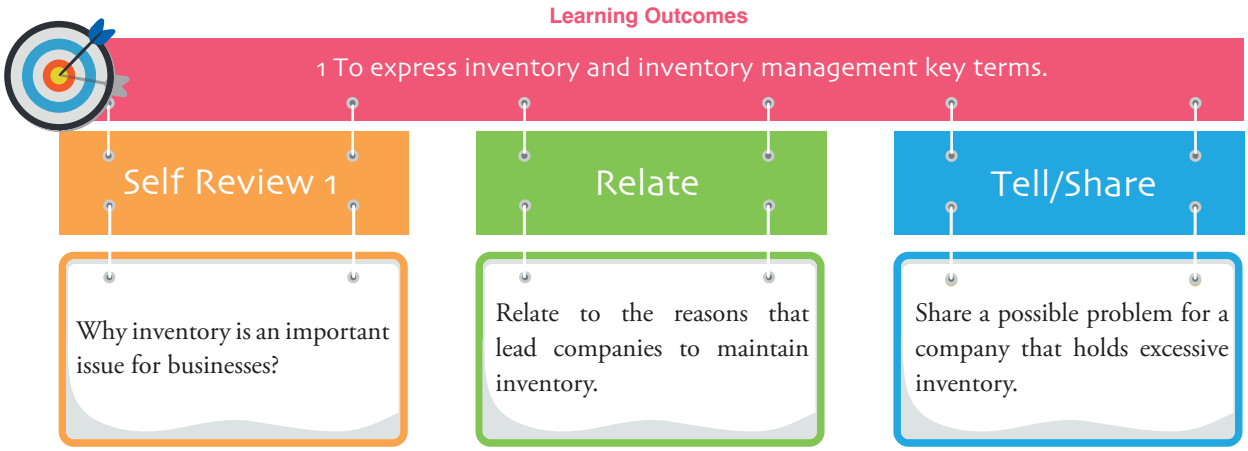
The factors listed above are practical reasons for holding inventory. On the other hand, inventory shows that there are problems to be solved for the enterprises. Inventory can also be considered as the main problem that hides the problems and hinders the recovery. Problems related to production should not be hidden by using excessive inventory and should be solved as soon as problems arise.

important

Inventory is a complex element in which there can be a cost in both extremeness and shortage.

The level of the inventory companies holds in the warehouses or in the process, whether they are high or low, have benefits or drawbacks. In the case of inventory shortage, loss of customer, risk of stopping production and loss of image may occur. If the inventory level is less than necessary, the business may face a depletion situation, which leads to consumer dissatisfaction and sales losses. On the other hand, the availability of excess inventory brings an additional cost to the enterprise.

For these reasons, the purpose of inventory control is to keep production at the desired level at all times. Inventory control aims to keep appropriate and the most economic materials in terms of time and quantity in order to realize the delivery and sale of orders in forecasted amounts.



INVENTORY CONTROL SYSTEMS

Inventory control systems are the ordering and monitoring methods used to control the ***quantity*** and ***timing*** of inventory transactions. The purpose of inventory control is to ensure that the material requirements are met at the "*desired time*", at the "*desired quantity*", at the "*desired location*" and at the "*desired quality*". In order to achieve this goal, it is necessary to determine "*which materials*" are to be stocked and to decide "*what amount of inventory*" is to be kept.

Determining *lot sizes* in production areas is an essential task of production planning and control. Inventory management involves lot sizing, which is the determination of how frequently and in what quantity to order inventory. In other words, lot size basically refers to the total quantity of a product ordered for manufacturing.

Lot size refers to the quantity of an item ordered for delivery on a specific date or manufactured in a single production run.

The ultimate goal of inventory control is to increase the long-term profitability of the company's investments. The short-term goals of inventory control are as follows:

- To meet the expectations of the customers and to increase the competitiveness of the company by keeping the inventory depletion at a certain and acceptable level.
- To ensure that the company maintains inventory in economic quantities by arranging the procurement procedures to minimize the costs of ordering and inventory.

important

The purpose of inventory control is to keep the inventory in required quantity and quality in the required time with minimum investment.

In order to achieve the above objectives, inventory control provides systematic methods regarding the time and quantity of supply and ensures that these are matching. The methods used in inventory control systems change from simple counting, visual inspection and two-bin methods to electronic data processing systems. The inventory control method of products with shelf life is different with inventory control methods of products that can last long. Also, in similar sectors, there may be differences among the companies using the same basic raw materials due to the business culture.

The main reason why an inventory control system adapted by one industrial enterprise is not applicable to another one is that the raw material, auxiliary material, etc. used by them and their relative importance are different. Since most industrial enterprises use a wide range of raw materials, auxiliaries, and inventory control systems, depending on the type of items to be checked accordingly, it is essential for the company to have several methods of inventory control, not one (Barutçugil, 1988, p.187).

Traditional inventory control systems can be examined under two groups as "***continuous***" and "***periodic***" review systems. However, there are several hybrid systems that use the features of both of these systems. Today, various production systems such as "***material requirements planning***" and "***just in time***" which are integrated with inventory control systems have become widespread. In the following chapters, detailed information will be given for the subjects that are important for the inventory control systems.

Continuous Review System

In the *continuous review system*, a fixed amount of order is placed when the inventory level falls to a predetermined level. This amount is calculated by considering the annual average demand amount, order expenses, and unit price. The order point is also determined by the level of *safety stock*, usage speed and the duration of the *lead time*.

Continuous Review System: A system designed to track the remaining inventory of an item each time when a withdrawal is made to determine whether it is time to reorder.

Every inventory item that comes out of inventory is recorded in the continuously reviewed inventory system. A re-order is given when the inventory level falls to the *pre-calculated re-order point* (r). *Order quantity* (Q) is a predetermined constant value. As can be seen in Figure 5.1, the design of this system requires the determination of the order quantity and the re-order point.

These values, which can also be called decision variables, should be selected so as to minimize the total inventory costs. When the inventory goes down to a certain level, a predetermined fixed amount is ordered in order to make the total cost of inventory in a minimum level. In this model, for each inventory item, an order quantity, order level and safety stock that minimizes the total inventory control cost must be calculated.

The safety stock is kept for the unexpected and abrupt needs of the enterprise and for long supply times and supply problems.

The **safety stock** is the amount of inventory held against the uncertainties in demand.

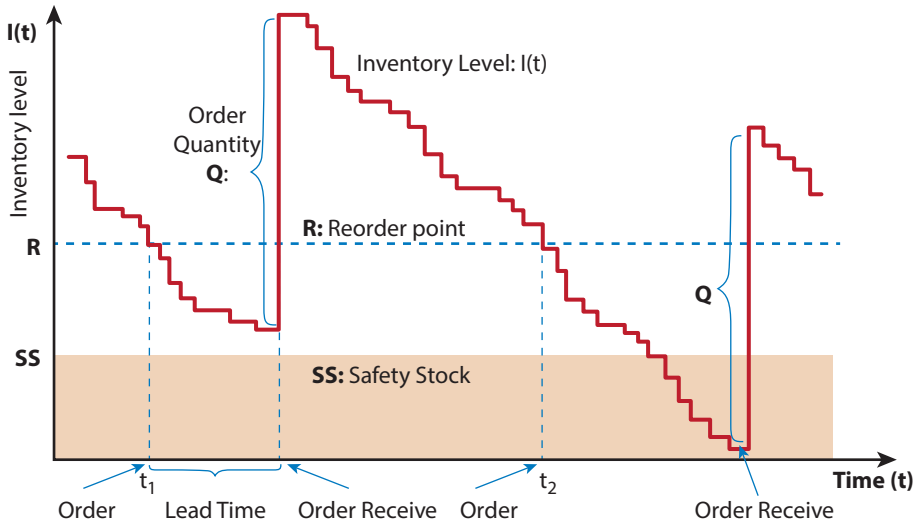


Figure 5.1 Continuous Review System

The time between the two orders is different depending on the change in demand. Similarly, the lead time (L) in each cycle is also different. However, it is normal for a given inventory item's lead time to remain unchanged over a long period of time. Although the order quantity is fixed, the order cycle times may be variable, which can cause problems in the supply. This problem is eliminated if the consumption speed or demand (D) is constant.

The time between the initiation and completion of a production process *is* called **lead-time**.

In the continuous review system, once the values of the decision variables are calculated, the determined inventory policy is applied continuously.

The control is carried out by the eyes, by two-bin methods, by hand-held records or by the help of a computer. It is recommended to use this method for inventory items in group A. Thus, the risk of being under stock is minimized in the business.

When the first bin is used up, an order is made out for replenishment. The second bin contains enough quantity of the item to last until the ordered quantity arrives.

Two-bin system, is a simple and effective method commonly used in enterprises. The materials followed by the two box systems are kept in boxes (or shelves), which are large (Q) and small (r). The materials here are used until the big box is empty. At the bottom of the large box, there is a material request form for ordering material again. This renewal request is sent to the relevant unit, whereby the materials in the small box begin to be used. The small box contains an adequate amount of safety stock (SS), which will be sufficient until new material orders are received and in case delivery of the order is delayed or if more material is used than the estimated. When the inventory is renewed, the material request form is put under the large box again, both boxes are filled and operations continue in this way.

Periodic Review System

In *periodic review system*, the inventory level is controlled at the beginning or end of predetermined time intervals. During this check, the available inventory level is compared with the predetermined order completion target (R). If the level of inventory at the time of review I(t) is below *the point of re-order* (r), a new order is placed to complete inventory levels to the order completion level (Q=R-I(t)). The operation of the periodic review inventory system is shown in detail in Figure 5.2.

Periodic Review System: A system in which an item's inventory position is reviewed periodically rather than continuously.

important

Periodic review system, requires regular periodic reviews of the on-hand quantity to determine the size of the replenishment order.

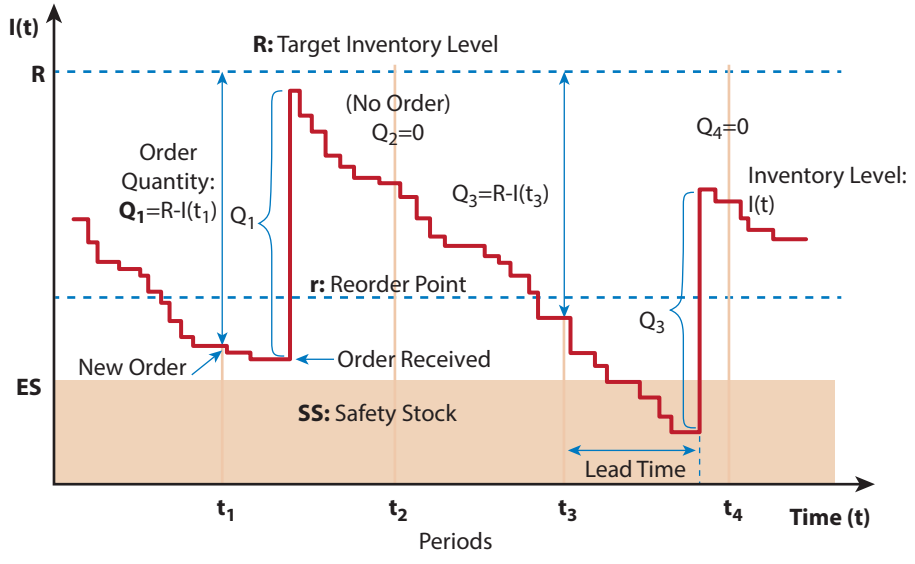


Figure 5.2 Periodic Review Inventory System

As can be seen in Figure 5.2, the inventory level is reviewed at moments t_1, t_2, t_3 and t_4.

In these reviews, the inventory level is controlled at moments t_1 and t_3, and orders for Q_1 and Q_3 are given respectively as the current inventory levels are below the re-order point ($I(t_1) < r$ ve $I(t_3) < r$).

In other periods, t_2 and t_4, the inventory level is larger than the re-order point, so there is no order in these periods.

Visual control is the review of inventory levels by the experienced worker individually on the place of the inventory.

Visual control, is a simple and practical method that is widely used in small businesses or markets. In this method, inventory levels are periodically reviewed by an experienced warehouse officer. Order items that fall below a certain level are immediately ordered. The level of order and the order quantity are entirely left to the official's experience. However, because the review period, order level and quantity are based on personal judgment, the probability of an error is high. Also, if the consumption speed, lead time or another factor changes, it may be too late to take precautions.

Material Requirement Planning

Material Requirement Planning (MRP) is a system that regulates production plans for final product's production decisions, control of inventory levels of raw materials and parts, and programs of workshop and assembly unit. MRP is a method that tries to find the most economical answer to the questions of "*when to order*" and "*how much to order*" for dependent inventory items.

The basic principle of material requirement planning is to have the necessary parts and materials backwards from the finished product with independent demand at the time they are needed. This approach significantly reduces the waiting time of inventory items in the warehouse and hence the cost of holding.

The MRP determines when and how much a material is needed, taking into account the bill of materials, inventory, open orders in the purchasing system and production targets in the main production program.

The processes have a time dimension, with this feature, a production program is prepared for all sub-parts and purchasing.

MRP is a production and purchasing programming system applied to parts and components purchased or manufactured with a dependent demand.

The MRP system has several advantages over the control of the inventory items produced. Comparison of fixed order system and MRP system is given in Table 5.1.

Table 5.1 Comparison of Fixed Order System and MRP System

Traditional Ordering System	Material Requirements Planning
Independent demand	Dependent demand
Order renewal at the point of ordering	Ordering up to actual requirement
Intended for raw materials and pieces	For product
Continuous demand	Discrete demand
Random demand behavior	Known demand behavior
Continuous lead time demand	No demand for lead time
Order sensitive to the point of order	Order is based on requirement and time
History based demand	Demand due to future production
Estimation of all items	Estimation of the items in the master production
Quantity based system	Quantity and time-based system
Safety stock for all items	Safety stock for the final products

The main purpose of the MRP system is to produce information for the accurate execution of inventory management. To achieve this goal, the MRP system identifies the net requirements and timing of the requirements of all materials.

An important step in the MRP system is the conversion of gross requirements into net requirements. Net requirement values are obtained from the gross requirements determined during this translation process by decreasing the inventory quantities or order quantities to be received. The net requirement values in MRP are given within the time dimension.

The three important factors for successful implementation of the MRP system are:

1) Supply sources should be reliable and punctual. Since the delay allowances are too small, the smallest failure in the supply can cause the entire production to stop.
2) MRP requires a great deal of information and processing capacity. For this reason, MRP application is not possible without computer and other information technologies.
3) All employees such as operator, analyst, purchasing agent, planner, quality controller, must be fully trained in the updating of the system,

The MRP system contributes to the provision of effective inventory management at the following points:

- Inventory investments are kept in a minimum level.
- The MRP system is sensitive to changes.
- MRP creates a forward-looking perspective based on inventory items.
- Order quantities are determined according to the requirements.
- It focuses on the timing and complete fulfillment of requirements.

MRP has achieved very good results in mass production companies, especially in assembly lines. And these developments have led to improvements such as reducing in-process inventory levels, enabling labor force utilization, increasing customer service and increasing inventory turnover.

MRP is a method that recognizes the differences between production and distribution activities within its own system and has been developed to meet the basic needs of the production environment.

Just-in-time Production System

Just-in-time (JIT), can be defined as the production of the required products at the required quality level, at the required time (Acar, 1999). Just-in-time production system is defined as zero inventory, non-stop production or *kanban* system. It considers all elements that do not add value to the product as "waste". In this context, inventories at every stage of production and poor quality are considered as the most fundamental waste elements.

Just-in-time (JIT), is the production of required products at the required quality level, at the required time.

Minimizing intermediate inventory levels in production, minimizing changes in intermediate inventory levels, facilitating inventory control, reducing production demand fluctuations, streamlining production flow, providing effective control with a simple system and reducing waste rate are the main objectives of JIT.

JIT is based on pull, not on the basis of push, as in conventional systems. The factor that drives production is the customer demand. The customer may be the ultimate buyer or another production unit in the enterprise. A production unit draws the intermediate products required for its production from the previous production unit. The previous production unit produces as much as the drawn parts and pulls the amount it needs from the previous unit. As can be understood from this point, starting from the customer, it is essential that the requests are made retrospectively and the inventory is available as required. It is important to keep detailed records for the control of stocks in traditional systems. In JIT, inventories are kept to a minimum, since they are ideally intended to work with zero inventory.

For information communication in JIT, the Kanban system, which means card in Japanese, is used. Kanban is a card attached to standard containers that allow the production and withdrawal of parts between production units. Kanban can be described as an information system that controls production. In a just in time production system, kanban controls the delivery of the product-related card from the cell with semi finished product to the supplier cell, and manages production in the cells in the light of the information written on the card.

Kanban, which means card in Japanese, is a simple production planning technique.

Kanban connects the production units end to end. It always moves in the opposite direction to the production flow however, it changes position together with the physical units. As a result of connecting the production units in this way, the required parts are produced in the required amount and when required and there is no need for intermediate inventories among the units. It is even possible to remove raw material inventories if this chain is extended to vendors outside the enterprise.

The Kanban system ensures improvement in production, reduction in the amount of inventory and reduction of the production time of parts. In addition, lower amount of waste, and the reduction of the physical space due to the higher quality and lower inventory amount are the other benefits of this system. The Kanban system also regulates the material flow depending on the part flow rate at the final assembly station.

JIT is an important component of lean production system. Lean production in the production of goods or services is a production philosophy that eliminates all the factors that cause waste and does not add any value to the goods or services provided and eliminates the costs caused by them. In the eyes of the customer, the elements that do not add value to the product or service are waste and should be avoided.

The objective of lean manufacturing is to develop value-creating activities and to eliminate activities that cause waste.

The ultimate goal to be achieved in this way is to produce quality products or to provide services at a lower cost, in less time.

The seven wastes that causes the costs to increase were determined by Toyota, the developer of the lean production system, as follows:

1. Overproduction
2. Transport
3. Inventory
4. Motion
5. Defects
6. Over-processing
7. Waiting

internet

Lean Enterprise Institute (LEI) (http://www.lean.org/), is a nonprofit publication-training and research organization founded in the United States in 1997 to promote a broad range of lean thinking principles from production to service sectors and in all aspects of business. The main purpose of LEI; is to publish papers for enterprises to use in transforming their traditional business to lean.

internet

Lean Institute Turkey (http://www.lean.org.tr/ or www.yalinenstitu.org.tr) is also a non-profit association as well as similar organizations established in various countries of the world. It has been active since 2002 as part of the "Lean Network" with LEI and other organizations. To learn more about lean manufacturing, you can visit the related websites.

important

More information about lean systems is given in Chapter 7: Lean systems.

Further Reading

How to Use Technology to Track Inventory

Inventory management is the set of practices that seek to achieve the goals of having the right products available in the right quantities and at the right time. It is part of the larger field of supply chain management and, when done well, can significantly reduce the costs associated with carrying excess or static inventory and help improve sales. The best kind of inventory management is the kind that helps you to streamline the whole process and track your inventory in real time.

Many of the challenges that businesses face, such as running out of stock, or having excess stock, or having obsolete stock or spoilage are as a result of poor inventory management.

When you use inventory management software in conjunction with inventory control technology, you improve your bottom line. Using technology to augment inventory management helps your business to stay on top of things by streamlining the ordering and tracking process throughout the sales cycle of a product.

- Good inventory management technology should be able to:
- Improve your cash flow, reduce your costs, and improve your bottom line.
- Track your stock in real time.
- Help foresee future demand for your products.
- Help prevent shortages in production as well as ready inventory.

- Help prevent excess raw materials or ready inventory.
- Make it easier for you to analyze your inventory on multiple devices.
- Be accessible to you from the point of sale, also known as the POS.
- Be able to optimize employee time and warehouse organization.
- Offer quick inventory intake through painless scanning.
- Allow you to manage your inventory from multiple warehouses and locations, also known as multilocation management.

There are very important financial benefits that come with a good inventory tracking system. With this kind of control over inventory, it's easier for you to know how many units of a product you have on have, how many units of the product you have ordered from the supplier, how much you paid for them, how many units you have already sold, and how much revenue they generated.

The right kind of inventory management technology will decrease your spending on inventory because electronic systems are unlikely to forget about inventory or lose records. As a result, you are unlikely to have untracked or obsolete inventory on your shelves.

What Are the Different Inventory Tracking Technologies?

Point of Sale Systems

A point of sale is the point where a customer pays for a product and walks away from the store with it. When you computerize the point of sale, you have better control over the inventory since you can now track it with ease.

The point of sale system has the inventory amounts for each product that is sold by the business. It will simply reduce the inventory available by one each time a unit is sold. Once the sale and reduction have occurred, the inventory will be updated. In the event that the store is low on stock or a stock out is imminent, the user will be alerted, and more will be ordered. This streamlines the overall ordering process.

Electronic Records

In the event that the user would like to do a manual count of inventory in order to verify the levels, the point of sale system is capable of printing out inventory counts. That way the supervisor can compare the electronic records with the actual inventory levels to ensure that they are on the same level.

Massive savings are realized with such a system because any problems with the inventory are noted very early on and the risk of a rush order, which can often be pricey, is averted.

Barcode Scanners

The barcode is one of the most important innovations to be used in the world of business. All that you need to start an inventory system based on barcodes is the inventory management software, which can sometimes be no more than a simple point of sale software, and a barcode scanner. The barcode scanner can be used to record inventory coming into the business. The products are counted and labelled with a barcode as they are received, then scanned with the barcode scanner so that they are entered in the inventory system.

Whenever the products leave the warehouse or shop, such as in the event of a sale, they are scanned and checked out, with the inventory system being updated. Barcode solutions are quite simple to implement and there are many vendors that offer barcode solutions for business owners, whether small, medium or large.

Radio Frequency Identification Scanners

Also known as RFID, such systems make inventory control very easy. Both RFID technology and barcode technology involve the scanning of products in order to enter them into the system. The main difference between the two is that barcode systems use barcodes printed on pieces of paper, which are then stuck on the products, while RFID uses small microchips that are either placed on a tag attached to the product or on the packaging of the product itself.

Another major difference is the bandwidth of the two technologies. A barcode scanner needs to scan each unit individually for it to be entered into the system. An RFID reception device, on the other hand, will pick up on the signals coming from all of the microchips within a given radius. With RFID technology, the task of controlling inventory is made much easier and faster. Each product is assigned its own RFID chip, and products can easily be scanned en masse.

Audit Your Stock

You should audit your stock regularly. Even with the best inventory management technology, it is still important to manually count your stock every now and then in order to ensure that what your system claims you have is exactly what you have on hand. There are many different strategies you can use here, including annual stock counts, spot checking, and many others.

Always track your inventory trends and levels. That way you know when you need to order new stock. Prioritize the stock in terms of price, with the most expensive stock receiving the highest priority. This should be easy to do with good inventory management software.

Source: N LaMarco, 2019, March 6

Learning Outcomes

2 To define the different types of inventory control systems and the roles they play.

Self Review 2

What are the differences between traditional stock control systems and inventory control approaches for systems such as MRP and JIT?

Relate

Describe the basic variables related to the stock systems given below and explain the relationship between them.

- Order quantity (Q)
- Re-order point (r)
- Lead time (L)
- Safety stock (SS)

Tell/Share

Tell success stories of companies that apply JIT in their organizations.

INVENTORY MODELS

Determining economic lot sizes is an important administrative task in the industrial practice and is becoming more critical due to the increasing number of product variants. In the application of inventory systems, a wide range of mathematical models are utilized while describing the functional relationships among the variables related to inventories. In inventory control, the use of mathematical models should be preferred instead of intuitive decisions. Thanks to the inventory models, the time and amount of materials to be renewed can be determined with the minimal total cost. The first introduction of the inventory models was made in 1915.

Inventory Related Cost Components

In addition to the unit cost (C) associated with the inventory models, the three cost components that will be described below should also be taken into account.

Inventory holding cost (H): Costs are arising due to inventory holding. Inventory holding cost is the sum of the cost of capital plus the variable costs of keeping items on hand, such as storage and handling costs and taxes, insurance, and shrinkage costs. When these components change with inventory levels, so does the holding cost.

A large part of this cost arises from cost of investment tied to the inventory. This cost can be considered as the cost of opportunity loss which is the result of the deprivation of loan interest or other investments that could have been done with this money. Aside from the cost of tied investment in inventories it is the sum of the costs resulting from storage costs, taxes paid for inventory, insurance, cost for transfer of materials, cost of physical counting of inventories, and costs related to deteriorated, stolen, lost, damaged inventories. It is usually obtained by multiplying (h=iC) the value of the product (C) by a certain ratio (i). As the amount of product in inventory increases, the total cost of holding will increase. On the other hand, the possibility of meeting possible demands will increase.

Shortage cost: Costs that occur when there is no inventory or when the stock is out of stock. In this case the demand will not be met, and there are two options: Customer demands are subsequently met or loss of sales occurs when the customer's demand is not met. Both cases are negatively reflected in costs. Although these costs are difficult to estimate, they are cost components that should be considered for stock management.

Order cost (A): The cost of ordering depends on the production or purchase of the material ordered. If the material to be ordered is produced within the enterprise, the total annual inventory cost will be the sum of the costs described above.

Businesses require the total inventory cost to be as small as possible.

The purpose of inventory management is to develop stock policies for determining the "Economic Order Quantity" that will minimize the Total Cost (TC), which is the sum of the costs described below in Figure 5.3.

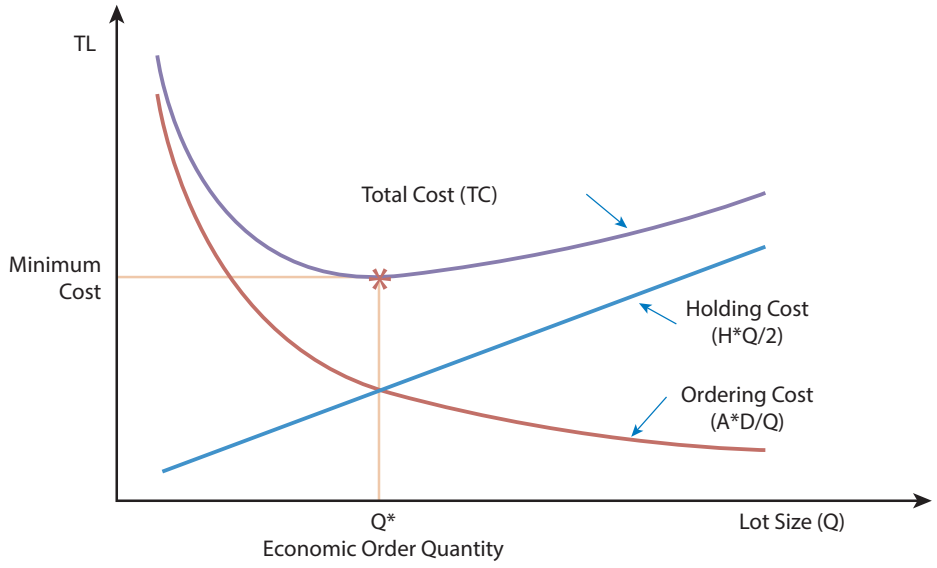


Figure 5.3 Total Annual Inventory Cost Function

As shown in Figure 5.3, the cost of ordering decreases as the order quantity (Q) increases. On the other hand, since the increase in order quantity also increases the inventory, the cost of holding also begins to increase. Therefore, it is not possible to minimize both of the costs at the same time. However, we can ensure that the total cost is the smallest by determining the "Economic Order Quantity" which will provide the minimum cost of the sum of the two costs, in other words, the crossover point.

Economic Order Quantity

Economic Order Quantity (EOQ) is one of the oldest classical production planning models. EOQ is the level of inventory that minimizes the total inventory holding costs and ordering costs. This amount is at the point where the cost of holding is equal to the cost of ordering. This point, represented by Q*, in Figure 5.3, is also the minimum point of the total cost function.

Economic order quantity refers to that number (quantity) ordered in a single purchase so that the accumulated costs of ordering and carrying costs are at the minimum level.

Following are the underlying assumptions for the EOQ model.

- The demand rate for the product (D) is constant and uniform throughout the entire planning horizon.
- The order quantity (Q) is constant.
- The demand rate for the year is known and evenly spread throughout the year.

- The product price is constant for the entire planning period.
- The lead time is not fluctuating.
- The average inventory level is taken into account when calculating the cost of holding.
- The cost of ordering is constant and independent from order quantity.
- All the demand in the planning period must be met.
- All orders are delivered simultaneously.

important

Without these assumptions, the EOQ model cannot work to its optimal potential.

The variables used in the EOQ model are as follows:

D = Annual demand (unit/year)

C = Purchasing price per unit (₺/unit)

A = Ordering cost per batch (₺/batch)

i = Annual interest rate (%)

H = Annual cost of holding per unit (₺/unit-year)

Q = Order quantity (unit)

According to the definitions, the total cost function can be written as follows:

(Total Cost) = (Annual Purchasing Cost) + (Annual Ordering Cost) + (Annual Holding Cost)

$$TC = DC + \frac{D}{Q}A + H\frac{Q}{2}$$

When we take the derivative of this function according to Q, we get;

$$\frac{\partial TC}{\partial Q} = 0 + \left(\frac{-DA}{Q^2}\right) + \frac{H}{2} = 0$$

When Q is extracted from this equation we get,

$$Q^* = \sqrt{\frac{2AD}{H}}$$

The order quantity at this point where the total cost is the smallest is called Q* optimum or "*economic order quantity*".

Example

The annual demand for a material stocked in an enterprise is 180 units. The cost of ordering the material is ₺ 200 per batch and the purchasing cost is ₺ 100 per unit. The inventory holding cost is determined as 20%. Lead time of the product is 1 month. Calculate the economic order quantity for this material, the order in which it should be ordered, how many times to order in a year, and the stock related cost components.

Data of the problem:

Annual demand (D) :	180 unit/year
Cost of ordering (A) :	200 ₺/batch
Unit purchasing cost (C) :	100 ₺/unit
Ratio for cost of holding (i) :	20%
Cost of holding (H=iC) :	20 ₺/unit

Solution of the problem:

The economic order quantity and related operations for this example are shown below:

Economic order quantity (EOQ) (unit/batch):

$$Q^* = \sqrt{\frac{2AD}{H}} = \sqrt{\frac{2\times(200)\times(180)}{20}} = 60\,units$$

Number of orders per year: $N = \frac{D}{Q} = \frac{180}{60} = 3\ orders/year$

Time between orders (cycle time): $T = \frac{Q}{D} = \frac{60}{180} = 0,33\,year = 4\,months$

Total inventory cost: $TC = DC + \frac{D}{Q}A + H\frac{Q}{2}$

$$TC = (180)(100) + (200)\frac{180}{60} + (20)\frac{60}{2} = 19.200₺ / year$$

Average inventory level: $I_{avg} = \frac{Q}{2} = \frac{60}{2} = 30\,units$

Total Cost (₺/year)

Annual cost of ordering (₺/year):

(Annual Ordering Cost) = (Number of Orders)× (Ordering Cost)

$$AOC = \frac{D}{Q}A = \left(\frac{180}{60}\right)\times(200) = 600\ ₺ / year$$

Annual cost of holding inventory (₺/year):

(Annual Holding Cost) = (Holding Cost Per Unit)× (Average Stock Level)

$$AHC = H\frac{Q}{2} = (20)\times\left(\frac{60}{2}\right) = 600₺ / yıl$$

Annual purchasing cost (₺/year):

$$(Annual\ Purchasing\ Cost) = (Annual\ Demand)\times\frac{Unit}{Price}$$

$$APC = DC = (180)\times(100) = 18.000₺ / yıl$$

Total annual inventory cost: $TC = DC + \frac{D}{Q}A + H\frac{Q}{2}$

$$TC = (180)(100) + (200)\frac{180}{60} + (20)\frac{60}{2}$$
$$= 18.000 + 600 + 600$$
$$= 19.200₺ / year$$

In the light of these results, the enterprise should order in batches of 60 units. In order to meet the annual demand, the company must place a total of 3 times a year, once every 4 months. 30 units of materials will be available in the inventory on average. The enterprise should re-order when the inventory level falls to 15 units. The annual inventory cost will be 1,200 ₺ / year without the purchasing price. Figure 5.4 shows the cost components for the problem graphically.

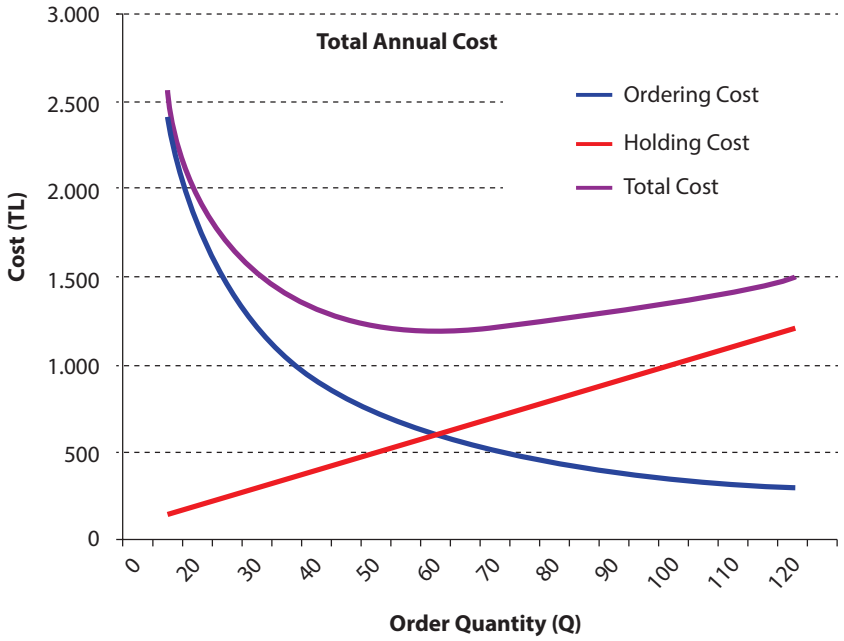
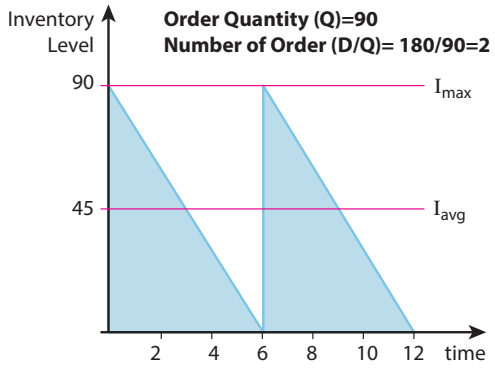


Figure 5.4 Representation of Total Annual Cost Components for the Sample Problem

For the example discussed above, how the cost components corresponding to different order quantities vary are examined in Figure 5.5. When the order quantity is taken as Q=90 units, the maximum inventory quantity is I_{max}=90 units. If this amount is consumed, the inventory level is (zero). So the average inventory level is I_{avg}= (Q+0)/2=Q/2. On the other hand, the annual number of orders equals to D/Q. If the annual demand is D=180 units/year and the order quantity we give each time equals to Q=90 units, then we need to order twice a year to meet the demand.



Parameters	Values
Demand rate (unit/year)	D: 180
Ordering cost (TL)	A: 200
Unit purchasing cost (TL/unit)	C: 100
Inventory holding cost percentage	i: 20%
Inventory holding cost (TL/unit) H=iC	20

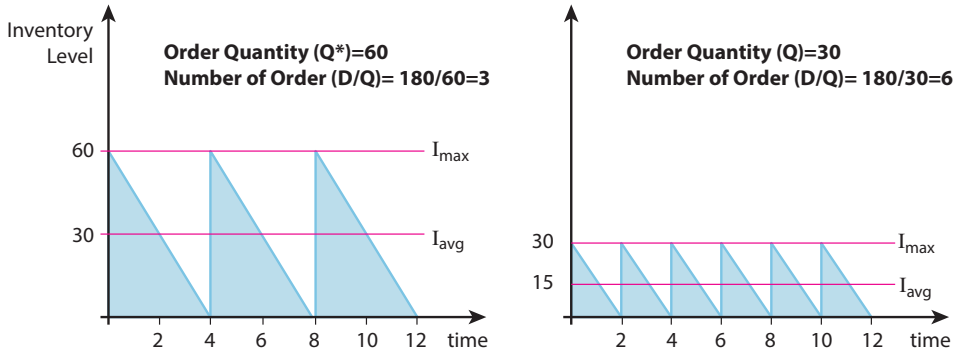
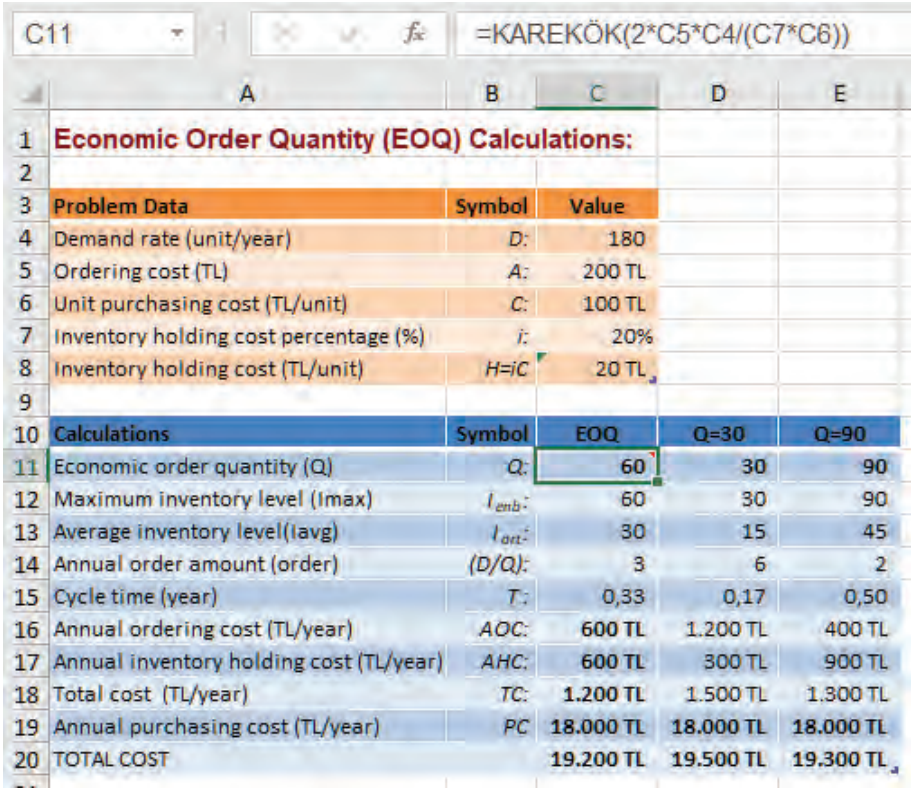


Figure 5.5 Inventory Renewals for Different Order Quantities

When we order in larger quantity, the cost of holding will increase, but the cost of ordering will be reduced. In other cases, if we order a smaller quantity with an order quantity of Q=30 units, the cost inventory holding will be reduced. However, this time we need to order more often as shown in Figure 5.5, and the total cost of ordering increases. The cost values for all these special cases can be examined in Figure 5.6.

The calculations for the problem are solved in Microsoft Excel environment and the screenshot of the results is given in Figure 5.6.



C11 =KAREKÖK(2*C5*C4/(C7*C6))

	A	B	C	D	E
1	**Economic Order Quantity (EOQ) Calculations:**				
2					
3	**Problem Data**	**Symbol**	**Value**		
4	Demand rate (unit/year)	*D:*	180		
5	Ordering cost (TL)	*A:*	200 TL		
6	Unit purchasing cost (TL/unit)	*C:*	100 TL		
7	Inventory holding cost percentage (%)	*i:*	20%		
8	Inventory holding cost (TL/unit)	*H=iC*	20 TL		
9					
10	**Calculations**	**Symbol**	**EOQ**	**Q=30**	**Q=90**
11	Economic order quantity (Q)	*Q:*	60	30	90
12	Maximum inventory level (Imax)	I_{enb}:	60	30	90
13	Average inventory level(Iavg)	I_{ort}:	30	15	45
14	Annual order amount (order)	*(D/Q):*	3	6	2
15	Cycle time (year)	*T:*	0,33	0,17	0,50
16	Annual ordering cost (TL/year)	*AOC:*	**600 TL**	1.200 TL	400 TL
17	Annual inventory holding cost (TL/year)	*AHC:*	**600 TL**	300 TL	900 TL
18	Total cost (TL/year)	*TC:*	**1.200 TL**	1.500 TL	1.300 TL
19	Annual purchasing cost (TL/year)	*PC*	**18.000 TL**	**18.000 TL**	**18.000 TL**
20	TOTAL COST		**19.200 TL**	**19.500 TL**	**19.300 TL**

Figure 5.6 Excel View for EOQ Calculations

The EOQ model is the simplest inventory control model assuming that demand is known. The mentioned inventory control model, is a model that consist of three costs; unit purchasing cost, cost of ordering and cost of holding and considers that the demand and inventory utilization ratio is known exactly. Furthermore, the lead time is fixed and the order quantity in all order periods is fixed.

Economic Production Quantity Model

Orders placed in production systems cannot be entered into inventory at the same time. Products are stocked at a certain delivery speed. In this model, a certain period of time is required to complete the Q unit order. The Economic Production Quantity (EPQ) is determined similarly to the EOQ model. For the materials produced in the enterprise cost of preparation and cost of holding are taken into account.

Assuming a fixed consumption rate (D), the difference (P-D) between production speed (P) and consumption rate (D) will increase the inventory level continuously, therefore the production should be interrupted after a certain period of time. Production will be resumed when the ongoing consumption rate (D) minimizes the inventory level. Thus, in the production in batches, it will be necessary to determine the production party size, which will minimize the total cost.

Inventory movements are shown in Figure 5.7. An inventory cycle consists of two periods. There are both production and demand in the first period called as the accumulation period. During this period, the production speed of the inventories will be (P-D), since there will be demand by D speed when producing at P speed. In the second period, which is called the demand period, the production of the Q unit party is completed. Only production in inventory is consumed by the D speed.

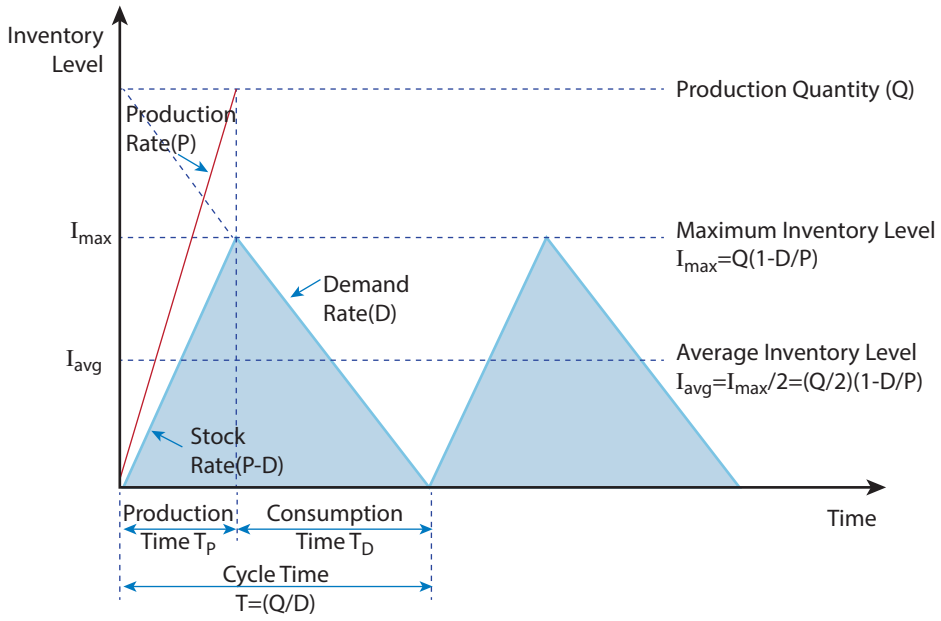


Figure 5.7 Cycle of the Basic EPQ Inventory Model

As can be seen in Figure 5.7, although batch production is Q units, the inventory level never reaches this level. Because; only a portion of Q unit is consumed in the accumulation circuit. Therefore; in case of production, the cost of stocking will be lower than EOQ.

The variables used in the EPQ model are as follows:

D = Annual demand rate (unit/year)

P = Annual production rate (unit/year)

C = Product cost per unit (₺/unit)

A = Production preparation cost per lot (₺)

i = Annual interest rate (%)

H = Annual inventory holding cost per unit (₺/unit-year)

Q = Production order quantity (unit)

Using the explanation given in Figure 5.7, the following definitions can be made:

Cycle time: $T = \frac{Q}{D}$

Production time (accumulation period): $T_P = \frac{Q}{P}$

Consumption time (consumption period): $T_D = \frac{I_{max}}{P}$

Maximum inventory level: $I_{max}\ Q\left(1-\frac{D}{P}\right)$

Average Inventory level: $I_{avg}\ \left(\frac{Q}{2}\right)\left(1-\frac{D}{P}\right)$

According to these definitions, the total cost function can be written as follows:

(*Cost of Holding Stock*) = (*Cost of Holding Stock Per Unit*) × (*Average Inventory Level*)

$$SBM = H\frac{Q}{2}\left(1-\frac{D}{P}\right)$$

(Total *Cost of Ordering*) = (*Order Quantity*) × (*Ordering Cost*)

$$SVM = \frac{D}{Q}A$$

(*Total Cost*) = (*Product Cost*) + (*Preparation Cost*) + (*Cost of Holding Stock*)

$$TC = DC + \frac{D}{Q}A + H\frac{Q}{2}\left(1-\frac{D}{P}\right)$$

The size of the production batch to minimize the total cost can be found by equalizing the derivative of the total cost function to zero, as in the EOQ equation. From this, the best production quantity can be determined by the following formula:

$$Q^* = \sqrt{\frac{2AD}{H\left(1-\frac{D}{P}\right)}}$$

Learning Outcomes

3 To apply the knowledge and skills of basic inventory models.

Self Review 3	Relate	Tell/Share
Why is determining economical lot sizes an important administrative task for organizations?	Build a relationship between holding cost, ordering cost and total cost.	Tell under which assumptions EOQ can be applied.

ABC ANALYSIS

There may be thousands of inventory items in inventory management systems. In the case of a wide variety of inventory items, it is difficult to control all inventories at equal importance. Controlling all inventory items at the same level of importance can be very difficult or even meaningless. Not all products are of the same value. Some inventory items may be too small or unimportant.

For this reason, when applying inventory control systems, it is considered to develop a classification system that will help management in order to determine order decisions of the materials to be kept. In other words, the materials in the class that have a significant amount of money must be controlled more strictly. Likewise, the more critical the materials in a class, the harder they need to be controlled. ABC analysis is used in order to classify inventories and to determine required degree of control.

In order to determine the level of control of various inventory items in the warehouse it may be necessary to classify them according to their criticality or value. As a result, the categories found are sorted by the required degree of control. Each class refers to the amount of money that is invested to it or the importance of itself.

Pareto principle can be interpreted as that a minority of inputs (around 20 percent of the input) results in the majority of outputs (around 80 percent of the output).

Pareto, has studied that most of the wealth is owned by a small part of the population. With the implementation of these studies in inventory management, ABC analysis has emerged. The analysis helps to examine the inventories if there are many different inventory items. This analysis divides a large number of inventory items into three groups representing letters A, B and C to identify and control significant inventory items.

ABC Analysis collects the inventory items in three groups:

Class A Inventory: Very few inventory items in this class receive the largest share of the inventory investment in monetary terms. For example, the materials in this class constitute 15% of the total number of materials and they constitute 75% of the inventory investment. Inventory items in group A should be followed closely such as daily or weekly check.

Class B Inventory: Inventory items in this class cover 30% to 35% of the total inventory items and account for approximately 20% of the total inventory investment. It is sufficient to check the materials in this category every two weeks or monthly.

Class C Inventory: The materials in this class constitute 50% -55% of the total inventory items however, they constitute approximately 5% of the total inventory investment. It may not be necessary to check the materials in this class, or it is sufficient if they are checked every 2-3 months.

Example

For the 10 materials stocked in a company, the annual demand amounts and unit prices are given in Table 5.2.

Table 5.2 ABC Material List for ABC Analysis

Material Code	Annual Demand (unit/year)	Unit price (₺/unit)
M-01	1,000	10.00
M-02	1,750	4.00
M-03	4,000	1.00
M-04	750	15.00
M-05	4,750	35.00
M-06	2,000	3.00
M-07	200	500.00
M-08	1,500	5.00
M-09	3,500	10.00
M-10	500	2.00

Based on the data in Table 5.2, the annual amounts of the materials, the annual amount ratios and the cumulative rates are calculated and the results are given in Table 5.3. After the calculation process, the rows of the table are sorted in descending order according to the annual amount column. Then, the annual amount ratio of each inventory item and the ABC classification are calculated and the results are shown in Figure 5.8.

Table 5.3 ABC Analysis Calculation and Classification Operations for Sample Data

Material Code	Annual Demand (unit/year)	Unit Price (₺/unit)	Annual Amount (₺/year) ↓	Annual Amount Rate (%)	Cumulative Rate (%)	ABC Classes
M-05	4,750	35.00	166,250	47.8%	47.8%	A
M-07	200	500.00	100,000	28.7%	76.5%	A
M-09	3,500	10.00	35,000	10.1%	86.6%	B
M-04	750	15.00	11,250	3.2%	89.8%	B
M-01	1,000	10.00	10,000	2.9%	92.7%	B
M-08	1,500	5.00	7,500	2.2%	94.8%	C
M-02	1,750	4.00	7,000	2.0%	96.8%	C
M-06	2,000	3.00	6,000	1.7%	98.6%	C
M-03	4,000	1.00	4,000	1.1%	99.7%	C
M-10	500	2.00	1,000	0.3%	100.0%	C
Total			348,000	100.0%		

From Table 5.3, the classes of the materials are shown graphically in Figure 5.8.

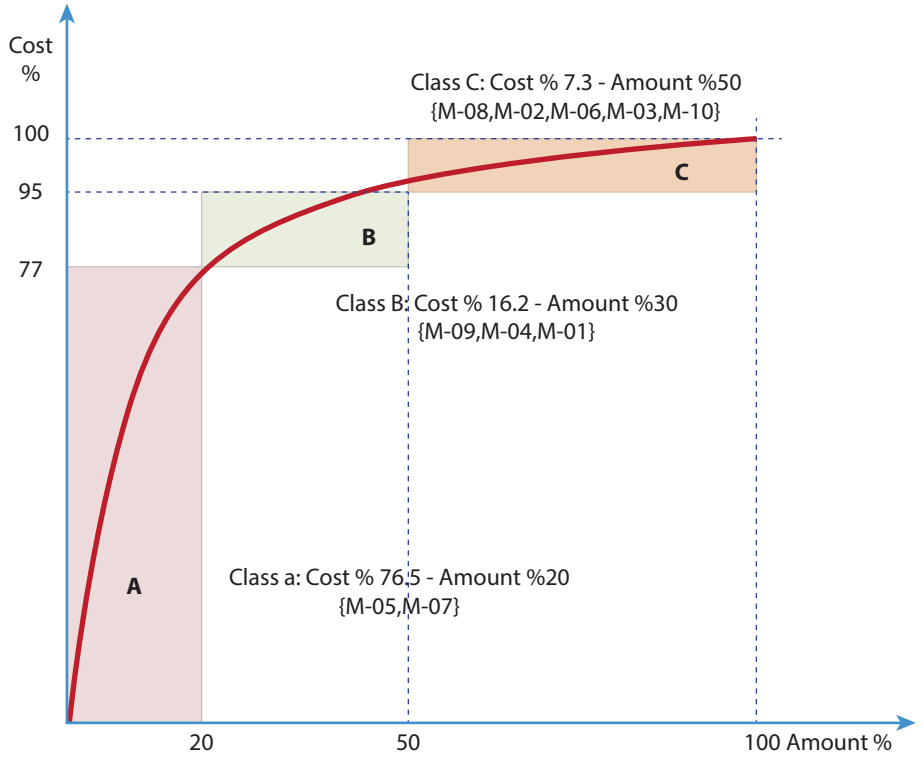


Figure 5.8 Graphical Representation of ABC Analysis Results

Group A inventory items consists of M-05 and M-07, and group B inventory items consists of M-09, M-04 and M-01, group C inventory items consists of M-08, M-02, M-06, M-03 and M-10. In this way; inventory items with low quantity but a high unit price are included in Group A and Group C keeps inventory items with low price but large in quantity.

In order not to apply the same inventory management techniques to all items in inventory, important items that require close monitoring and control are distinguished from the others. The ABC inventory classification system is an efficient simple technique for separating items that require close control from items that do not require close monitoring and control.

Learning Outcomes

4 To use ABC analysis to determine the items deserving the most attention.

Self Review 4	Relate	Tell/Share
In ABC analysis, according to which criteria is the classification of products carried out?	Associate usage of ABC analysis with increase in efficiency of inventory control.	Tell what class of inventory receives the largest share of the inventory investment in monetary terms.

LO 1 Express inventory and inventory management key terms.

The materials that are kept in an enterprise until they are needed are called inventory. Each organization holds inventory to serve as a buffer between demand and supply. The main purpose of inventory keeping is to deal with uncertainty and variability. Due to the significant investment in inventory, it requires careful planning and control. In inventory management, it is important to decide on what materials will be kept as inventory, the amount of inventory to hold, and how long the inventory will be stored.

LO 2 Define the different types of inventory control systems and the roles they play.

There are several methods for stocking and controlling these inventories. Businesses develop methods to control inventories to meet various objectives. The purpose of inventory control is to have the desired goods ready at the desired time and to realize this in the most economical way. Each company implements an inventory control system that is formed according to their business size, top management policies, production type, financial opportunities and many other factors. The methods used in these systems may vary from simple counting and visual control to complex probability models with the support of computers.

- **Continuous review system:**

  In the continuous review inventory control system, the inventory level is continuously monitored. When the inventory level falls below a certain level, it is ordered again. The *order quantity* is a predetermined and fixed value. The design of this system requires that the order quantity and re-order point be determined to minimize the total inventory costs. The control is carried out with visually control, by two-bin methods, by hand-held records or by the help of a computer.

- **Periodic review system:**

  In the periodic review system, the inventory level is checked at regular intervals. During this check, the available inventory level is compared with the pre-set order completion target. If the inventory level at the time of review is below the re-order point; the order is renewed until the order completion level is met.

- **Material Requirement Planning:**

  The basic principle of MRP is; to go backwards from the finished product with independent demand and to have the necessary parts and materials ready when needed. This approach significantly reduces the waiting time of inventory items in the warehouse and hence the cost of ownership. MRP determines the material requirements by taking into account the production targets in the product tree, inventory records and the master production schedule. Net requirement values are obtained from the gross requirements determined in this translation process by decreasing the quantity of inventories in hand or the order quantities planned to be received. The net requirement values in MRP are given within the time dimension.

- **Just in Time Production System:**

  Just-in-time production system is defined as zero inventory, no inventory production and kanban system. Minimizing intermediate inventory levels in production, minimizing changes in intermediate inventory levels and facilitating inventory control, reducing production demand fluctuations, streamlining production flow, providing effective control with a simple system and reducing waste rate are the main objectives of JIT. JIT is based on pull principle, not on the basis of push as in conventional systems. In JIT, Kanban is used for information communication. JIT is an important component of lean manufacturing system. In the production of goods or services, lean manufacturing is a production philosophy that aims eliminating the costs that does not add value to goods or services and by eliminating all the elements that cause waste.

Summary

LO 3 Apply the knowledge and skills of basic inventory models.

In the application of inventory systems, mathematical models are widely used. Keeping inventories at the economical level can be provided by investigating and finding the balance between various cost elements.

Three cost components related to inventory models should be considered. The *Cost of holding inventory* is the summation of the investment costs of the inventories, the total cost of storage, taxes, insurance, aging of the inventories, theft, loss, damage. The *cost of not holding* inventory is the costs that arises when the company goes out of inventory. Although these costs are difficult to estimate, they are cost components that should be considered for inventory management. The *cost of ordering* is taken as preparation cost if the ordered material is produced in-house. The purpose of inventory management is to develop inventory policies to determine the Economic Order Quantity (EOQ), which will minimize the sum of these costs.

- **Economic order quantity:**

  The EOQ model is the simplest inventory control model that assumes that the demand is known. In this inventory control model, it is assumed that the rate of demand and inventory utilization is strictly known. It consists of three cost elements: unit cost of purchase, cost of holding inventory and cost of ordering. In addition, the supply time is fixed and the order quantity in all order periods are fixed.

- **Economic production quantity:**

  It is a technique used to find the optimal production quantity by taking into consideration the production, preparation, inventory holding and not holding inventory costs. It is used when products are produced and sold at the same time.

LO 4 Use ABC analysis to determine the items deserving the most attention.

Thousands of items, often referred to as stock-keeping units, are held in inventory by a typical organization, but only a small percentage of them deserves management's closest attention and tightest control.

ABC analysis is a classification technique based on Pareto Principle. With ABC Analysis in inventory management, items forming inventories are classified according to their importance. In this classification, inventories are divided into 3 main groups: A, B and C groups. ABC Analysis can be used to increase the efficiency of time and effort spent on inventory control.

- **Class A Inventory:** Very few inventory items in this class receive the largest share of the inventory investment in monetary terms. For example, the materials in this class constitute 15% of the total number of materials and they constitute 75% of the inventory investment. Inventory items in group A should be followed closely such as daily or weekly.
- **Class B Inventory:** Inventory items in this class cover 30% to 35% of the total inventory items and account for approximately 20% of the total inventory investment. It is sufficient to check the materials in this category every two weeks or monthly.
- **Class C Inventory:** The materials in this class constitute 50% -55% of the total inventory items however, they constitute approximately 5% of the total inventory investment. It may not be necessary to check the materials in this class, or it is sufficient if they are checked every 2-3 months.

1 Which one of the followings is not the reason that leads businesses to increase inventory?

a. To be able to respond quickly to changes in demand.
b. To have short shelf life of stocked materials.
c. To have the desire of taking precautions against the problems arising from the suppliers.
d. To ensure that different products can be produced in the same facility.
e. To increase competitiveness with an image such as delivery from inventory

2 Which one of the following inventory systems does recommend to place a new order when the inventory level falls below a certain value by using fixed time intervals (eg weekly) to review the inventory level?

a. Visual control system
b. Two-bin system
c. Continuous review system
d. Periodic review system
e. Just in Time Production System

3 Which one of the question can be answered economically for dependent inventory items by MRP Method?

a. How to order
b. Why to order
c. Where to order
d. When to order
e. What to order

4 Which one of the followings is the tool that means card in Japanese and used as a means of information communication in JIT system?

a. Muda
b. Muteki
c. Kanban
d. Manga
e. Cartoon

5 Which one of the followings **cannot be** a decision variable for an inventory system?

a. Economic order quantity
b. Order point
c. Safety stock level
d. Backorder amount
e. Demand level

6 The time between the ordering and delivery of a product (lead time) takes four days. If the daily demand of the product is 10 units, what is the point of re-ordering?

a. 10
b. 20
c. 40
d. 100
e. 400

7 Which one of the followings is the basic assumptions underlying the Economic Order Quantity (EOQ) model?

a. The material is delivered at once at the end of the lead time.
b. Demand shows normal distribution throughout the order period.
c. The purchase price per unit varies depending on the quantity ordered.
d. The lead time is variable depending on the quantity of material ordered.
e. The average demand level is taken into account when calculating the cost of holding inventory.

8 In an inventory model, if the purchase price is reduced by 50%, inventory holding cost is doubled, and the demand level is increased by 400% what would the EOQ value be?

a. Double
b. Triple
c. Quadruple
d. Reduces by half
e. Remains unchanged

9 For a filter used in a car service, it is known that the weekly demand is 50 pieces and the order cost is 8 ₺ / per order. While the cost of keeping the filter in inventory for one year is 4 ₺ / piece, it is not allowed to remain out of inventory. How often should the order of the filter be ordered when using the Economic Order Quantity (EOQ) method? (One year is accepted 50 weeks.)

a. Every week
b. Every two weeks
c. Every three weeks
d. Every four weeks
e. Every 25 days

10 In ABC analysis, according to which one of the following criteria is the classification of products carried out?

a. Order cost
b. In alphabetical order
c. Cost of holding stock
d. Unit price of materials
e. Cumulative cost percentages in total inventory

Answer Key for "Test Yourself"

1. b	If your answer is wrong, please review the "Inventory Management" section.	6. c	If your answer is wrong, please review the "Inventory Models" section.
2. d	If your answer is wrong, please review the "Inventory Control Systems" section.	7. a	If your answer is wrong, please review the "Inventory Models" section.
3. d	If your answer is wrong, please review the "Inventory Control Systems" section.	8. e	If your answer is wrong, please review the "Inventory Models" section.
4. c	If your answer is wrong, please review the "Inventory Control Systems" section.	9. b	If your answer is wrong, please review the "Inventory Models" section.
5. e	If your answer is wrong, please review the "Inventory Models" section.	10. e	If your answer is wrong, please review the "ABC Analysis" section.

Suggested Answers for "Self Review"

Why inventory is an important issue for businesses?

self review 1

The materials that are kept in an enterprise until they are needed are called inventory. Each organization holds inventory to serve as a buffer between demand and supply. The main purpose of inventory keeping is to deal with uncertainty and variability.

Inventories are important for both manufacturing and service systems and require significant financial investment by making up a significant portion of the production cost of products. At the same time, the control of stocks requires significant physical effort. For these reasons, it is important for enterprises to decide on what materials will be kept as inventory, the amount of inventory to hold, and how long the inventory will be stored.

What are the differences between traditional stock control systems and inventory control approaches for systems such as MRP and JIT?

self review 2

Continuous and periodic review systems are the systems that can place orders based on the past usage data. They require opening new orders when the stock level or the time elapsed between orders reaches a predetermined point. Therefore, it is an appropriate approach for stocks for distribution purposes that require the use of safety stock against uncertainties.

The MRP and JIT philosophies require prior planning based on a demand estimate or orders received. In MRP, material orders are placed in such a way that they are delivered when necessary. This approach is suitable for environments where parts and materials are converted into stocks of finished products in the planned quantity.

Why is determining economical lot sizes an important administrative task for organizations?

self review 3

Determining economic lot sizes is an important administrative task in the industrial practice and is becoming critical due to increasing number of product variants. Keeping inventory at an economic level can be achieved by balancing various cost elements. The purpose of inventory management is to develop inventory policies to determine the Economic Order Quantity (EOQ), which will minimize the sum of these costs. These cost components are: the cost of holding inventory, the cost of not holding inventory and the cost of ordering.

In ABC analysis, according to which criteria is the classification of products carried out?

self review 4

ABC analysis is a classification technique based on Pareto Principle. With ABC Analysis in inventory management, items forming inventories are classified according to their importance. The classification of products in ABC analysis is carried out according to the cumulative cost percentages in total inventory. By this way, the ABC Analysis can be used to increase the efficiency of time and effort spent on inventory control. In this classification, inventories are divided into 3 main groups: A, B and C.

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Chapter 6 Production and Resource Planning

After completing this chapter, you will be able to;

Learning Outcomes

1. Learn resource planning terms and explain its importance.
2. Describe the evolution of the manufacturing resource planning.
3. Apply the basic modules of manufacturing resource planning.
4. Explain how Enterprise Resource Planning Systems improve enterprises.

Chapter Outline

Introduction
Manufacturing Resource Planning
The Evolution of MRP II
Basic Modules in MRP II and Applications
Enterprise Resource Planning

Key Terms

Production and Sales Planning
Master Production Scheduling
Bill of Materials
Rough Cut Capacity Planning
Material Requirements Planning
Capacity Requirements Planning
Enterprise Resource Planning

INTRODUCTION

In today's complex world, customers expect to have finished products or services available at the right time. Moreover, customer demand is constantly changing in quality and quantity making it difficult to predict this change. Companies can gain a competitive advantage in this environment by focusing on resource planning.

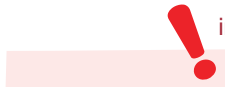
The opportunities provided by the computers were transferred to the production management by taking inventory tracking in the computer environment. These approaches were based on information technologies, provided important contributions in the production management that can be considered as a revolution. Resource planning lies at the heart of any organization, cutting across all of its different functional areas. Resource planning can increase the production and overall efficiency. To achieve this, tools that utilize information in a common database are used. These tools provide the senior management a better decision-making process aligned with the strategies of the company.

This chapter begins with Manufacturing Resource Planning (MRP II) which is a specific resource planning approach that aims to keep required amount of resources at the time and place they are needed, in order to increase the efficiency of the production. Later, historical developments of systems such Material Requirement Planning, Closed-loop MRP, Manufacturing Resource Planning (MRP-II), Enterprise Resource Planning (ERP) and their differences are explained. Subsequently basic modules in MRP II and their applications are introduced.

MANUFACTURING RESOURCE PLANNING

Manufacturing Resource Planning (MRP II) aims to keep required amount of resources at the time and place they are needed, in order to increase the efficiency of the production. It consists of tools that utilize information in a common database. These tools provide the senior management a better decision-making process aligned with the strategies of the company.

MRP II is an integrated series of planning techniques developed to ensure the efficient use of all resources such as materials, machinery, money and people. The MRP II system was introduced by adding functions such as marketing, finance and capacity planning to the Material Requirement Planning (MRP) system. In addition to MRP, MRP II also covers capacity planning activities for machinery and labor. MRP II takes sales and operations plans; processes information in the way of time standards, routings, and other information on how services or products are produced; and then plans the input requirements. MRP II also can create reports for managers of the firm's major functional areas, such as human resources, purchasing, sales and marketing, and finance and accounting. In essence, resource planning is a process that can be analyzed relative to the firm's competitive priorities.



Manufacturing Resource Planning is mentioned in the literature with the abbreviation MRP II to avoid confusion with the Material Requirements Planning (MRP).

Wight (1984), one of the pioneers of the topic states basic features of MRP II, as follows:

- In a business, the production system and the financial system are identical. Both have the same operations and the same numbers. Based on this feature, MRP II ensures that the numbers generated at the time of the transaction are reflected in the financial system.
- A good system should be the simulation of the real system. MRP II gives the opportunity to examine the results of different master production schedules or different policies with what-if analysis.
- MRP II is a system that integrates basic components of planning and control such as sales, products, inventories, business centers, production schedules, cash flows and so on.

The American Production Control and Inventory Control Society (APICS) has played an important role in the spread and development of MRP II. In the 1970s, APICS pioneered the MRP movement and carried out a number of studies on

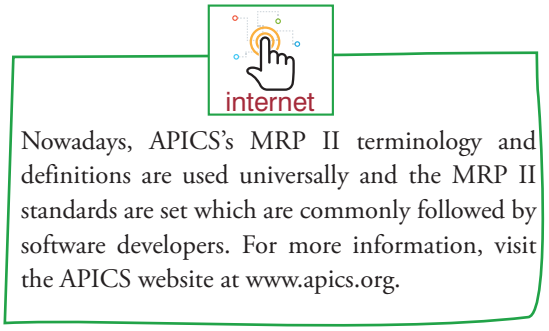
MRP II. Still, the concepts and terminology proposed by APICS are widely used today.

These approaches, which are based on information technologies, have provided important contributions that can be considered as a revolution in the execution of production management activities.

For planning and controlling activities, including business functions, the representation given in Figure 6.1 is used (Volman et al., 2005).

The MRP II system is followed by a top-down approach. The starting point is the sales and production (business) plan developed by the top management. Starting from this point, the processes and functions are defined towards the lower levels of the organization.

As can be seen from the explanations above, the concept of MRP II includes a large number of terms and concepts. In addition, the technological terminology, excessive different expressions used by the software firms can cause to miss the essence of the important concepts. In order clarify this complex concept, it will be useful to explain related terms and to examine its historical development in the following section.



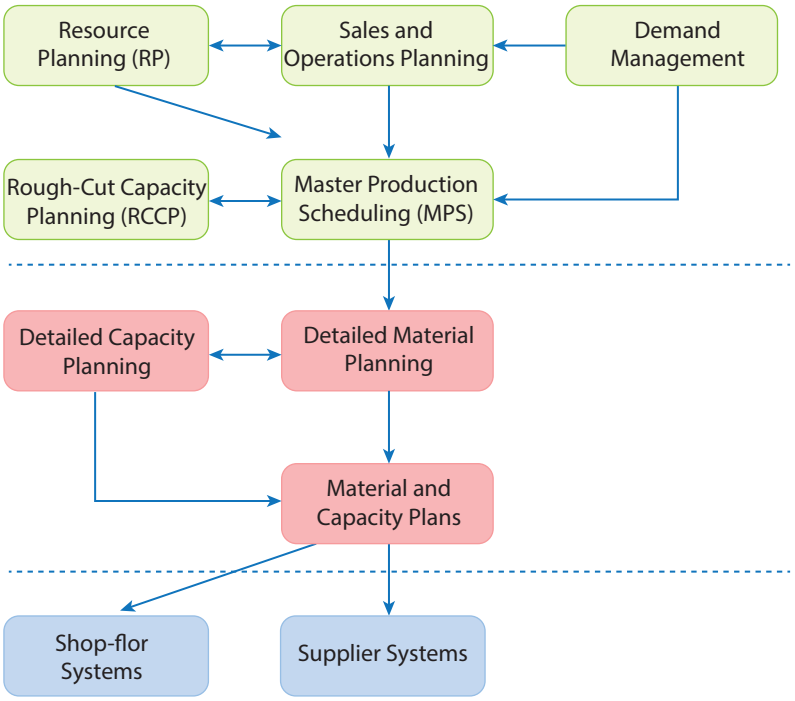


Figure 6.1 Basic Modules of Manufacturing Resource Planning: This model is also Called the Manufacturing Planning and Control (MPC) System

Learning Outcomes

1 To learn Resource Planning terms and explain its importance.

Self Review 1

What is the aim of Manufacturing Resource Planning (MRP II)?

Relate

Relate to the reasons top-down approach is being used in the Manufacturing Resource Planning (MRP II)

Tell/Share

Share the differences between Material Requirement Planning (MRP I) and Manufacturing Resource Planning (MRP II)

THE EVOLUTION OF MRP II

The opportunities provided by the computers were transferred to the production management by taking inventory tracking in the computer environment. However, *MRP* approach is the most important start in the renewal of the production planning and control activities and transformation to computer-aided format.

In 1960, the MRP concept was introduced to the business world, as IBM launched the first economic computer that commercial enterprises could own. Later, MRP systems that consider the dependent demand structure became widespread. Transferring to the computer environment has been an important solution in the field of material ordering for the production companies.

Material requirements planning (MRP) is a computerized information system developed specifically to help manufacturers manage dependent demand inventory and schedule replenishment orders.

The MRP system calculates the requirements for each material by examining the levels of BOM according to the determined production plan and it calculates whether the stocks of these materials meet the requirement.

After the MRP, a more efficient system called "*Closed Loop MRP" (CL-MRP)* was developed in order to overcome some of the inadequacies of MRP. With CL-MRP companies were able to answer additional questions such as: "Is there enough capacity for the orders received?" and "Which resources are the bottleneck resources?".

In the 1970s, the closed loop MRP allowed the Master Production Schedule (MPS) to be changed with a feedback scheme, considering the status of the workshop.

With the closed-loop MRP given in Figure 6.2, material requirements and priorities as well as capacity planning and workshop control are considered.

Closed-loop MRP is an MRP system that includes production planning, master production scheduling, and capacity requirements planning.

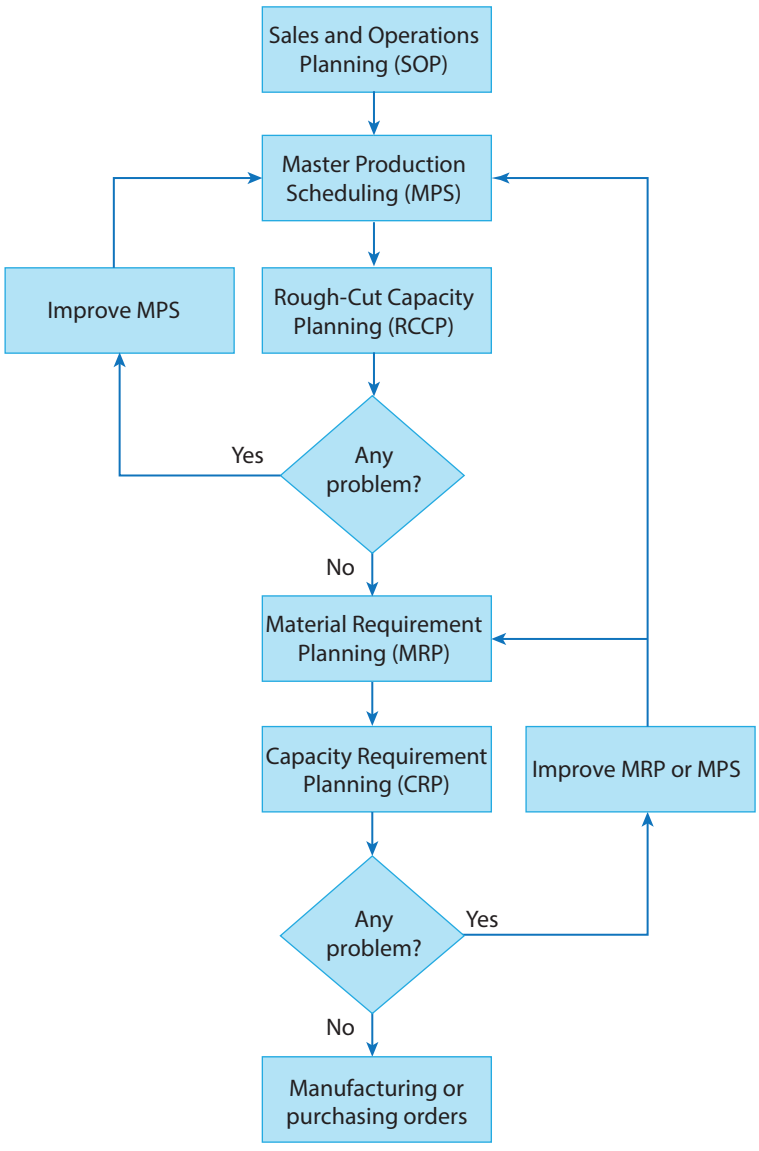


Figure 6.2 Closed Loop MRP System

The Closed Loop MRP, controls the capacity and warns the master production schedule by sending a feedback if the available capacity is not sufficient. With this system, MRP is not only a material management tool that plans the orders, but also contributes to production control.

MRP, which is a technique developed to determine when and what amount of material or part is to be supplied in accordance with the master production schedule, is the basis of *MRP II*. As the closed-loop MRP is integrated into the capacity requirement planning of MRP, it formed MRP II, a system that integrates the functions of general operation and production management in a common database.

Furthermore, in the late 1970s, purchasing activity was covered by MRP software and new systems started to monitor not only material requirements and stocks but also orders to be purchased. In the same years, information technologies have also evolved significantly and online processes have been adopted instead of the batch process approach.

In 1980s, MRP II systems covering all activities related to the production of production companies started to become widespread. Thanks to the new developments, MRP II systems have not only covered stocks and procurement but also production planning, production control, capacity planning, product costing, accounting and limited financial management. MRP II systems collect all company-level resources in a common database and enable all employees within the company to speak the same language.

Manufacturing resource planning (MRP II): A method for the effective planning and integration of all internal resources.

MRP II has three major components: management planning, operations planning, and operations execution. The company's strategy is translated into business objectives for the current year. These objectives drive the development of the marketing plan that in turn drives the development of the production plan. The production plan identifies the resources available to manufacturing to achieve the output needed by marketing. Then the master production schedule shows how the resources from the production plan are to be used. Operations planning is the MRP function. One of the primary inputs of the MRP system is the master production schedule. The output from the system is the order release schedule. Operations execution brings the plan to life. Raw materials and components are purchased, subassemblies and final assemblies are scheduled, quality is assured, labor is managed, and production is completed. Problems encountered in production are fed back to the MRP component. Ongoing performance evaluation provides feedback to business planning for any necessary corrective actions.

The emergence of a large number of firms offering MRP II software products in the 1980s showed that a new business area was born in this area. As time passed, the development continued by adding new modules to the MRP II software and integrating it with other functions. On the other hand, developments in information technologies have increased the ease of use and flexibility of MRP II systems.

With the intense competition in the 1990s, the need to expand to international markets has created the need for integration across the international firms for the enterprises that are central to different geographical regions. Thus, a new need for information technology has emerged. Moreover, technological developments have made it difficult for companies to hold on to the market. With the discovery of the inadequacy of classical approaches, managers have had to revise their production technologies and management approaches. With the strong changes in the market, technological developments and the orientation towards the institutionalization of the organizational structure of the companies, a new concept, **Enterprise Resource Planning** (ERP), has emerged. Thus, the opportunity to benefit from the synergy created by the simultaneous planning of the resources of the facilities located in different geographical regions was born.

MRP II is an integrated system in itself and is also an important component of ERP. Since the MRP II methodology is used mainly in manufacturing sectors, it can be perceived as having two different methods with a common misconception. These systems, however, evolved by including one other, as shown in Figure 6.3.

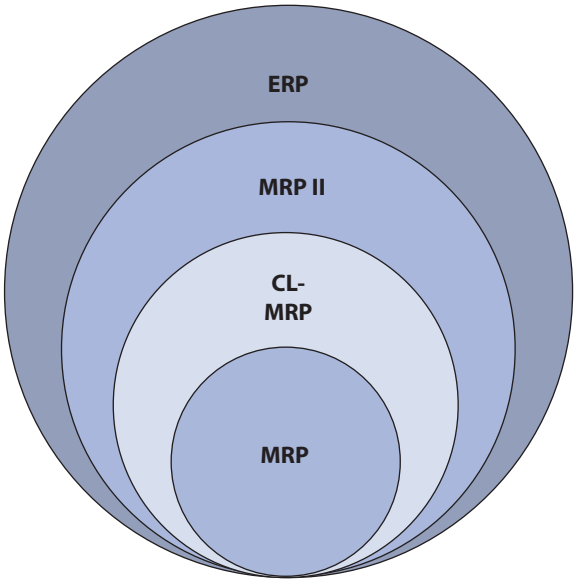


Figure 6.3 Inclusive Feature of Enterprise Resource Planning

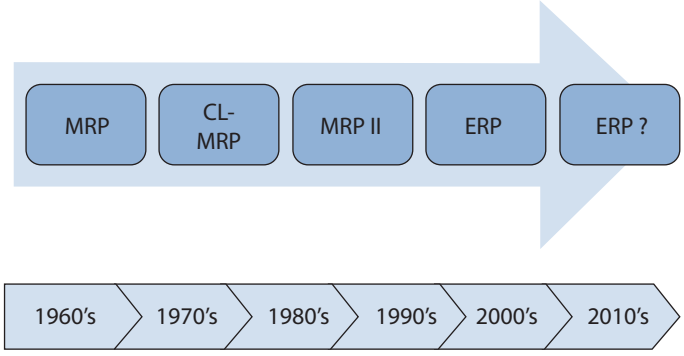


Figure 6.4 Chronological Development of Enterprise Resource Planning

In case ERP is implemented in a manufacturing company, activities that require planning studies such as inventory management, order, manufacturing, purchasing are usually regulated by MRP-II methodology.

In the 2000s, new concepts such as Supply Chain Management (SCM) and Customer Relationship Management (CRM), which included the whole production process and the customer, become popular. In this way, an enterprise was able to make a more holistic planning and monitoring with its customers and suppliers. The second-generation ERP systems were named ERP 2, but the ERP concept remained and got updated.

When the developments explained above are analyzed, it is seen that the scope has been constantly expanding. The chronological order of this transformation process in time is shown in Figure 6.4.

The third generation of ERP, which is described as the future of ERP emerged in 2010's. It includes the cooperation of Web 2.0 technology with the ERP functions, provides enterprises with an extroverted and interactive environment in corporate management. The most fundamental feature of the new ERP solution is that it covers all the processes of the business. It meets the requirements of all units, including more customer-oriented and value-oriented functions, and completely internet-based. The Internet-based feature provides the opportunity to collaborate and communicate with customers, dealers, suppliers and all market components through the ERP system.

New generation ERP systems, also called ERP 3, uses the internet-based infrastructure; e-business portal functions managed directly through the corporate ERP system, including social media integration, video conferencing, online messaging, e-mail, forum, survey management. Thus, it includes a communication and information sharing environment that can integrate the enterprise with all its components such as dealers, customers and suppliers.

Learning Outcomes

2 To describe the evolution of the Manufacturing Resource Planning.

Self Review 2

What are the milestones in the development of the Manufacturing Resource Planning?

Relate

Relate to the reasons that lead companies to depend more on the information technologies.

Tell/Share

Share which new features can be adopted to the future systems.

BASIC MODULES AND APPLICATIONS IN MRP II

In this section, the introduction of MRP II modules, which are widely used in manufacturing enterprises, will be explained on an integrated sample problem.

Production and Sales Planning

The installed capacities of enterprises are generally stable. However, the level of demand for products varies according to time. The purpose of the production and sales plan is to meet the demand of the variable market by using the production tools, labor force and other resources of the enterprise as effectively as possible. *Production and sales planning* is aimed at determining the stock, labor and best production levels for the given production resources and constraints for each period in the planning horizon. In general, it relates to the planning of production for a time interval of 6-18 months. Production managers determine how best to meet the anticipated demand by adjusting production speeds, labor levels, overtime and other controllable variables. Generally, the aim of the process is to minimize the costs during the planning period. Undoubtedly, as the other objectives of the process, it is possible to give examples of minimizing fluctuations in the labor force or maintaining certain production levels.

Production and sales planning is the process of planning the amount and timing of output in the medium to long term by regulating production speed, workforce size, inventory and other controllable resources.

Table 6.1 A Sample Production Plan

Months	1	2	3	4	5	6	Total
Estimated Demand (unit)	370	470	450	500	450	400	2640
Production Quantity (unit)	350	500	500	500	400	400	2650

The production and sales plan are expressed by a common unit representing all products produced. In general, the master production schedule is a production plan that aims to minimize costs in accordance with capacity constraints. However, the amount of resources in the long term may not be constant. In this case, the prepared production plan can be considered as a tool that regulates the necessary changes in the amount of resources.

Master Production Schedule

Master Production Schedule (MPS) is the process of preparing a schedule to show the date and amount of all materials to be sold or to be produced within a certain planning horizon. The master production schedule is the main input of MRP and MRP II. The master production schedule is created for end products or spare parts that are sold. In other words, the MPS covers the determination of the production targets required to meet the independent demand.

MPS is a plan that details how many end items will be produced within specified periods of time.

Since the demand for the final product for a manufacturing enterprise consists of independent sources outside the production system, it is called independent demand. The demand for the parts that make up the product depends directly on the planned production quantities of the final products. Once a master production schedule has been created for the final products, the quantity of parts required for the respective final products can be easily calculated. Therefore, demand for parts is called dependent demand. The demand for parts used both in production and directly sold is both independent and dependent. The demand for the bicycle that is independent, should be estimated. The demand for the parts of the bicycle is dependent on the amount of bicycle production and can be calculated precisely.

The purpose of the master production schedule;

- To keep customer satisfaction as high as possible. To do so, balance product stock levels and delivery dates to customers.
- To ensure the best use of material, labor and production tools.
- To keep the level of investment in the material at the desired level.

The master production schedule is the basic mechanism that directs the MRP process. This plan is a detailed list showing which products are produced, when and how much. Two main factors are considered when determining the main production plan:

- Sales forecasts
- Customer orders

The sales estimates required for the planning are recorded by the marketing department and the order information is recorded by the sales department. Generally, recent sales volumes are based on actual order data; the values of the subsequent periods are based on sales estimates. Since the transactions are made according to the forecasted demand, the master production schedule is kept up-to-date as the new order is received or repeated periodically. Sales and marketing updates pending orders and forecast figures for each period. As time progresses, the planning horizon can also be extended forward. In the master production schedule, past periods are deleted and further forecasts are added. This is a very important process that must be repeated periodically. In addition, MPS provides opportunity to report a delivery date to the customers. The amounts not allocated to meet an order can be promised to the customer during the order and the deliveries to the customer can be planned correctly.

Example Problem

Two different models of a product (Model A and Model B) are produced in an enterprise. The expected demand values for both models and the final order quantities are given in Figure 6.5.

MPS for Model A:

Initial inventory level (I_o) = 100 unit

Production lot size (Q_A) = 200 unit

Week	1	2	3	4	5	6	7	8
Forcasted demand (F_t)	50	60	70	80	90	90	90	60
Customer orders (O_t)	60	40	30	0	0	0	0	0
Inventory balance (I_t)	40	180	110	30	140	50	160	100
Production quantity (MPS - A)	0	200	0	0	200	0	200	0

$* I_1 = 100 - max\{50, 60\} = 100 - 60 = 40$ $\quad I_t = I_{t-1} - \max(F_t; 0_t)$

MPS for Model B:

Initial inventory level (I_o) = 40 unit

Production lot size (Q_B) = 50 unit

Week	1	2	3	4	5	6	7	8
Forcasted demand (F_t)	25	25	30	30	25	25	40	50
Customer orders (O_t)	50	40	30	0	0	0	0	0
Inventory balance (I_t)	40	0	20	40	15	40	0	0
Production quantity (MPS - B)	50	0	50	50	0	50	0	50

Figure 6.5 Preparation of Master Production Schedule for the Sample Problem

Production quantities in the master production schedule are determined according to whether the inventory level meets the demand in the relevant period. For example, for the Model B, the demand for week 1 was forecasted to be 25 while the final order level was 50. In this case, the maximum amount of consumption should be deducted from the stock level of 50 units. Since the available stock level does not meet the order, a new production amount is required for the 1st week. In this case, because the order quantity is 50 units, in the first week B unit is programmed to produce 50 units. At the end of week 1, the stock level will be transferred back to 40 units. For the explanations above, we can write the relevant equations as follows:

$$I_t = I_{t-1} - max\{F_t; 0_t\}$$

$$MPS_t = \begin{cases} Q & I_{t-1} - \max\left(F_t; O_t\right) < 0 \\ & if \\ 0 & I_{t-1} - \max\left(F_t; O_t\right) \geq 0 \end{cases}$$

Following these calculations, the Master Production Schedule (MPS) covering the 8-week period for A and B models is given in Table 6.2.

Table 6.2 Master Production Schedule for the Sample Problem

Week	1	2	3	4	5	6	7	8
MPS for Model A	0	200	0	0	200	0	200	0
MPS for Model B	50	0	50	50	0	50	0	50
TOTAL PRODUCTION	50	200	50	50	200	50	200	50

Rough Cut Capacity Planning

Rough cut capacity planning (RCCP) is the approach of roughly estimating and determining the required level of capacity problems in order to realize the master production schedule. It can also be considered as a transformed form of the master production schedule into workloads. The planning horizon is the same as the main production program and usually one year. Time periods and review times are

usually weekly or monthly. Loading is done according to the man or machine hours at the work stations. It is not possible to make full use of the MRP II system without a study on whether sufficient capacity can be achieved or without knowing the existence of excess capacity.

When Figure 6.1 is examined, it is observed that the modules related to capacity vary according to the nature of the material plan used as the basic input. In the planning hierarchy, capacity plans become more realistic when moving from long-term to short-term.

The production plan showing what the output level of the period is the starting point of the capacity decisions. Production plans should be arranged by taking the possible capacity constraints into consideration. The time dimension of the production plans is usually long enough for the capacity to vary.

Capacity planning carried out in the MRP II system with material planning systems can be defined as determining the level of capacity required to perform the scheduled production, comparing it with the available operational capacity, and planning the necessary arrangements in capacity levels or production schedules.

important

The production plan is generally carried out by transforming it into a master production schedule with more specific details than product and product models.

As seen in Figure 6.3, a master production schedule is prepared at this stage which can be realized by the rough-cut capacity plan. If the master production schedule is exaggerated and overloaded, then the MRP's priorities will be invalid and the desired result will not be achieved.

In the example problem, the manufacturing processes of the models that is given in the master production schedule in Table 6.2 are performed in the Manufacturing, Assembly and Control departments and the weekly available capacity levels are at the level of 200, 100, 50 hours / week, respectively. For each product, the required processing times (capacity list) are set as in Table 6.3.

Table 6.3 Standard Processing Times for Products

Products	Processing Time (hours / piece)		
	Manufacturing	Assembly	Control
Model A	1	0.5	0.1
Model B	2	0.3	0.1

The rough-cut capacity plan for the 8-weeks planning period for the sample problem can be seen in Table 6.4 with the capacity lists techniques by using master production schedule in Table 6.2 and the Standard Processing Time data is given in Table 6.3.

Table 6.4 Rough-Cut Capacity Plan for Sample Problem

Week	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
MPS for Model A	0	200	0	0	200	0	200	0
MPS for Model B	50	0	50	50	0	50	0	50
Required capacity for Manufacturing	100	200	100	100	200	100	200	100
Available capacity for Manufacturing	200	200	200	200	200	200	200	200
Required capacity for Assembly	15	100	15	15	100	15	100	15
Available capacity for Assembly	100	100	100	100	100	100	100	100
Required capacity for Control	5	20	5	5	20	5	20	5
Available capacity for Control	20	20	20	20	20	20	20	20

When Table 6.4 is examined, it is seen that the required capacity levels for each period is smaller than the available capacity. After this stage, MRP calculations can be made.

Material Requirements Planning

Material requirement planning is a more useful technique in the management and control of production operations when compared to other systems. The primary task of MRP is to determine when all parts and components for the products included in master production schedule should be ordered individually by going backwards from gross requirements and lead times. One of the most important reasons that the system is based on time is that each of the parts has different lead times in determining the material requirements.

important

MRP is a very useful system for the companies that assemble mixed materials and companies that want to make the material priorities and capacity control in the best way.

The main activity in the production planning and control system is the planning of material requirements. MRP is mainly based on the final product. In the MRP system, the quantities of the final products or the raw materials for each end product are calculated in detail. MRP calculations include future time. MRP determines the material requirement times by considering the timing of the deadlines.

The study that determines the time and amount of material requirements by using bill of materials, stock and order data and master production schedule is called **material requirements planning.**

The MRP system determines the priorities of the orders with the appropriate reporting method and makes the necessary updates for the timely delivery of the material. The system modifies charts in exceptional circumstances and tries to prevent delays in delivery dates.

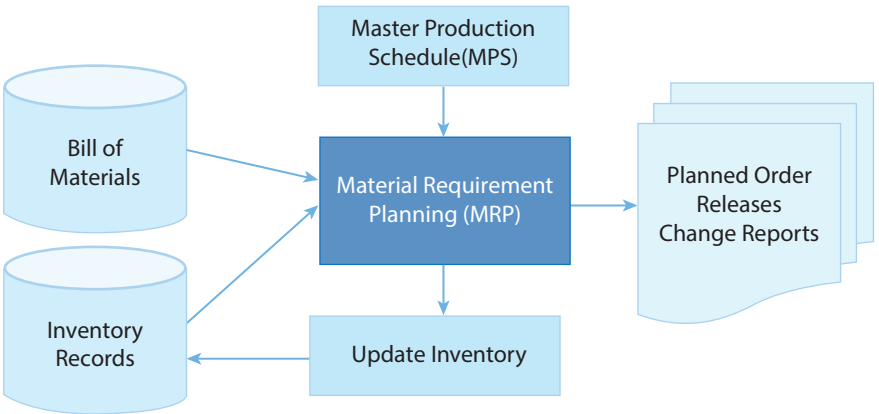


Figure 6.6 Input and Output of Material Requirements Planning System

The realization of production depends only on the availability of production resources in sufficient quantities and at the appropriate time. The MRP system is a computer-based production planning and control system element that fulfills this task. The place of this system in the integrated production planning and control system is given in Figure 6.2 schematically. The inputs and outputs of MRP are shown in Figure 6.6.

MRP collects MPS quantities, combines them with product structure information and stock records, resulting in production / purchase schedules in terms of quantity and time for each part.

The orders given to each of the actions that must be taken in order to obtain the product are called **work orders.**

According to Figure 6.6, the master production schedule, product structure information and inventory records are the main inputs of MRP; *work orders*, purchase orders and new chart reports are also the main outputs. In addition to these main outputs, users can also produce other reports from MRP systems according to their requirements.

important

Work orders that detail the daily activities of workers are prepared using MRP outputs.

Bill of Materials

In order to introduce the product structure, bill of materials or a product tree tool is used. *Bill of Materials (BOM)* is a list of materials, components and subassemblies for the production of a unit end product and their usage quantities. BOM is a list of materials; or an engineering document that includes a list of sub-assemblies, components and components that define the product and form the product. The schematic representation of the material list is called the product tree. In general, it shows the components of any product and the amount (units, kg, lt, etc.) per unit.

In a similar manner; the product tree shows all parts, semi-finished products and materials used to produce the product and the amount that is used. In general, product tree defined for any assembly or master part determines the components of the unit in question and how many units are used per part.

BOM is a record of all the components of an item, the parent–component relationships, and the usage quantities derived from engineering and process designs.

A level coding system should be used to construct the systematic structure of the material list from the final product to all subcomponents. The final product will be at level 0; level is coded so that its direct components are at level 1, and each component of any n^{th} level is located at the level (n + 1). This coding process is continued until raw materials.

Product trees may vary depending on their level, location and function. Figure 6.7 shows the product tree for Model A and Model B, which is introduced as a finished product in the sample problem.

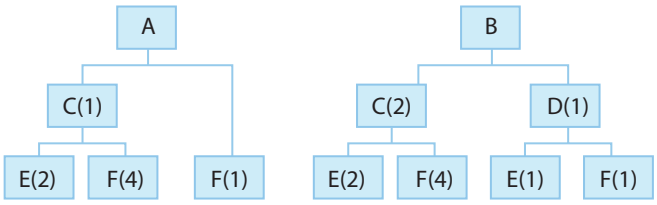


Figure 6.7 Bill of Materials of Model A and Model B in the Sample Problem

For each component at each level of the product structure, the item number, explanations about the item, the amount required for each assembly, the next level of use and the number of uses for the final product are available.

The use of a part in more than one part makes MRP operations difficult. In calculating the clear requirements for such parts, which are of common use, the total of the gross requirements arising from them should first be determined, considering all the upper parts in which the part is used.

For the sample problem, the gross requirements of the components that make up the dependent demand based on the usage amounts stated in the product trees given in Figure 6.7 are calculated as shown in Table 6.5, taking into account the MPS values given in Table 6.2. For the calculation of the values in the table, it will be appropriate to evaluate the MRP operations together with the data in Figure 6.8.

Table 6.5 Combining Gross Requirement Quantities for Dependent Demands

Weeks	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
MPS A		200			200		200	
MPS B	50		50	50		50		50
Gross requirements of component C for product A		200			200		200	
Gross requirements of component C for product B	100		100	100		100		100
Gross requirements of component D for product B	50		50	50		50		50
Gross requirements of part E for component C		500		500		500		
Gross requirements of part E for component D				100				
Gross requirements of part F for product A		200			200		200	
Gross requirements of part F for component C		1000		1000		1000		
Gross requirements of part F for component D				100				

Inventory Records

Inventory records are a set of data for all materials in the warehouse such as material entry, exit, order, supply time, availability, order quantities. Some of the materials will be in the warehouse (the stock amount at hand), and some will arrive at the warehouse within a certain delivery time (orders to be taken). The stock status information for the sample problem is given in Table 6.6.

Table 6.6 Stock Records Data for Sample Problem

Code	Part Name	Initial Inventory	Unit	Lot size and method	Lead time (week)	Scheduled receipts
A	Model A	100	Units	200 EOQ	1	
B	Model B	40	Units	50 EOQ	1	
C	Component C	100	Units	250 FOQ	1	250 (1st week)
D	Component D	50	Units	LFL	2	100 (2nd week)
E	Part E	100	Units	L4L	1	
F	Part F	100	Units	L4L	1	500 (1st week)

MRP Logic

The basic concepts used in MRP operations can be defined as follows:

- **Gross Requirement:** Gross requirements are derived from MPS data for end products from the combined requirements for other components. It indicates the estimated amount required by the end of the planning period.
- **Scheduled receipt:** Shows orders that have been ordered but not yet received for delivery at the beginning of the term.
- **Projected inventory:** Indicates the amount expected to be available at the end of the period. This value is calculated by subtracting the gross requirement values from the sum of the orders that are received at the end of the previous period and planned to be received and are to be received.
- **Net Requirement:** The net amount needed during the period. It is calculated from the gross requirements by deducting the orders to be received with the available stocks at the end of the previous period.
- **Planned receipts** It is the order of material to be given to a vendor at the beginning of the relevant period or work orders to be produced in the enterprise. This value is either equal to the net requirement value, or it is calculated based on a batch size determination.
- **Planned order release:** It is the amount of material to be ordered in the relevant period. The period that the order is to be given shall be determined by taking back the requirement from the moment of supply until the material comes in the planned period. After the orders are placed, these orders will be converted into orders to be received.

MRP determines the net requirements and planned order release of all materials. An important step in the MRP system is the transformation of gross requirements into net requirements. The net requirement values are obtained by deducting the available stock and the quantities to be received from the gross requirements.

In the MRP system, the net requirement values are determined in time. Then, the net requirements are met with the orders that are planned to be delivered. The order determined by the MRP system is given either by the same or by the appropriate *batch size*. The timing of the orders to be issued by taking lead time into account.

MRP explosion is a process that converts the requirements of various final products into a material requirements plan that specifies the replenishment schedules of all the subassemblies, components, and raw materials needed to produce final products.

Detailed operations are shown on MRP forms given in Figure 6.8.

Component C

On-hand inventory (I_o) = 100 unit Lead time = 1 week
Lot size (Q) = 250 unit (Fixed Order Quantity, FOQ)

Weeks	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Gross requirements	100	200	100	100	200	100	200	100
Scheduled receipts	250							
Projected inventory (Io=100)	250	50	200	100	150	50	100	0
Net requirements			50		100		150	
Planned receipts			250		250		250	
Planned order releases		250		250		250		

Component D

On-hand inventory (I_o) = 50 unit Lead time = 2 weeks
Lot size (Q) = 100 unit (Fixed Order Quantity, FOQ)

Weeks	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Gross requirements	50		50	50		50		50
Scheduled receipts		100						
Projected inventory (Io=50)	0	100	50	0	0	50	50	0
Net requirements						50		
Planned receipts						100		
Planned order releases				100				

Part E

On-hand inventory (I_o) = 100 unit Lead time = 1 week
Lot size (Q) = LFL (Lot for Lot)

Weeks	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Gross requirements		500		600		500		
Scheduled receipts								
Projected inventory (Io=100)	100	0	0	0	0	0	0	0
Net requirements		400		600		500		
Planned receipts		400		600		500		
Planned order releases	400		600		500			

Part F

On-hand inventory (I_o) = 200 unit Lead time = 1 week
Lot size (Q) = LFL (Lot for Lot)

Weeks	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Gross requirements		1200		1100	200	1000	200	
Scheduled receipts	500							
Projected inventory (Io=200)	700	0	0	0	0	0	0	0
Net requirements		500		1100	200	1000	200	
Planned receipts		500		1100	200	1000	200	
Planned order releases	500		1100	200	1000	200		

Figure 6.8 MRP Calculations

When examined, in Figure 6.8 it is understood that there is no problem for the applicability of material requirement planning. However, MRP should be controlled with CRP.

important

One of the most important issues in the design of the MRP system is the determination of order quantities, in other words batch sizes.

For all net requirements that will arise during the planning horizon, if there is an order for each period up to the requirement; it will be subject to repeated orders and will be subjected to the fixed cost of ordering each time.

Since the primary objective in designing any production system is to minimize costs; the number of orders must also be reduced. Accordingly, the collective provision of the order to meet the net requirements in some periods is taken into consideration; however, this also results in higher cost of holding.

The concept of **batch size** refers to the purchase order quantity for the materials to be purchased and the production work order amounts for the materials to be produced.

In this case, the aim will be to minimize the cost of ordering and the total cost of ownership. In MRP systems, there are many different methods in which we can determine batch sizes. The most common order size determination methods for MRP systems are:

- Fixed Order Quantity-FOQ
- Fixed Period Quantity-FPQ
- Lot For Lot-LFL
- Economic Order Quantity-EOQ
- Periodic Order Quantity-POQ
- Part Period Algorithm-PPA
- Part Period Balancing-PPB
- Least Unit Cost-LUC
- Least Total Cost-LTC
- Silver-Meal Heuristic SMH
- Wagner-Whitin Algorithm WWA

In MRP systems, it is inevitable to use computer in order to be able to process large volumes of data in a short time, fully and accurately. One of the most important features of the material requirement planning system is its ability to re-planning and scheduling against unforeseen changes. The material requirement planning system can predict the absence or excess of material. This ensures that measures are taken on time.

Capacity Requirements Planning

Capacity Requirements Planning (CRP) includes efforts to ensure the compatibility between an enterprise's MPS and its production capacity. CRP determines the short term and medium-term bottleneck resources according to the time axis by determining the required labor force and hardware resources for the implementation of MRP plan prepared in line with the main production program. Therefore, the results obtained after MRP need to be confirmed.

CRP supports management in the following areas:

- Design of new plant and manufacturing systems or dispatch work
- Checking whether the current capacity is sufficient to obtain a new job
- To examine the utilization levels of existing or planned facilities
- Evaluation of different routes or priority rules
- Determining the parts that are in the process and determining the facilities that are idle

The route is a record that shows which operations the part will go through in the factory in order for a production to take place. In route registers, it also provides data for capacity planning, including preparation times and standard processing times in these work centers.

The route shows the orders of business centers, and operations a product pass through.

important

Capacity Requirements Planning (CRP) uses detailed MRP outputs and production capacity requirements of products and parts.

MRP does not consider capacity when calculating production quantities for each component. Therefore, limited production capacity may be exceeded in some periods. In closed loop MRP, the information obtained from the MRP is sent to the capacity requirement planning (CRP) module; and the suitability of the charts is checked. If the capacity plan is appropriate, the obtained charts are converted into production / purchase orders for implementation. If the capacity plan is not suitable, this information is transferred to the MPS and MRP modules and necessary arrangements are made. Regulations in the MPS and MRP continue until an appropriate capacity plan is obtained.

In the sample problem, the "Order Values Planned to Be Given" in the MRP operations given in Table 6.8 show the production quantities. The manufacturing processes of the parts and products are carried out in the Manufacturing, Assembly and Control departments and the weekly available capacity levels are 200, 100, 50 hours / week respectively. The standard processing times for each product and parts are set as in Table 6.7.

Table 6.7 Standard Times for Products and Parts

Products and Parts	Processing times (hours / unit)		
	Manufacturing	Assembly	Control
A	0	0.4	0.05
B	0.25	0.05	0.01
C	0.5	0.1	0
D	0.5	0.05	0
E	0.25	0	0
F	0	0	0.01

The capacity requirement planning for the 8-week planning period for the sample problem was calculated as in Table 6.8 using the standard processing times of the products and parts given in Table 6.7.

Table 6.8 Capacity Requirement Planning Calculation Results

Week	1	2	3	4	5	6	7	8
Planned order releases for product A	0	200	0	0	200	0	200	0
Planned order releases for product B	50	0	50	50	0	50	0	50
Planned order releases for component C	0	250	0	250	0	250	0	0
Planned order releases for component D	0	0	0	100	0	0	0	0
Planned order releases for part E	400	0	600	0	500	0	0	0
Planned order releases for part F	500	0	1100	200	1000	200	0	0
Required capacity for Manufacturing	112,5	125,0	162,5	187,5	125,0	137,5	0,0	12,5
Available capacity for Manufacturing	200	200	200	200	200	200	200	200
Required capacity for Assembly	2,5	**105,0**	2,5	32,5	80,0	27,5	80,0	2,5
Available capacity for Assembly	100	100	100	100	100	100	100	100
Required capacity for Control	5,5	10,0	11,5	2,5	**20,0**	2,5	10,0	0,5
Available capacity for Control	20	20	20	20	20	20	20	20

When Table 6.8 is examined, it is seen that there is a capacity problem in the assembly workshop in the second week. In order to solve this problem, changes can be made in the master production schedule or in MRP orders. MRP cannot solve the capacity problems because it cannot edit the workloads in the workshop. Changing the master production schedule can reduce the irregular changes in capacity. However, the previous policies and batch size policies have led to an irregular change in the capacity requirements at the workshop level. Fluctuations in capacity requirements can be partially corrected by the forwarding or postponing of planned orders.

Learning Outcomes

3 To apply the basic modules of Manufacturing Resource Planning.

Self Review 3	Relate	Tell/Share
What are the functions of the basic modules in Manufacturing Resource Planning (MRP II)?	Build a relationship between inputs and outputs of Material Requirements Planning System.	Share the Bill of Materials (BOM) for an every day item such as chair or table.

ENTERPRISE RESOURCE PLANNING

Enterprise Resource Planning (ERP) is an integrated management system that enables the efficient use of resources such as labor, machinery and materials required for the production of goods and services. Enterprise Resource Planning, as a system designed to integrate all the functions of the enterprise and to use the resources efficiently, has a wide area of use in production enterprises, non-profit organizations such as foundations and government institutions. ERP aims to monitor all processes and resources of institutions.

Enterprise resource planning (ERP) is an information system designed to integrate internal and external members of the supply chain.

It is very difficult to make a clear definition of ERP. According to APICS, ERP is defined as follows; "It is an accounting-oriented information system that determines and plans to buy, manufacture, and dispatch the resources required throughout the enterprise and the enterprise to meet customer orders".

It is a known fact that customer demand is constantly changing in quality and quantity and it is difficult to predict this change. The way to make our operations able to act in accordance with this change is through ERP approach. To be able to make the company activities sensitive to change by paying attention to the goals and targets determined by strategic planning activities, and the capacity and characteristics of production and distribution resources; is only possible with an ERP approach.

Another feature of ERP is the coordinated planning of the companies' geographically diverse plants (domestic and foreign), their supplier companies and distribution centers (warehouses). ERP determines, which order of which customer should be met from which distribution center, or which factory should be produce it; where it is appropriate to meet the material and service requirements of all factories; how the production and distribution resources such as machinery, materials, labor force, energy, information can be used in coordination and jointly. In other words, the capacity and features of the distribution, production and supply resources of all affiliated companies are taken into consideration simultaneously in order to meet the customer's order as soon as possible, at the desired quality and cost.

Similarly, different factories or different production processes in different production types within the same factory require a flexible resource planning approach. ERP has a structure that can cope with these differences. It performs the integration between factories in accordance with the principle of flexibility in factories. The aim is to provide the coordination and integration between the factories in line with the basic strategies of the company while taking advantage of the central management on the basis of the factory.

As explained above, even if the company has different factories and different production processes, some functions such as design, central purchasing, storage, shipment can be common or more economical. In this case, ERP will ensure an efficient and efficient working order by ensuring coordination between the factory and production processes in question.

important

The ERP System aims to reduce procurement times and costs with an enterprise-wide understanding. It is a system where work at all levels is carried out with the idea of a single global operation.

With a proactive thinking, problems can be anticipated and the necessary measures can be taken in advance. The effects of a decision to be taken at any point can be determined in advance. The effect of a method change on the enterprise's global performance can be evaluated. Every employee can access the data he wants at any time, simplifying the management structure.

As a result, ERP is a software system that provides the most efficient and effective planning, coordination and control of procurement, production and distribution resources in different geographical regions in order to meet customer demands in accordance with strategic objectives and objectives of the enterprise.

The basic principles and systematic of planning, coordination and control are the same as MRP II (Manufacturing Resources Planning). The most striking feature of MRP II, which collects all the sections of the system such as sales, manufacturing, engineering, stock control and cash flow, is the simulator. Data integration between MRP II and administrative and production units is ensured and this integration increases coordination among groups.

Due to the reasons mentioned above, many companies are in search of a suitable system. Changes in a company that is considering implementing an ERP system evident with the search for a more appropriate package.

An ERP system provides a single interface for managing all routine activities performed in manufacturing sales customer service. In late 1990s, ERP systems were reached out to external members of the supply chain. This extension supported the customer interaction and supplier management modules. Using a single interface can provide considerable savings for the companies.

Figure 6.7 shows some of the typical applications with a few subprocesses nested within each one. Some of the applications are for back-office operations such as manufacturing and payroll, while others are for front-office operations such as customer service. The Manufacturing and Supply Chain Management modules in Figure 6.6 specifically deal with resource planning. In fact for many firms, MRP II ultimately evolved into ERP.

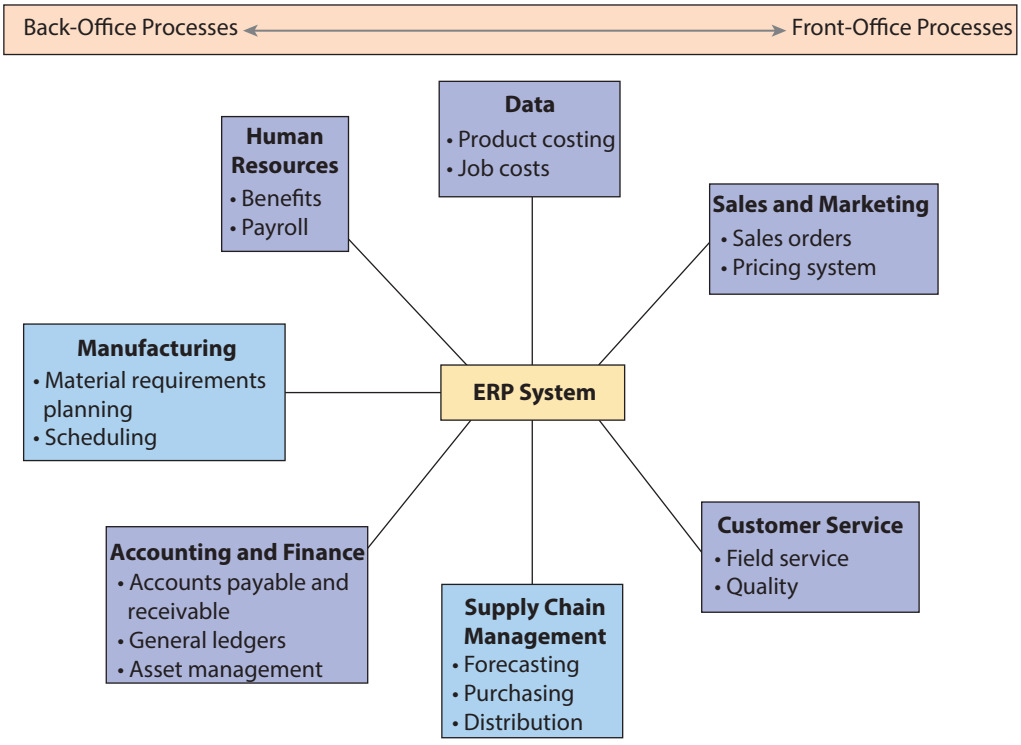


Figure 6.9 ERP System and Basic Modules (Krajewski et al., 2015)

At first, ERP was designed to handle business transactions and not to support supply chains. The second generation of ERP was redesigned to overcome this insufficiency.

The original ERP was designed to automate routine business transactions and it was very successful at that. Later the advancement of second-generation ERP frameworks has started. It aims to use existing frameworks to increase efficiency in handling transactions, to enhance decision making, and to support e-commerce.

Even though first-generation ERP systems gave planners plenty of statistics about what happened in the company, in terms of costs and financial performance, the reports were merely snapshots of the business at a single point in time. These reports did not support the nonstop planning required in in supply chain management. This insufficiency prompted the advancement of planning systems focused on decision making. These new systems are called as SCM (supply chain management) software.

SCM system is designed to improve decision making in the supply chain. It helps answer such questions as (Reid et al., 2012):

(1) What is the best way to ship a product to a specific customer?

(2) What is the optimal production plan?

(3) How much product should ship to specific intermediaries?

(4) How can outbound and inbound transportation costs be minimized?

SCM systems usually consist of decision-support modules, such as optimization and simulation to help answer these questions.

Let us think about how ERP systems and SCM software can cooperate together. Consider the task of order processing. In SCM software, the question is, "Should I take your order?" whereas, in the ERP system the approach is "How can I best take or satisfy your order?". Both are just information systems. SCM softwares support the ERP systems, contributing intelligent decision support. The SCM system is designed to overlay with existing systems and obtain information from all aspects of the supply chain. In this fashion, the company can see the clear picture of where it is headed as a substitute for having automated processes. *Supply chain intelligence (SCI)* is the capability of gathering business intelligence along the supply chain. This intelligence empowers strategic decision making by analyzing data along the whole supply chain.

Supply chain intelligence (SCI) enables strategic decision making along the supply chain.

Another choice for organizations needing ERP functions is to rent these instead of building these systems. In leased applications, the ERP provider handles the functionalities and internal integration problems. The ERP provider is commonly called as an *Application Service Provider (ASP)*. The ASP sets up the framework and operates it for the organization. This methodology frequently functions admirably for small to medium organizations. The software is often provided via the Internet.

More information about Supply Chain Management is given in Chapter 8.

Application Service Provider (ASP) sets up and runs ERP systems.

As numerous organizations associated with e-commerce have ERP frameworks, and since e-commerce needs to interface with the ERP systems, integration is fundamental, essentially for order fulfillment and collaboration with business partners.

After implementing an ERP system, the following strategic and financial benefits were noted:

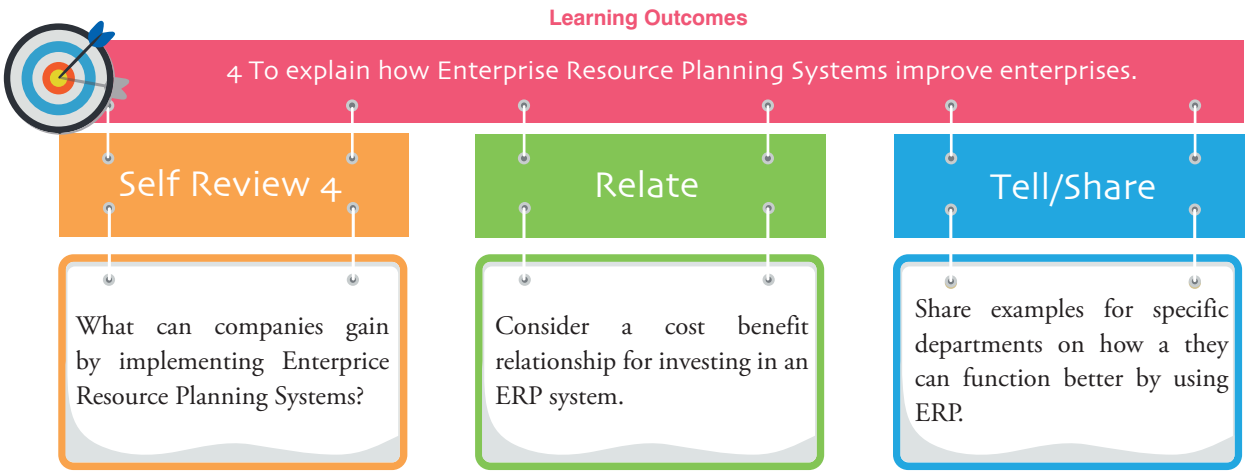
- elimination of redundant financial systems;
- improved timeliness and accuracy of key reports;
- improved vendor relations and increased negotiating power;
- improved visibility;
- compliance with the latest government reporting requirements;
- more staff time for value-added tasks; and
- increased vendor payment discounts.

One advantage of ERP is that it coordinates the total scope of an association's activities so that it exhibits a holistic perspective of the business functions from a single information and IT architecture. This single information source improves the organizational data stream. In the light of improved data stream, an association builds its capacity to consolidate best practices that facilitate better managerial control, faster decision making, and cost cuts throughout the organization. The essential design of an ERP system rests upon a single database, one application, and a unified interface across the entire enterprise, thus allowing an integrated approach.

ERP provides both tangible and intangible advantages for a company. Tangible advantages can be listed as: decreases in inventory and staffing, increased productivity, improved order management, quicker closing of financial cycles, reduced IT and purchasing costs, improved cash flow management, increased revenue and profits, reduced transportation and logistics costs, and enhanced on-time delivery performance. Intangible advantages result from the improved visibility of corporate data, enhanced customer responsiveness, better integration among systems, standardization of the computer platforms, improved flexibility, worldwide information sharing, and better visibility into the supply chain management process.

By utilizing this software, manufacturers would now be able to improve supply chain activities by observing, managing, and optimizing their internal and external activities. For instance, manufacturers can contact promptly with suppliers and shippers in real time and can analyse the supply chain. Furthermore, manufacturers can acquire reports that examine effectiveness and estimate potential issues.

An enterprise process is a company wide process that cuts across functional areas, business units, geographic regions, product lines, suppliers, and customers. Enterprise resource planning (ERP) systems are huge, integrated information systems that support many enterprise processes and data storage needs. By integrating the firm's functional areas, ERP systems allow an organization to view its operations as a whole rather than having to try to put together the different information pieces produced by its various functions and divisions. Today, ERP systems are being used by traditional brick-and-mortar organizations such as manufacturers, restaurants, hospitals, and hotels, as well as by Internet companies that rely extensively on Web connectivity to link their customers and suppliers (Reid et al., 2012).



Further Reading

Cloud ERP vs. On-Premise ERP

When selecting a new enterprise resource planning (ERP) system, one of the most critical factors in your decision will be whether you choose to deploy it on-premise or in the cloud.

Cloud-based ERP systems are more common than ever before. Today, nearly every ERP vendor offers some form of cloud deployment option, and some have ditched their on-premise offerings altogether.

But there are still several reasons why a small or midsize business might choose a traditional on-premise system, which, until recently, was the norm in the ERP space. Which one is right for your organization? Well, only you can make that decision, but this rundown on the pros and cons of each should make it easier.

The biggest difference between these two systems is how they are deployed. Cloud-based software is hosted on the vendor's servers and accessed through a web browser. On-premise software is installed locally, on a company's own computers and servers. Some vendors also offer "hybrid" deployments, in which cloud software is hosted on an organization's private servers.

Another key difference between cloud and on-premise solutions is how they are priced:

While there are many exceptions to this rule, in general, cloud software is priced under a monthly or annual subscription, with additional recurring fees for support, training and updates.

On-premise software is generally priced under a one-time perpetual license fee (usually based on the size of the organization or the number of concurrent users). There are recurring fees for support, training and updates.

Thus, on-premise systems are generally considered a capital expenditure (one large investment upfront). Cloud-based systems, on the other hand, are typically considered an operating expenditure.

Cloud software's low cost of entry -especially compared to hefty upfront perpetual license fees- has contributed to its widespread adoption. According to one recent study, 93 percent of enterprises currently use cloud-based software or system architecture, and use of hybrid cloud systems increased from 19 percent to 57 percent in one year. Over time, however, system costs tend to converge.

Security is often the top concern for prospective ERP buyers. Small wonder, considering the critical the information stored in an ERP system—including company financials, corporate trade secrets, employee information, client lists and more. But while buyers once were wary about the security of cloud-based software, many are becoming less skeptical today (evidenced by the adoption rates above).

Reputable cloud vendors have strict standards in place to keep data safe. To further ease concerns, prospective buyers can seek a third-party security audit of a vendor they're considering. This can be especially useful if the vendor is less well-known.

Most cloud systems enable easy mobile accessibility, and many even offer native mobile apps. But this ease of access also comes with greater security considerations, especially if employees are accessing company files on their personal mobile devices.

Similarly, more accessibility means less customization—and cloud ERPs offer less flexibility for businesses that seek to tailor their system to their hearts' content. But organizations with less specialized needs, such as general consulting firms, can get by just fine with a cloud system's out-of-the-box capabilities.

Cloud ERPs are therefore best suited for small and midsize businesses seeking lower upfront costs, system stability and ease of access.

You'll typically find many of the same features in an on-premise ERP system. However, there are a few notable differences in the two deployment strategies.

In general, on-premise systems are much easier to modify. The ability to customize to their specific needs and requirements is paramount for many organizations, especially in niche industries, such as specialized manufacturers with unique processes.

On-premise ERPs put more control in the hands of the organization, up to and including the security of its data. It's therefore essential that a business be capable of safeguarding an ERP's most sensitive information—a frequent target of cyber criminals.

Mobile accessibility can pose an issue for on-premise deployments. These often require a third-party client to communicate between a mobile device and the on-premise software. It's definitely not an insurmountable problem, but it can be a pain point.

On-premise ERPs are therefore best suited for larger enterprise businesses with higher budgets; a desire to customize system operations; and the existing infrastructure to host, maintain and protect its ERP data.

When it comes to choosing a new ERP system, there are more ERP options than ever for businesses of all sizes. Cloud-based deployment models have made this software more accessible for SMBs—though these systems come with a few drawbacks, such as more limited customization and potential security concerns.

Conversely, on-premise ERP systems offer advantages in customization and control, but are more expensive upfront, and many don't support mobile. This can be problematic for smaller buyers but, as is usually the case, it depends on the specific needs of the individual business.

Source: Z Hale, 2018, October 4.

Summary

LO 1 Learn Resource Planning terms and explain its importance.

The objectives of the Manufacturing Resources Planning (MRP II) system can be summarized as; reduction of stocks, good control and planning of production in a way not to cause loss of capacity, improvement of customer service, reduction of overall costs, better control of production, and discipline, increase in product quality and thus increase efficiency in general.

LO 2 Describe the evolution of the Manufacturing Resource Planning.

MRP systems became popular in 1960s when computers began to be used in manufacturing management. Then, in the 1970s, closed loop MRP including functions such as capacity planning and sales, and then MRP II systems began to spread rapidly. In the 1980s, MRP II became widespread and developed due to the development of information technologies. In line with the need to ensure the harmonious functioning of these systems and the need for new functions such as human resources, quality management, integrated systems, called ERP, have emerged from the beginning of 1990s, collecting all these functions under a modular but also integrated system. To sum up, MRP, which started with the material lists in the 1960s, continued its journey with the Closed Cycle MRP which emerged in the 1970s with technological developments. The MRP II concept emerged in the late 1970s and early 1980s as a system that integrated the main functions of a company, such as logistics, production, finance, distribution and auditing on a single database, over the basic skill of MRP to coordinate production plans. On the other hand, global integration of business activities in different geographical regions has become mandatory with the effect of globalization winds that have emerged in recent years and a transition from MRP II to ERP has been experienced.

LO 3 Apply the basic modules of Manufacturing Resource Planning.

The MRP system is based on the principle of finding the amount and time of the item or material to be ordered by going back from the table which contains the completion dates and quantities of the final product. MRP produces workshop orders and orders for purchase, based on demand forecasts and customer orders; and according to the master production schedule and the components in the bill of materials. While the work order is given to the workshop, the material for this production is allocated. According to the work order, work pieces are pushed through the workshop regardless of the condition of the next process. MRP does not consider capacity when calculating production quantities for each component. Therefore, limited production capacity may be exceeded in some periods. In closed loop MRP, the information obtained from the MRP is sent to the capacity requirement planning (CRP) module; and the suitability of the charts is checked. If the capacity plan is appropriate, the obtained charts are converted into production / purchase orders for implementation. If the capacity plan is not suitable, this information is transferred to the MPS and MRP modules and necessary arrangements are made. Regulations in the MPS and MRP continue until an appropriate capacity plan is obtained.CRP uses detailed MRP outputs and production capacity requirements of products and parts.

LO 4 Explain how Enterprise Resource Planning Systems improve enterprises.

Enterprise Resource Planning (ERP) is an integrated management system that enables the efficient use of resources such as labor, machinery and materials required for the production of goods and services in enterprises. Enterprise Resource Planning, as a system designed to integrate all the functions of the enterprise and to use the resources efficiently, has a wide area of use in both production enterprises and non-profit organizations such as foundations and government institutions. ERP aims to monitor all processes and resources of institutions.

It is a known fact that customer demand is constantly changing in quality and quantity and it is difficult to predict this change. The way to make our operations able to act in accordance with this change is through ERP approach. To be able to make the company activities sensitive to change by paying attention to the goals and targets determined by strategic planning activities, and the capacity and characteristics of production and distribution resources; is only possible with an ERP approach.

Another feature of ERP is the coordinated planning of the companies' geographically diverse plants (domestic and foreign), their supplier companies and distribution centers (warehouses). ERP determines, which order of which customer should be met from which distribution center, or which factory should produce it; where it is appropriate to meet the material and service requirements of all factories; how the production and distribution resources such as machinery, materials, labor force, energy, information can be used in coordination and jointly. In other words, the capacity and features of the distribution, production and supply resources of all affiliated companies are taken into consideration simultaneously in order to meet the customer's order as soon as possible, at the desired quality and cost.

Test Yourself

1 What is the **most important** component for the Manufacturing Resource Planning system in a manufacturing enterprise?

a. Resource planning (RP)
b. Master Production Schedule (MPS)
c. Bill of Materials (BOM)
d. Material Requirements Planning (MRP)
e. Rough Cut Capacity Planning (RCCP)

2 Which technique has been made possible by the emergence of the closed loop MRP system?

a. Resource planning (RP)
b. Master Production Schedule (MPS)
c. Bill of Materials (BOM)
d. Manufacturing Resource Planning (MRP II)
e. Capacity Requirements Planning (CRP)

3 Which one of the following systems is used for the abbreviation of MRP II?

a. Manufacturing Resource Planning
b. Master Production Schedule
c. Bill of Materials
d. Material Requirements Planning
e. Rough Cut Capacity Planning

4 Which one of the following **is not** the main input of the Master Production Schedule (MPS)?

a. Customer orders
b. Material Requirements Plan
c. Production and sales plan
d. Inventory records
e. Forecasted demand

5 Which one of the following **is not** a primary input of Material Requirements Planning (MRP)?

a. Capacity Requirements Planning (CRP)
b. Master Production Schedule (MPS)
c. Bill of Materials (BOM)
d. Inventory records
e. Product tree

6 Which one of the following is the main output of Material Requirements Planning (MRP)?

a. Production and purchase orders
b. Product tree
c. Bill of Materials (BOM)
d. Orders received
e. Master Production Schedule (MPS)

7 Which one of the following is correct for orders planned to be given?

a. It is the sum of the available stock level and net requirements.
b. It is obtained by deducting orders that are planned to be received from net requirement value.
c. It is the sum of the gross requirements and the orders placed.
d. Stock level at hand and scheduled orders to be received.
e. It is obtained by timing the order which is planned to be received by taking into consideration the supply time.

8 Which one of the following **is not** a method of determining the size of a lot.

a. Fixed Order Quantity (FOQ)
b. Economic Order Quantity (EOQ)
c. Part-Period Algorithm (PPA)
d. Supply Chain Management (SCM)
e. Lowest Unit Cost (LUC)

9 Which one of the following is the **basic** input of Capacity Requirements Planning (CRP)?

a. Customer orders
b. Materials Requirements Planning (MRP)
c. Bill of Materials (BOM)
d. Master Production Schedule (MPS)
e. Rough Cut Capacity Planning (RCCP)

10 Which one of the following **is not** the financial and strategic benefit of ERP system?

a. Elimination of redundant financial systems;
b. Improved timeliness and accuracy of key reports;
c. Improved vendor relations and increased negotiating power;
d. Improved visibility
e. Decreased vendor payment discounts

1. d	If your answer is wrong, please review the "Manufacturing Resource Planning" section.	6. a	If your answer is wrong, please review the "Basic Modules in MRP II and Applications" section.
2. e	If your answer is wrong, please review the "Manufacturing Resource Planning" and "The Evolution of MRP II" section.	7. e	If your answer is wrong, please review the "Basic Modules in MRP II and Applications" section.
3. a	If your answer is wrong, please review the "Manufacturing Resource Planning" and "The Evolution of MRP II" section.	8. d	If your answer is wrong, please review the "Basic Modules in MRP II and Applications" section.
4. b	If your answer is wrong, please review the "The Evolution of MRP II" section.	9. b	If your answer is wrong, please review the "Basic Modules in MRP II and Applications" section.
5. a	If your answer is wrong, please review the "Basic Modules in MRP II and Applications" section.	10. e	If your answer is wrong, please review the "Enterprise Resource Planning" section.

self review 1

What is the aim of Manufacturing Resource Planning (MRP II)?

Manufacturing Resource Planning (MRP II) is an integrated series of planning techniques developed to ensure the efficient use of all resources such as materials, machinery, money and people. MRP II consists of tools that utilize information to provide the senior management a better decision-making process. MRP II aims to keep required amount of resources at the time and place they are needed, in order to increase the efficiency of the production.

The objectives of the Manufacturing Resources Planning (MRP II) system can be listed as: reduction of stocks, good control and planning of production in a way not to cause loss of capacity, improvement of customer service, reduction of overall costs, better control of production, and discipline, increase in product quality and thus increase efficiency in general.

self review 2

What are the milestones in the development of the Manufacturing Resource Planning?

MRP, is a technique developed to determine when and how much of material or part is to be supplied in accordance with the master production schedule. MRP systems became popular in 1960s when computers began to be used in manufacturing management.

Later, more efficient system called "Closed Loop MRP" (CL-MRP) was developed in order to overcome some of the inadequacies. In the 1970s, the closed loop MRP allowed the Master Production Schedule (MPS) to be changed with a feedback scheme.

Then closed loop MRP included functions such as capacity planning and sales, and formed MRP II systems. In the 1980s, MRP II became widespread and developed due to the development of information technologies.

With the need to ensure the harmony of these systems and arising need for new functions such as human resources, quality management, a new integrated system called ERP emerged in the beginning of 1990s.

Suggested Answers for "Self Review"

What are the functions of the basic modules in Manufacturing Resource Planning (MRP II)?

self review 3

Basic modules in Manufacturing Resource Planning MRP II are:

Production and After Sales Planning: The process of planning the amount and timing of output in the medium to long term by regulating production speed, workforce size, inventory and other controllable resources.

Master Production Schedule (MPS): Process of preparing a schedule to show the date and amount of all materials to be sold or to be produced within a certain planning horizon.

Rough Cut Capacity Planning (RCCP): Determining the level of capacity required to perform the scheduled production, comparing it with the available operational capacity, and planning the necessary arrangements in capacity levels or production schedules.

Material Requirements Planning (MRP I): The study that determines the time and amount of material requirements by using bill of materials, stock and order data and master production schedule.

Capacity Requirements Planning (CRP): Determining the level of capacity required to perform the scheduled production, comparing it with the available operational capacity, and planning the necessary arrangements in capacity levels or production schedules.

What can companies gain by implementing Enterprise Resource Planning Systems?

self review 4

Enterprise Resource Planning (ERP) is an integrated management system that enables the efficient use of resources such as labor, machinery and materials required for the production of goods and services in enterprises. Enterprise Resource Planning, as a system designed to integrate all the functions of the enterprise and to use the resources efficiently. ERP aims to monitor all processes and resources of institutions.

It is a known fact that customer demand is constantly changing in quality and quantity and it is difficult to predict this change. To make the company activities sensitive to change by paying attention to the goals, strategic plans, distribution resources capacity and characteristics of production is possible only with an ERP approach.

Another feature of ERP is the coordinated planning of the companies' geographically diverse plants (domestic and foreign), their supplier companies and distribution centers (warehouses).

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Chapter 7 Lean Systems

After completing this chapter, you will be able to;

Learning Outcomes

1. Express the history and principles of lean systems
2. Explain the enemies of lean systems
3. Discuss the philosophy of lean systems
4. Identify the tools and techniques in lean systems

Chapter Outline

Introduction
History and Principles of Lean Systems
Enemies of Lean Systems
Lean Systems Philosophy
Tools and Techniques in Lean Systems

Key Terms

Lean Systems
Value
Waste
Kaizen
Just-in-Time
Total Quality Management

INTRODUCTION

In today's competitive environment, firms need to deliver more value to their customers with fewer resources. Lean systems have the objective to maximize customer value while minimizing waste. A lean system designs its processes to continuously increase customer value with the ultimate goal to achieve perfect value with zero waste. Eliminating waste over the whole business creates a system that requires less effort, less space, less time and less costs with fewer defects, compared to traditional systems. Firms that apply the lean systems approach can become more competitive by being able to respond to changing customer requirements with higher variety, higher quality, lower cost and fasterthroughout times. Lean systems approach is a way of thinking rather than a simple tactic or a program.

Lean approach is commonly applied in manufacturing systems, however, it is suitable for every type of business and process, such as service systems including healthcare, finance, etc. Even though lean systems approach started with the Toyota production system over 70 years ago, it is widely adopted today across various industries all over the world.

HISTORY AND PRINCIPLES OF LEAN SYSTEMS

Lean systems are built on the principle of defining value from the viewpoint of the customer, and they aim to continually improve their system by eliminating every waste that does not contribute to the value of the product. Lean tries to improve value with less work to provide perfect value to the customer with a perfect value creation process with zero waste (Skhmot, 2017). Lean systems focus on producing exactly what the customer wants, when the customer wants with less resources.

Lean systems are built on the principle of defining value from the viewpoint of the customer, and they aim to continually improve their system by eliminating every waste that does not contribute to the value of the product.

"Continuous improvement" and "respect for people" are the two main pillars of lean systems. Lean systems always aim to design better processes and search for improvement. The concept of "kaizen", which means continuous improvement, has a very important place in lean systems. Lean philosophy also includes respect for people. It aims to benefit from human potential by including workers in decision processes and caring about their ideas in order to improve their work. Leaders of lean systems often spend their time advising and actively working with their workers to identify problems and to improve their systems by eliminating wastes.

History of Lean Systems

Lean systems are derived from the Toyota Production System (TPS) in the middle of the 20th century. However, in order to understand lean systems, we should go back to the beginning of the 20th century, at which time the mass production system was developed by Henry Ford. Ford designed a mass production system that involves continuous movement of elements through the production process, which was very successful and allowed the Ford Motor Company to produce millions of cars in a very short time.

Toyota was founded in 1926 by Sakichi Toyoda. Several years later, in 1950, Eiji Toyoda visited the largest Ford facility in Michigan, USA, which was producing almost 8,000 cars per day, while Toyota was producing only 2,500 cars per year at that time. After his visit, Eiji Toyoda decided that the Ford's mass production system is not suitable for Toyota since Japanese market was too small and diverse for mass production. In addition, the customers of Toyota were demanding a high variety of cars from compact cars to luxury vehicles. Mass production system was focusing on the amount of production rather than customer expectations.

In order to develop a new system that is more suitable to Toyota, they collaborated with Taiichi Ohno and concluded that through a new system, they can make products faster, lower in cost, higher in quality and higher in variety. Ohno developed new ideas that became known as the Toyota Production System, which is later also named as the Lean System.

Toyota Production System was built on two concepts: Jidoka and Just-in-Time. Jidoka is about

quality at source and means "automation with a human touch", requiring that when a problem occurs, process should be automatically stopped to prevent defective products to be produced. On the other hand, Just-in-Time requires each process to be done only when it is needed by the next process in a continuous flow. Just-in-Time approach aimed to minimize inventories by producing what is needed at the exact time when it is needed.

important

Toyota Production System was built on two concepts: Jidoka and Just-in-Time.

Ford's mass production system was designed to produce a few types of products with large quantities. However, TPS was designed to handle product variety and it was much easier to make changes in the products or processes depending on customer needs. They developed new approaches to decrease the setup and changeover times in production that allowed them to be much more flexible. They could produce small batches of multiple types of products and apply Just-in-Time principles. Thus, Toyota became much more successful in satisfying customer needs and increased their sales significantly in a very short time. Different than Ford's mass production system, TPS also focused on the workers and cared about their thoughts and cooperative efforts. They designed a "Team Development" approach to improve the processes and the quality of production. A comparison of Ford and Toyota production systems are shown in Table 7.1.

Table 7.1 A comparison of Ford and Toyota production systems

	Ford System	Toyota System
Production Planning	Based on forecasts	Based on customer orders
Production System	Push	Pull
Inventory	High	Low
Setup Times	Long	Short
Production Quantity	Large batches	Small batches
Inspection	Done by managers/controllers	Done by workers
Worker authority/responsibility	Low	High
Flexibility	Low	High

Using these concepts, Toyota was able to produce high quality products efficiently and quickly that will satisfy customer requirements. After the success of Toyota, these principles and lean thinking ideas spread over to many other companies all over the world.

Principles of Lean Systems

Five main principles of lean systems, which were first introduced by Womack et al. (1990), are stated as: value, value stream, flow, pull and perfection, as shown in Figure 7.1.

Figure 7.1 Five Main Principles of Lean Systems (Lean Enterprise Institute, n.d.)

important

Five main principles of lean systems are: value, value stream, flow, pull and perfection.

Value: Lean systems approach starts with understanding the value of products and services for the customers. Value is defined by what the customer is willing to pay for. Companies need to apply different methods to understand what their customers want. Womack and Jones (2003) state that: "The critical starting point for lean thinking is value. Value can only be defined by the ultimate customer. And it's only meaningful when expressed in terms of a specific product (a good or service, often both at once) which meets the customer's needs at a specific point in time." Value needs to be specified from the end customer's standpoint and it also defines the price. Then, the companies need to focus on eliminating waste to deliver the value that the customer expects at lowest cost and highest profitability.

Value Stream: *Value stream* is the combination of all steps and processes over the entire life cycle of products or services, from the raw materials until the delivery of the end result to the customers. In order to apply lean systems approach, the value stream should be accurately and completely understood. Mapping the value stream as a diagram might be the best way to understand it. Each step and process in the transformation of the product or service can be traced and analyzed through the map of the value stream. Each process needs to be analyzed to determine what value it adds to the product. As a result of the analysis of the value stream, many steps will be found to create value. But, there will also be many steps that creates no value and every step that does not add value is defined as a waste and needs to be eliminated, if possible. However, some of these steps cannot be eliminated under the current technology, even though they are also defined as waste.

Value stream is the combination of all steps and processes over the entire life cycle of products or services.

Flow: *Flow* is the creation of a chain of value adding steps with no interruption between the processes. In a flow setting, each activity should be fully in line with the others and value-creating steps should be sequenced tightly one after the other, so that the product flows smoothly from the beginning to the end customer. If the value adding steps do not move forward at any point, it leads to the creation of waste.

Flow is the creation of a chain of value adding steps with no interruption between the processes.

Pull: In a flow setting, pull principle states that nothing should be made until it is needed by the next step. The classical push systems, such as Ford's mass production system, was focused on making production in large quantities. However, pull principle requires that no process should be made ahead of time and all inventories should be eliminated. All production should be done in a synchronized setting such that each process should be completed exactly when it is needed by the next step. This principle is related to the Just-in-Time idea. In this system, products are not built in advance and expensive inventory costs are eliminated. In addition, customer expectations can be better met since production is only started after the customer gives the order and products can be produced according to customer specifications. However, this system requires great flexibility in the production process and efficient ways of communication and thus the production system should be designed accordingly.

Perfection: Perfection principle aims to reach to a perfect system that satisfies the customer expectations completely by producing the highest quality products in a very short time at a very low cost by eliminating all waste from the system. After the four steps defined above are accomplished, these steps should be re-applied over and over again until a system with perfect value is created with no waste. Lean approach propose continuous improvement, also called Kaizen, such that the system is perfected over time.

Kaizen (Continuous Improvement)

Kaizen is a Japanese term for continuous improvement and has an important place in lean systems. It proposes to continually improve activities, processes and products to satisfy customer needs. It focuses on value-added activities and aims to eliminate waste. Kaizen requires all employees at all levels of the company work together to improve the system. Kaizen essentially uses a strategy composed of 4 phases known as the PDCA cycle: Plan (P), Do (D), Check (C), Act (A) as shown in Figure 7.2.

Kaizen is a lean principle that means continuous improvement.

Plan: In this phase the problem or the improvement opportunity is identified and analyzed. In this step, the current situation is analyzed, objectives are clearly determined, solution alternatives are identified, and a plan is made to improve the system.

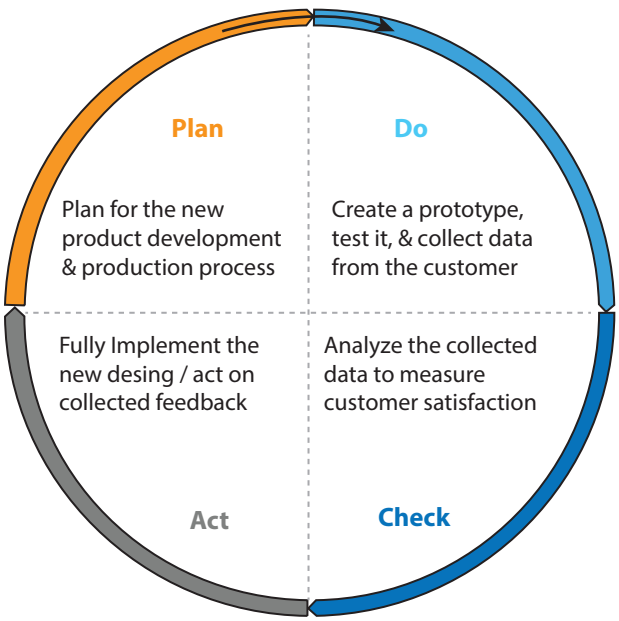

Figure 7.2 PDCA Cycle (Citoolkit, n.d.)

Do: In this phase, potential solutions are implemented and tested on a small scale of the real system and data is collected about the results.

Check: In this phase, the collected data and the results are analyzed and their effectiveness are measured. Unexpected issues and their causes are also identified in this step, and key learnings are obtained. Do and Check steps might be repeated many times until the expected results are obtained and determined objectives are reached. The best solution is decided as a result of Check phase.

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In a PDCA cycle, Do and Check steps might be repeated many times until the expected results are obtained and determined objectives are reached.

Act: In this phase, the decided solution is implemented on a full scale and this level is used as the new standard. Standardizing, documenting, integrating it into the organization's system and sustaining the improved process are also applied in this step.

After the Act phase, new improvement opportunities are identified and the PDCA cycle is started again at the Plan phase for continuous improvement. PDCA cycle is also known as "Deming Wheel" or "Shewart Cycle" since it is defined by Shewart and developed by Deming later on.

Kaizen strategy is based on many, small improvements rather than radical changes that generally arise as a result of Research & Development. Small improvements generally do not require high capital investments and thus they are easier to be accepted by the managers and implemented in a fast manner. A successful implementation of Kaizen requires the participation of workers. Generally a group of 6-8 workers is formed and they meet regularly over a short period of time. Improvement ideas are expected to come from the workers themselves, thus all employees should continually seek ways to improve the system. This strategy encourages workers to own their work and strengthens teamwork. It also improves worker motivation. Since workers take place in this process from beginning to the end, it makes the acceptance and implementation of the solution much easier at the factory floor.

In a typical Kaizen study, generally the current process is analyzed first by a group of workers using different techniques. A problem, waste or defect is identified and objectives are determined. Then, improvement ideas are developed and immediate action is taken if these ideas are accepted by the managers. The benefits of the study are measured by comparing the improved system results with the previous system. Then, new problems or improvement opportunities are searched with the objective of continuous improvement.

Learning Outcomes

1 To express the history and principles of lean systems

Self Review 1	Relate	Tell/Share
What are the main principles of lean systems?	Associate value and customer with each other.	Share an improvement that can be considered as Kaizen in your life.

ENEMIES OF LEAN SYSTEMS

Lean systems have three types of enemies that cause inefficient use of resources. These three types are named as Muda (waste), Mura (unevenness) and Muri (overburden), also called 3Ms of lean systems.

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3Ms of lean systems; Muda (waste), Mura (unevenness) and Muri (overburden) are the main factors that cause inefficient use of resources, and should be eliminated.

Muda (Waste)

Lean systems aim to eliminate waste (*Muda*), which is defined as anything that does not add value for the customer. Some activities that do not directly add value to the product might be necessary, such as inspection and safety testing. These activities are also considered as Muda. However, more importantly, there are several non-value added activities that are also unnecessary for the customer and they should be eliminated. Originally, 7 types of such waste were defined by Taiichi Ohno as Defects, Transportation, Overprocessing, Overproduction, Inventory, Waiting, and Motion. These 7 types of waste are shown in Figure 7.3 and explained in detail below.

Figure 7.3 Seven wastes in Lean Systems (Kanbanize, n.d.)

Muda (waste) is anything that does not add value for the customer.

important

7 types of waste were defined originally by Taiichi Ohno as: Transportation, Inventory, Motion, Waiting, Overproduction, Overprocessing and Defects.

Defects: Defects are incurred when the final product does not meet the customer specifications. In such cases, a loss of value and a waste happens due to the scrap, repair, or rework of the product. These processes cause additional costs in the system. Quality problems in the production, excessive variation in processes, high inventory levels, inappropriate equipment, insufficient training or workers, or damages that happen during transportation and handling are the main reasons of defect waste. In order to eliminate this waste, all these reasons should be eliminated and processes should be designed so that they do not lead to defects.

Standardized and consistent processes should be used with lower variations. In addition, a system that can detect abnormalities in the production process as soon as possible should be developed.

Transportation: Unnecessary movements of products, materials, tools, inventory, equipment, etc. are considered as the *transportation waste*. These movements do not add any value to the product and lead to unnecessary work, loss of effort and time, and also can cause damages to the products. In order to avoid such waste, several measures can be applied such as developing a U-shaped production line, locating facilities that have more interactions closer to each other, creating flow between processes, avoiding unnecessary handling of materials, decreasing work-in-process inventories etc.

Unnecessary movements of products, materials, tools, inventory, equipment, etc. are considered as the **transportation waste.**

Overprocessing: *Overprocessing* means doing more than what the customer requires. Adding more components to the product, doing more work than required, or having more steps in a product or service are considered as overprocessing since these operations are not wanted by the customer and thus they have no value for the customer. Some examples are running more analysis than needed, using a higher precision equipment than necessary, having more functionalities in a product than needed, generating more detailed reports than needed, requiring unnecessary signatures or more forms than needed (Skhmot, 2017). In order to avoid overprocessing, all the requirements should be understood from the customer's standpoint and production should be done to the level of quality and expectation of the customer.

Overprocessing means doing more than what the customer requires.

Overproduction: Overproduction is producing more than, faster than or before than it's needed. Overproduction causes high inventory costs, high lead times, wastage, prevents smooth flow of work and hides defects. Instead of overproduction, lean systems approach utilizes the Just-in-Time strategy such that all the production is done only when it is needed at the exact quantity that is needed. There are also several other strategies to avoid overproduction such as using the "Takt Time" to ensure evenness between the rates of manufacturing at different stations. In addition, reducing setup times to be able to produce in small batches, or using a pull or "Kanban" system to control the amount of work-in-process can help to avoid overproduction.

Inventory: All inventory that is more than necessary for a steady production flow in a Just-in-Time manner is considered as waste. Excess inventory can cause many problems such as higher lead times, damages to the products and inefficient allocation of capital. In addition, inventories hide the problems in the production process and cause the problems to continue without being solved. Inventory waste is mainly caused by overpurchasing, overproduction, inaccurate forecasting, inefficient or unbalanced processes, long setup times or poor inventory planning. In order to avoid inventory waste, Just-in-Time strategy should be applied effectively and buffers between processes should be reduced.

Waiting: Waiting refers to any idle time during the production of a product. Idle machines or workers waiting for material or equipment, production bottlenecks or production waiting for operators are considered as the waiting waste, which is generally caused by the lack of synchronization between the processes. Waiting can also be caused by long setup times, machine breakdowns, inconsistent work methods or lack of proper equipment or materials. In order to avoid waiting waste, processes should be designed as a continuous flow, workloads should be leveled by standardized work instructions, and flexible multi-skilled workers should be used.

Motion: Motion waste is defined as any unnecessary movement of people that doesn't add value to the product including walking, lifting, reaching, bending, stretching, and moving types of wastage. Motion waste is generally caused by inappropriate facility layouts and poor

organization of the workplace. In order to avoid the motion waste, the workplace should be organized such that movement requirements are minimized, equipments should be placed close to the production location and materials should be located ergonomically to reduce reaching, bending or stretching requirements.

Any unnecessary movement of people that doesn't add value to the product including walking, lifting, reaching, bending, stretching, and moving, are considered as the **Motion waste.**

In addition to the original seven types of waste as stated above, it should be noted that, later on, additional types of waste are also defined such as unutilized talent or skills of workers, unused resources, space or by-products of the processes.

Mura (Unevenness)

Mura means unevenness and imbalance of processes. Inconsistency between the activities, or non-uniformity and irregularity of the processes cause Mura, and Mura causes the wastes stated above. For example, in a production environment, if the capacity of one station is less than the others, a bottleneck occurs there, overproduction and accumulation of excess inventory is observed at the previous stations while waiting is observed at the next stations. In addition, some of the excess inventory might need to be transported to other locations due to space limitations and these excess inventory can be damaged during the handling process causing defects. All of these wastes of inventory, overproduction, waiting, defects and transportation are caused by the unevenness in the system. Lean systems aim to balance the workloads so that there is no Mura leading to waste. In order to avoid Mura, Takt Time, Just-in-Time, Kanban and other pull-based strategies can be utilized.

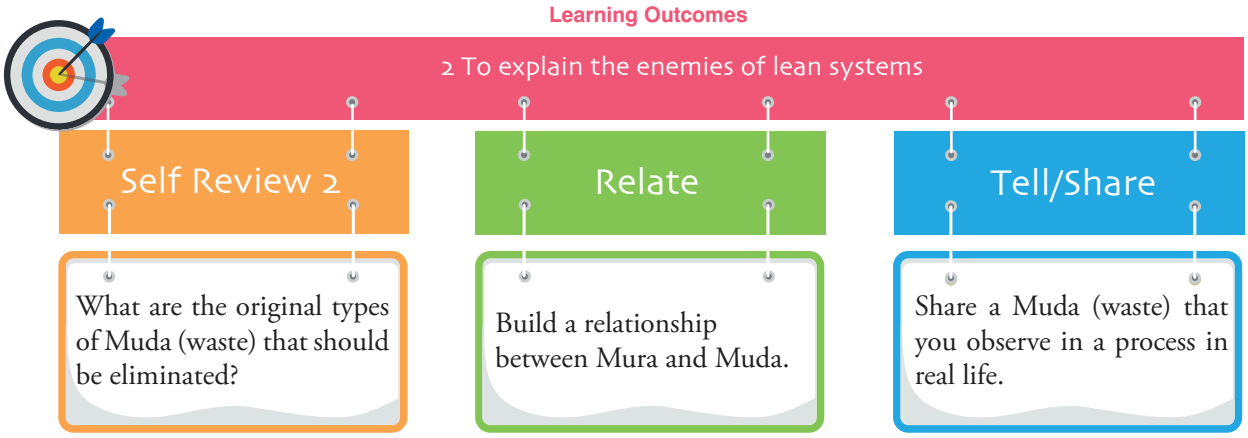
Muri (Overburden)

Muri is to cause overburden, meaning to give excessive or unreasonable work beyond one's power, causing unnecessary stress to workers. Muri can be caused by Mura such that uneven workloads can cause some workers to be overburdened. Also, other problems in the system, such as lack of training, undefined or unclear work instructions, inappropriate work assignments, excessive performance measures etc. can cause Muri. Muri is also observed when workers or machines are utilized over their capabilities to complete a task. Muri may result in worker absenteeism, fatigue, illness, problems in worker health, work accidents and breakdowns of machines. In order to avoid Muri, activities should be standardized and workloads should be evenly distributed according to worker capabilities.

Muri is to cause overburden, meaning to give excessive or unreasonable work beyond one's power, causing unnecessary stress to workers.

Lean systems approach aims to eliminate Muda, Mura and Muri and the first step to reduce these wastes is to recognize their existence. There are many tools and techniques in lean systems that aim to identify and eliminate waste. Value stream mapping can be used to analyze the current system to identify the value-added activities, non-value-added activities and wastes. All the processes should be looked over with the customer requirements in mind and a plan should be developed to eliminate all unnecessary activities that do not add value for the customer.

However, it should also be noted that completely eliminating 3Ms might not be realistic. For example, unless everything in the factory is placed next to each other, there will always be some sort of transportation. Similarly, there will always be some motion of people such as walking or reaching for a material during production. The same holds for Muri. There can always be a time where machines or workers have to provide a little extra effort or time to satisfy the customer demand. Even Mura may not always be reduced with 100%. For example, different products might require different materials, different process times or different workloads. It might not always be possible to completely even out these workloads and some level of unevenness might exist. We should focus on reducing these 3Ms as much as we can, even though they can not be totally wiped out.



LEAN SYSTEMS PHILOSOPHY

Lean systems philosophy first focuses on separating value and waste from each other. Any activity that does not add value for the customer should be eliminated. Lean approach also aims to design a balanced and continuous flow production system such that materials can flow from one station to another without waiting. It aims to design a system such that all the production is done at the same pace as the customer demand in order to eliminate unnecessary inventories. In this system, no production is done without the demand. To satisfy the customer demand in a short time, flow time of the product, which is the time between the start and finish times of a product is aimed to be shortened. The stations are also brought closer to each other in order to minimize transportation. Lean approach also suggests to decrease the setup times in order to be able to make production in small batches.

Lean philosophy also places a great importance in quality. It aims to produce the perfect product at the first time, without requiring any repair or rework operations, or causing scraps or defective products. Lean approach aims to minimize variation in the production process such that all products can be produced at the same quality level.

One of the main ideas in lean philosophy is to determine and solve the problems. Lean approach prefers to see the problems rather than bury it. It sees the problems as opportunities to improve the system. When a problem is determined, it does not only solve the symptoms, but instead it looks for the root cause of that problem and aims to wipe out the problem completely such that it will never occur again. Lean approach also respects for the workers and tries to develop their communication and problem solving skills. It does not see the people as the source of the problem, but instead it sees them as the solutions to the problems. It includes systems that allow the workers to contribute to the identifications and solutions of the problems. Finally, lean philosophy focuses on the whole system and aims to improve the system in general rather than just focusing on and improving parts of it. Just-in-time production and total quality management are two of the most important concepts in the philosophy of lean systems and they are explained in detail below.

Just-in-Time (JIT) Production

Just-in-Time production simply means producing the right quantity of products at the right place at the right time. Before JIT was developed by Toyota, most companies kept large amounts of inventory just in case they would need them to satisfy the demand. Instead of making production in large quantities and keeping inventories, Taiichi Ohno developed a production system that orders and makes production in small quantities in short production cycles. This system was designed to ensure that each part would arrive to a place exactly when it is needed (i.e. just in time to be used), eliminating the need to keep it in inventory.

Even though JIT is viewed as an inventory reduction program by many people, Reid and Sanders (2013) state that it is actually far more than that, explaining that JIT is a philosophy that aims to eliminate waste. JIT relies on a coordination system that withdraws parts from a previous work

center and moves them to the next. According to JIT system, no production is started until the customer orders it. Based on the customer order, each step of the production is planned such that every step is finished exactly when the next step needs it, and the final production is completed exactly when the customer wants the product.

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According to JIT, each step of the production is planned such that every step is finished exactly when the next step needs it, and the final production is completed exactly when the customer wants the product.

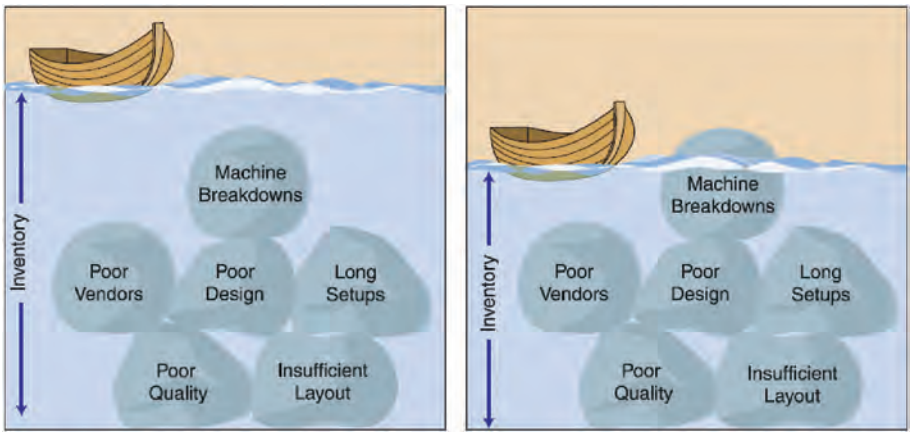
JIT system relies on principles such as the pull production strategy in a flow setting, and synchronization of the production rate with the demand rate based on the "*Takt Time*". Takt time is the rate of customer requests of products from the production line, and is calculated based on the available production time in a period and the amount of demand in that period, as stated in the equation below.

Takt Time = Available Production Time / Customer Demand

Takt time is the rate of customer requests of products from the production line.

For example, assume that the weekly demand of a product that is produced at a single machine is 1000 units in a factory that works 40 hours per week. Available production time in a week will be $40 \times 60 = 2400$ minutes and takt time will be equal to $2400/1000 = 2.4$ minutes, meaning that in order to satisfy the customer demand, this factory should produce one product in every 2.4 minutes. Production rate in this company should be arranged according to this takt time. Production cycle time, which is defined as the (average) time between the completions of two products on the production line, should be equated to the takt time, such that customer demand can be satisfied without inventory built-up. However, it should be noted that, in some cases, in order to compensate for small system failures or defects, some buffer can be allowed and a cycle time that is slightly lower than the takt time can be used.

JIT aims to produce a system that does not allow any failures or defects by eliminating all types of waste in order to decrease the flow time of the products in the production system. By setting the cycle time as close to the takt time as possible, it minimizes inventory. Inventory is seen to be the main factor that hides the problems and prevents improvements in lean systems, thus is seen as a waste that provides no value and needs to be eliminated. According to JIT, inventory covers up a wide variety of problems, such as poor quality, slow delivery, inefficiency, lack of coordination, and demand uncertainty. Reid and Sanders (2013) explain JIT's view of inventory using a stream, as shown in Figure 7.4. The rocks in the stream represent problems and the water represents inventory. When the water in the stream covers the rocks, they cannot be seen what they are, and thus can not be solved. When the amount of water in the stream is decreased (inventory is reduced), the problems can be identified and solved, rather than remaining under the stream.



a) Inventory hides problems b) Reducing inventory exposes problems

Figure 7.4 Inventory and Problems (Reid, & Sanders, 2013)

Total Quality Management (TQM)

Lean systems put a great emphasis on quality and focuses on the *Total Quality Management (TQM)* approach. TQM states that quality is not the responsibility of just one department like quality control, or just some people in the company, instead it states that quality is created through the whole production from the beginning until the delivery to the customer, and everyone taking part in these processes should take responsibility about the quality of the product. TQM aims to do the job right at the first time and it sees defects, repair or rework processes as wastes. Thus, every step of production should be done right and every person working at each step is responsible for the quality of their job. TQM states that if every step is done right at the first time, there would be no need for inspection or quality control later on.

TQM is a continuous improvement management concept and aims to reduce defects by standardizing each process and making the perfect production at the first time with very little variation to increase customer satisfaction. Six Sigma is a set of techniques that is used to decrease variation in production as a part of TQM, which aims to increase the quality of the processes by minimizing variability in manufacturing. In order to increase quality and decrease variability, TQM makes sure that all equipments are well maintained, all employees are well trained and all processes are well defined.

TQM is a continuous improvement management concept and aims to reduce defects by standardizing each process and making the perfect production at the first time with very little variation to increase customer satisfaction.

In order to achieve the highest quality, TQM aims to prevent defects during production, rather than determining them at the quality control phase after the production. According to TQM, mistakes should be determined and prevented at their source. One of the main mechanisms to prevent mistakes is called poka yoke which means mistake proofing or avoiding inadvertent errors. Poka yoke aims to design systems such that incorrect operation is prevented. It aims to prevent defects from occurring in the first place, and if it is not possible, it aims to detect and eliminate errors as early as possible. For example, a two-hand operating device is a poka yoke used to reduce injuries by requiring the operator to use both of their hands to control the machine. Child-proof electric sockets or the washing machine that does not start if the door is not closed properly in order to prevent flooding are other examples of poka yokes.

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Poka yoke aims to prevent defects from occurring in the first place, and if it is not possible, it aims to detect and eliminate errors as early as possible.

TQM employs many other techniques such as control charts, fishbone diagrams, check sheet templates, histograms, pareto charts, scatter diagrams, stratification diagrams etc. to detect errors as soon as possible, identify the root causes of the problems and solve them before they can occur again.

JIT and TQM approaches provide many advantages to companies. They help the companies to become more flexible and able to satisfy customer requirements much faster. Since production is based on actual demand in a pull setting, resources will be used only when they are needed in a better manner. Lean systems reduce wastes and workers will be more focused on value-added activities. This improves productivity, efficiency and quality at the same time. It should also be noted that lean systems are not only related to manufacturing industries and the philosophy of lean systems can be applied at many service industries such as healthcare, finance etc. For example, Graban (2012) discusses applications and benefits of lean systems at hospitals in a detailed manner.

Further Reading

Lean Healthcare – Interview with Mark Graban

(Mark Graban is an internationally-recognized expert in the field of "Lean Healthcare," as a consultant, author, keynote speaker, and blogger.)

Q: Lean has a long history in healthcare. What are some of the current trends and understanding of "lean" in hospitals and healthcare?

A: Some of the earliest experiments with Lean methods in healthcare were in Seattle in the late 1990s. Two of the longest-running examples of the adoption of Lean in healthcare include ThedaCare, a health system in Wisconsin, and Virginia Mason Medical Center, in Seattle, which have been using Lean as an improvement model and a management system for 12 or 13 years now. Those organizations, along with some others, have really embraced Lean as a new culture, modeling themselves after Toyota in some ways, while maintaining, of course, the special values and purpose of a hospital.

Even with those shining examples, however, far too many health systems have a limited view of Lean, thinking of it as just an improvement methodology or as a set of tools or projects. The best Lean success comes from adopting Lean as a culture and a management system… yet, we're still hoping to see more of that in healthcare. It's unfortunately easier for people to adopt a few new tools to use in their existing, and often dysfunctional, organizational cultures.

Q: Do healthcare organizations go through the lean hype cycle when trying to adopt Lean?

A: Yes, that same cycle applies in healthcare. Healthcare organizations and leaders are as likely, as any, to want easy, quick fix, silver bullet solutions. Lean is sometimes hyped as a cure all, which I think is irresponsible. Sometimes the fault is on the people selling the ideas (or services) and sometimes we can perhaps blame the buyers who think Lean is simple and is something that can be implemented fully in a short period of time. Or they think they can hire one internal Lean expert and expect them to change the organization.

Lean methods and practices can lead to pretty quick and immediate improvements to safety, quality, patient waiting times, cost, and more. But, the greatest benefits will come from changing the culture and the management system… and that all takes time. Some organizations have gotten impatient and have fired their internal Lean or process improvement departments because they weren't driving enough short-term cost savings, or that happened because the hospital has gotten new leadership that wasn't convinced that Lean was a good strategy. I sometimes say that Lean doesn't fail, but sometimes people quit practicing Lean.

Q: You wrote an article about how Lean applies to all forms of knowledge work and not just for manufacturing anymore. Can you please explain?

A: Lean is applicable to any situation where we are designing and managing work, delivering something to customers (products or services), and when we have people to inspire and help improve. While the term "Lean production" was used in the early book *The Machine That Changed the World*, Lean isn't just about manufacturing. Even in manufacturing companies, they realized that Lean can help with product development (see the Toyota Product Development System), in sales and marketing, human resources, and other administrative functions.

Lean helps us identify value to the customer (versus waste), how to look at the end-to-end value stream (thinking systematically), and how to engage people in improvement. It's quite a flexible methodology and management mindset. I've taught classes about Kaizen (continuous improvement) to groups that included people from manufacturing, healthcare, higher education, state government, software companies, and retailers. The principles and management practices are very consistent and applicable across industries (and across countries).

Q: What are the key similarities and differences in how Lean is commonly applied in large healthcare organizations compared to startups?

A: Lean Startup activities, by definition, are about creating a new product or service as a startup or within a large company. As I talked about a few years ago at The Lean Startup Conference, there are many similarities with the process a health system might go through to build a new hospital facility. The cycles of Build-Measure-Learn take place for a physical building. This process starts with getting out of the office to deeply understand the day in the life of a patient or a caregiver. Since it's expensive to iterate an actual building, the early cycles of experimentation and learning take place on paper or in full-size cardboard mockups. This allows learning to take place early on, when modifications to the design are easier and less expensive to make.

Most Lean healthcare activity, however, is focused on the redesign or tweaking and continuous improvement of existing processes and space. A "Kaizen" approach to continuous improvement includes small improvements that take place within a team and larger "events" or projects that help drive larger changes in the existing process. This is all built around the "Deming Cycle" of Plan, Do, Study, Adjust. This is very conceptually similar to the Build-Measure-Learn cycle. Philosophically, the goals are, first, to learn and develop people and, second, to solve problems and to improve.

Source: Kromatic. (2018, January 31)

Learning Outcomes

3 To discuss the philosophy of lean systems

Self Review 3	Relate	Tell/Share
What are the advantages of JIT production?	JIT and mass production systems.	Tell how TQM can be applied for a process that you observe in real life.

TOOLS AND TECHNIQUES OF LEAN SYSTEMS

There are several tools and techniques used in lean systems to identify and eliminate waste and to apply the philosophy of lean systems, such as one-piece flow, cellular or U-shaped layouts, Kanban mechanism, 5S, and Single Minute Exchange of Dies (SMED) among others. These tools and techniques are explained in detail below.

One-piece Flow and U-shaped Layout

One-piece flow, also known as "single piece flow" or "continuous flow", is one of the key techniques of lean systems in order to apply the JIT philosophy and pull system principle. One-piece flow requires that manufacturing is done one piece at a time (or a small batch at a time) with no work-in-process (WIP) inventory such that parts are continuously moved from one station to the next without waiting in between.

One-piece flow requires that manufacturing is done one piece at a time (or a small batch at a time) with no WIP inventory such that parts are continuously moved from one station to the next without waiting in between.

This system helps the manufacturers to produce the right quantity of products exactly when they are needed. In this system, the production rate is synchronized with the demand rate such that the cycle time and takt time are equal or close to each other. The number of manufacturing stations, their workloads, number of workers and machines at each station are determined in a balanced setting such that each station completes the manufacturing of one piece at the same time with the others, so that parts can move continuously between stations without waiting.

In the classical batch production system, generally functional layouts are used as shown in Figure 7.5(a). According to this layout, machines are grouped and placed based on their functions and each product type follows a different path depending on its manufacturing requirements. In addition, products are manufactured in large batches such that a large of number of products are processed at a station and this batch of products are only moved to the next station together, after all parts in that batch are completed at the current station. This system leads to a high number of parts to be waited in between the stations and a thus a high level of WIP is incurred.

On the other hand, lean systems propose a one-piece flow which works best with a cellular (generally U-shaped) layout. In this system, a separate cell is formed for each product type such that all necessary equipment are located within the cell according to the manufacturing sequence, as shown in Figure 7.5(b), and all parts in each cell follows the same path. In addition, based on the one-piece flow system, a batch is not formed and each part is moved to the next station immediately after it is processed at the current station, without waiting the next parts.

One-piece flow works best with a cellular (generally U-shaped) layout.

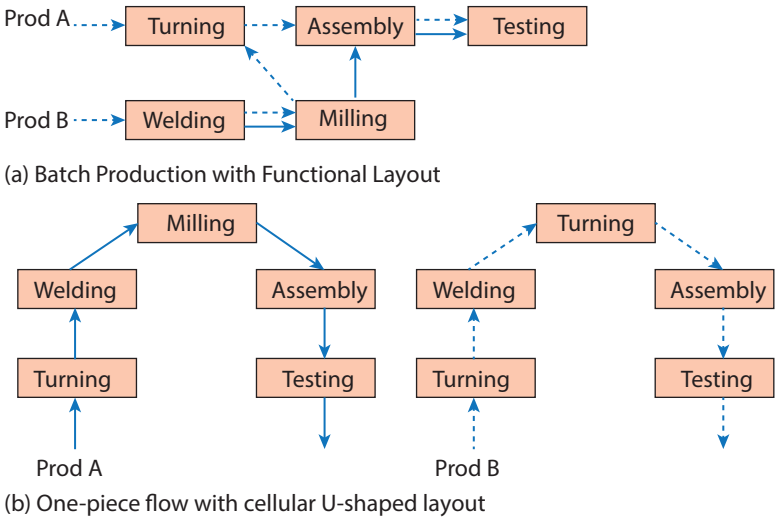

Figure 7.5 A comparison of functional and cellular U-shaped layouts

Batch production system is seen to cause several problems in the system. For example, if a defect happens, it can generally be seen at the next station, however due to batch production, large amounts of scrap occurs because of large batches of WIP. However, according to one-piece flow system, since each part is immediately moved to the next station, if a defect occurs, that defect can be seen immediately and only that single part will be scrapped while the next parts can be manufactured correctly. In addition, batch production causes long manufacturing lead times because when a part is manufactured at a station, it has to wait the other parts in that batch before moving to the next station and due to these waiting times, it can be completed after a long lead time. This situation also causes delays in delivery of products to the customers and customers need to wait a long time before obtaining their products. However, one-piece flow system allows the parts to be moved to the next station immediately without waiting, and each part can be completed in a very short time. Customer orders can be satisfied in much shorter times in this system. Batch production also leads to large amounts of WIP or finished goods inventory, while one-piece flow aims to eliminate inventories completely.

Read more: https://www.process.st/one-piece-flow/

Kanban

Kanban is a visual method for controlling production in lean systems as a part of the pull approach. It is used to control inventory levels and the production and supply of components. Junior and Filho (2010) state that kanban has been used with the meaning of card since it utilizes cards to manage the production of parts or raw materials. Graves et al. (1995) defines kanban as a material flow control mechanism to control the proper quantity and proper timing of the production.

Kanban is a visual method for controlling production in lean systems as a part of the pull approach.

Kanban aims to ensure that the production is done based on the customer demand in a pull setting. It utilizes a system of cards or signals through the value stream to pull product from customer demand back to raw materials. Karaesmen and Dallery (2000) state that kanban mechanism uses production authorization cards that transmit demand requests in order to coordinate the production. Claudio and Krishnamurthy (2009) state that kanban is simple to implement and very efficient. It limits inventories using kanbans (cards or signals) such that when one unit is consumed from inventory, a kanban signal is sent upstream to begin work to replenish this inventory.

important

Kanban utilizes a system of cards or signals through the value stream to pull product from customer demand back to raw materials.

Figure 7.6 presents a typical kanban control system. In this system, a certain number of kanban cards are defined for each product type that limits the inventories and transmits the information between manufacturing stations to coordinate the production. When the manufacturing of a part is completed at a station (let's call it station A), a kanban card is attached to it and placed at a location called the "supermarket" to be used by the next station (called station B). When this part is used by station B (or bought by the customer), the kanban card on that part is returned back to the kanban board at station A. In this system, each kanban card can be thought as a production order such that manufacturing is done at station A only if there exists a kanban card on the kanban board. When a part is produced at station A, it uses one kanban card from the kanban board, such that it is attached to the part and sent to the supermarket. If all the kanban cards are depleted at the kanban board, production is stopped. This system actually works like the shelf systems in supermarkets in real life. In supermarkets, customers buy products from the shelves and as the shelf is depleted, new products are placed. The kanban system also works in the same manner to determine when production should be done and when it should be stopped. It helps to arrange the production system such that a production is started only when a sale is made to the customer, which is in line with the JIT and pull system principle.

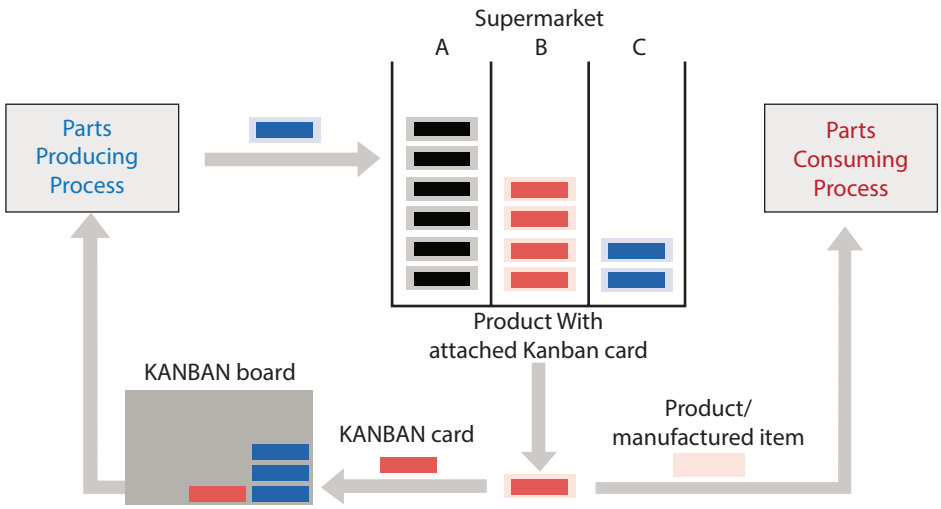

Figure 7.6 A typical Kanban system (Eurocharts, n.d.)

5S

5S is a methodology that aims to create a clean, uncluttered, safe, and well organized workplace to reduce waste and increase productivity. It is the most common tool that helps to improve productivity by removing all wastes (Panneman, 2019). 5S represents five Japanese words beginning with the letter "S" used to create a workplace suited for visual control and lean production. These words are Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain), as shown in Figure 7.7.

5S is a methodology that aims to create a clean, uncluttered, safe, and well organized workplace to reduce waste and increase productivity.

Figure 7.7 Steps of 5S (5sToday, n.d.)

important

5S words are Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain)

Seiri (Sort): In this first phase, all items in a workplace are sorted and necessary items are distinguished from unnecessary ones. Items that are not needed are removed from the workplace.

Seiton (Set in order): In this second phase, fixed locations are defined for all necessary items and they are placed at their optimal locations depending on their usage. There should be a place for everything that is easy to access, and everything should always be located at their own place so that the right item can be picked efficiently, without waste, when needed.

Seiso (Shine): In this third phase, the workplace should be cleaned and all garbage, dirt, dust etc. should be eliminated. The workplace including, equipments, machines etc. should always be kept clean and root causes of dirtiness should be determined and wiped away. It will always be easier to identify and solve problems in a clean work space.

Seiketsu (Standardize): In this fourth phase, standards for always keeping the work environment clean and neat should be set. The procedures and schedules for repetitively applying the first three phases should be established. The clean environment with everything in order should be the new standard of the workplace.

Shitsuke (Sustain): In this last phase, the established standards should be maintained over the long term. In order to achieve this, workers should develop a self-discipline and change their behaviors and habits to always keep their workplace clean and tidy. This is generally the hardest step of 5S since it is generally observed that, even though the workers clean their workplace at first, they have a hard time keeping it clean in the long run.

Single Minute Exchange of Dies (SMED)

Single-Minute Exchange of Dies (SMED) is a technique to reduce the equipment changeover

times. As the name suggests, SMED aims to decrease changeover times to "single" digits (i.e. less than 10 minutes). In manufacturing systems, different types products require different equipments, dies, machines, etc., and a different setup. The dies on the machines should be changed when changing the production from one type to another. In addition, the machine setup and the workplace need to be arranged according to the type of production. In the classical mass production system, one of the main reasons of making production in large batches was the long time periods required to change these setups. When the changeover time is long, managers do not want to change the setups frequently, since every changeover is a waste of time that passes without production. Thus, when a setup was made, a large batch of products was produced in a long production run before moving over to the production of another type of product. However, this leads to inventories and less flexibility in the production system. It was difficult to produce a high variety of products in this system and different types of customer demands cannot be satisfied in a short time in this setting.

SMED is a technique to reduce the equipment changeover times.

Lean systems aim to produce small batches of products in order to eliminate inventories, to produce higher varieties of products and to satisfy customer needs in a short time. Long setup time is the main obstacle in such a production system. In order to be able to make production in smaller batches, setup times needed to be decreased. A japanese industrial engineer, Shigeo Shingo, managed to develop a system that will reduce changeover times dramatically from a few hours to a few minutes, which is called the SMED system (Shingo, 1985).

SMED defines each step of the changeover process as an "element" and each element is classified as an internal or an external element. Internal elements are the ones that must be done when the machine is stopped and external elements are the ones that can be done while the machine is running. SMED focuses on simplifying and streamlining all elements and decreasing the number of internal elements by converting them into external elements, if possible. By this way, most of the elements can be done while the machine is running and machine needs to be stopped only for a short time period to complete the internal elements. Changing tires at pit-stops at Formula or NASCAR races can be given as a good example to the SMED system. Normally, changing a tire can take a long time, however, pit crews complete this process only in a few seconds and the race car only needs to stop a few seconds without wasting the valuable time. Most of the processes of changing the tires are completed externally before the race car is stopped at the pit and only the required internal processes are applied when the car is stopped. The same idea also applies in all SMED operations and the machines only need to be stopped for very short times in order not to lose their valuable time.

In a basic SMED application, the first step is identifying the internal and external elements of the changeover process. External elements should be completed before the machine is stopped and everything that is required for the internal elements should be ready when the machine is stopped. Then, in the second step, each internal element should be analyzed and new ways of doing things should be searched in order to convert internal elements into external ones, if possible. We need to ask ourselves whether it might be possible to complete a currently internal element without stopping the machine, such that it is converted into an external one. Finally, in the third stage, each internal and external element should be simplified as much as possible and unnecessary activities should be eliminated. Figure 7.8 presents a visualization of these three stages. In this figure, the changeover time is dramatically decreased from the initial five blocks into the final small block at the bottom that only contains the internal elements at the end.

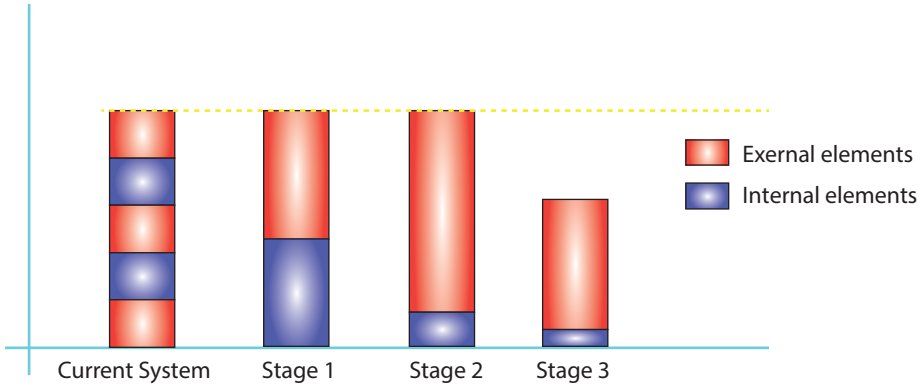

Figure 7.8 Visualization of three stages of SMED.

SMED helps companies to be able to produce many different types of products at the same facility in small batches depending on the customer orders. It also helps to eliminate inventories and thus decreases wastes. It is one of the most critical methods that allows the implementation of JIT in lean systems.

Learning Outcomes

4 To identify the tools and techniques in lean systems.

Self Review 4	Relate	Tell/Share
What are the main benefits of applying one-piece flow strategy?	Build a relationship between pull based production and Kanban mechanism.	Tell how you can apply 5S in your room or workplace.

Summary

LO 1 Express the history and principles of lean systems

The classical mass production system, developed by Ford, was designed to produce large quantities of products with a few varieties. In the middle of the 20th century, Toyota designed a new system, called Toyota Production System (TPS), that was able to produce large varieties of products in a short time to satisfy customer demand in an improved manner with less cost. They developed new approaches that allow them to be more flexible in production and to produce higher quality products based on customer expectations. TPS was built on two concepts: Jidoka (automation with human touch) and Just-in-Time. Lean systems are derived from TPS and this system helped Toyota to increase their sales significantly in a very short time.

Lean systems are built on the principle of defining value from the customer viewpoint and places a great emphasis on customer expectations. The production system is designed to increase the value of the product for the customer and aims to eliminate all activities that do not add value. Value, value stream, flow, pull and perfection are five main principles of lean systems. Value is defined by what the customer is willing to pay for. Lean systems first define the value based on customer expectations and identifies which activities add value to the product by analysing the value stream in the production process. It creates a chain of value adding steps with no interruption between the processes in a flow setting. A pull based production system is utilized in this system such that production is done only as a result of customer demand and every process is activated exactly when the next process needs it. Lean idea aims to achieve a system with perfect value with no waste.

Continuous improvement and respect for people are the two main pillars of lean systems. TPS cares a lot about the workers and aims to incorporate them in the improvement process. Lean systems propose continuous improvement, also called Kaizen, such that the system is perfected over time. Kaizen aims for small steps to improve the system rather than radical changes. It requires all employees at all levels of the company work together to improve the system. There are mainly 4 phases in a Kaizen implementation, known as the PDCA cycle: Plan (P), Do (D), Check (C), Act (A). In this cycle, first current situation is analyzed, the problem or the improvement opportunity is identified, alternative solutions are thought and a plan is made to improve the system. Then, the selected solution idea is implemented on a small scale of the system, data about the results are collected and the results are analyzed. Based on this analysis, new ideas can be implemented and checked over and over again until the determined objectives are reached. Finally, the best solution is implemented at full scale. Kaizen idea requires to search for new problems and improvement opportunities continuously to reach to the perfect system.

LO 2 Explain the enemies of lean systems

Lean systems have mainly 3 types of enemies called Muda (waste), Mura (unevenness) and Muri (overburden). Muda is defined as anything that does not add value for the customer and they should be eliminated. However, it should also be noted that there might exist some activities that are considered as Muda, such as inspection, safety testing etc., but these activities might be necessary and can not be eliminated, even though they do not directly add value to the product.

Originally, 7 types of Muda were defined by Taiichi Ohno that should be eliminated as: Defects, Transportation, Overprocessing, Overproduction, Inventory, Waiting, and Motion. A defect is observed when the final product does not exactly match what the customer wants and in such cases waste is observed in the form of scrap, rework or repair. Transportation waste is defined as any unnecessary movement of products, materials, inventory etc. Doing more than what the customer requires is overprocessing waste. Overproduction is the waste of producing more than, faster than or earlier than required. Inventory waste is also related with overproduction and any type of inventory in the system is considered as waste. Any idle time in the system, such as idle machines or workers, is called the waste of waiting. Finally, any movement of people that doesn't add value to the product, such as walking, lifting, reaching, etc. is called the motion waste.

Besides these types of Muda, unevenness of the workloads among stations or workers also lead to inefficient use of resources and is called Mura. In addition, overburden, which is caused by giving excessive or unreasonable work beyond one's power, causes unnecessary stress to workers, and is called Muri. Muri can be caused by Mura such that if the workloads are distributed unevenly, some workers or machines will be overburdened. Mura also would lead to Muda in the form of waiting, inventory, transportation or defects due to uneven workload distribution.

LO 3 Discuss the philosophy of lean systems.

Summary

Lean philosophy focuses on separating value and waste from each other and aims to design systems and processes that satisfies customer needs with zero waste. Just-in-Time (JIT) production and Total Quality Management (TQM) are two of the most important concepts in this philosophy. JIT production system is based on the idea that all production should be done as a result of actual demand and at the same pace with the demand so that customer orders can be exactly satisfied and no unnecessary inventory is built-up. JIT aims for a balanced and continuous flow production system based on the calculation of takt time and synchronizing it with the cycle time. In addition, with the elimination of inventory from the system, problems can be better identified and solved under JIT philosophy.

TQM is a continuous improvement management concept and aims to reduce defects by standardizing each process and making the perfect production at the first time. TQM states that quality is not the responsibility of just one department, and instead quality is created through the whole production. TQM philosophy states that every activity should be done right at the first time without requiring any inspection or control later on. Mistakes should be determined and prevented at their source. Poka yoke, which means mistake proofing or avoiding inadvertent errors, is one of the main mechanisms to prevent mistakes which aims to design systems such that incorrect operation is prevented. In addition, TQM makes sure that all equipments are well maintained, all employees are well trained and all processes are well defined in order to do everything right at the first time.

LO 4 Identify the tools and techniques in lean systems.

In order to implement the philosophy of lean systems and to satisfy customer needs with zero waste, there are several tools and techniques used in lean systems. One-piece flow is one of these techniques to apply the JIT philosophy. It creates a system in which parts are continuously moved from one station to the next without waiting in between. One-piece flow works best with a cellular (generally U-shaped) layout, such that each product type is manufactured in a seperate cell in which all equipment and machines are sequenced according to the manufacturing needs of that part. This system helps to eliminate defects by detecting problems much faster, decreases the lead time and inventories and helps to satisfy customer orders faster.

Kanban is a visual aid in applying the JIT philosophy to control production. It utilizes a system of cards or signals to coordinate production such that parts or products are pulled from customer demand back to raw materials. It also limits inventories such that parts can not be produced without the associated kanban card giving the production signal. In this system, production signals are only given when that part is used by the next station, creating a pull based production system.

5S is another method used in lean systems to identify and eliminate waste. It aims to create a clean, tidy and safe workplace such that production can be done much more easily without leading to any waste. There are five steps in 5S beginning with the letter S, which are Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain). Based on these steps, first the necessary items are separated from unnecessary ones at the workplace and unnecessary ones are eliminated. Then, fixed places are determined for the necessary ones such that they are placed optimally for production. In the third step, the workplace is cleaned and all garbage, dust etc. are eliminated. Then, standards to keep the workplace always clean and tidy are set, and corresponding procedures are determined and applied. Finally, as the last step, the clean workplace should be sustained in the long run.

Lastly, SMED is a technique to reduce the equipment changeover times. In order to produce multiple products in small batches and to apply JIT philosophy, frequent changeovers need to be done to move from producing one part to another. SMED aims to decrease these changeover times in order to make this production system efficient. It proposes to identify the activities required in a changeover process as internal and external elements and separates them from each other. Internal elements need to be done when the machine is stopped while external elements can be done when the machine is running. It suggests converting internal elements into external ones, if possible, and simplifying and shortening the times of all elements. As a result of these steps, changeover times could be decreased from a few hours to a few minutes.

Test Yourself

1 Which one of the following statements is applied to the Toyota Production System?

a. Production is done based on forecasts
b. Pull strategy is used in production
c. Inventory levels are high
d. Setup times are long
e. Production is done in large batches

2 Which one the followings is **not** one of the main principles of lean systems?

a. Identify value
b. Build inventory
c. Create flow
d. Establish pull
e. Seek perfection

3 Which one of the following statements is **not** correct about Kaizen?

a. Kaizen is a Japanese term for continuous improvement
b. Kaizen uses the PDCA cycle
c. Kaizen is based on radical changes
d. Kaizen requires the participation of workers
e. Kaizen does not require high capital investments

4 Which one of the followings is **not** a waste that should be eliminated?

a. Transportation
b. Inventory
c. Motion
d. Setup
e. Overproduction

5 Which one of the followings does mean to give excessive or unreasonable work beyond one's power, causing unnecessary stress to workers?

a. Muda
b. Mura
c. Muri
d. Kaizen
e. Poka Yoke

6 What is the Takt Time in a factory that works 8 hours per day with a daily demand of 300 units?

a. 0.625 minutes
b. 1.6 minutes
c. 2.4 minutes
d. 3.2 minutes
e. 37.5 minutes

7 Which one of the following terms is used for designing systems such that incorrect operation is prevented in order to increase quality in production?

a. Poka Yoke
b. Kaizen
c. Kanban
d. Muda
e. SMED

8 Which one of the followings is a visual method for controlling production in lean systems as a part of the pull approach?

a. Poka Yoke
b. Kaizen
c. Kanban
d. Muda
e. SMED

9 At which step of 5S, the workplace is cleaned and all garbage is eliminated?

a. Seiri (Sort)
b. Seiton (Set in order)
c. Seiso (Shine)
d. Seiketsu (Standardize)
e. Shitsuke (Sustain)

10 Which of the followings is a technique to decrease equipment changeover times?

a. Poka Yoke
b. Kaizen
c. Kanban
d. Muda
e. SMED

1. b	If your answer is wrong, please review the "History and Principles of Lean Systems" section.
2. b	If your answer is wrong, please review the "History and Principles of Lean Systems" section.
3. c	If your answer is wrong, please review the "History and Principles of Lean Systems" section.
4. d	If your answer is wrong, please review the "Enemies of Lean Systems" section.
5. c	If your answer is wrong, please review the "Enemies of Lean Systems" section.
6. b	If your answer is wrong, please review the "Lean Systems Philosophy" section.
7. a	If your answer is wrong, please review the "Lean Systems Philosophy" section.
8. c	If your answer is wrong, please review the "Tools and Techniques in Lean Systems" section.
9. c	If your answer is wrong, please review the "Tools and Techniques in Lean Systems" section.
10. e	If your answer is wrong, please review the "Tools and Techniques in Lean Systems" section.

self review 1

What are the main principles of lean systems?

There are five main principles of lean systems, which are value, value stream, flow, pull and perfection. Value is defined by what the customer is willing to pay for. Companies need to apply different methods to understand what their customers want. Lean systems first define the value based on customer expectations. Then, the second principle, value stream, analyzes the activities in the production process and identifies which activities add value to the product. The third principle, flow, aims for a continuous movement of parts through the production process such that value is added at each step with no interruption between the processes. Pull principle requires that production should be activated as a result of actual customer orders and each process in the system should be activated exactly when the next process needs it, without building any inventory. Finally, perfection principle suggests continuous improvement and aims to achieve a system with perfect value with no waste.

Suggested Answers for "Self Review"

What are the original types of Muda (waste) that should be eliminated?

self review 2

Originally, there are 7 types of waste (Muda) that should be eliminated, which are: Defects, Transportation, Overprocessing, Overproduction, Inventory, Waiting, and Motion. Waste of defect is observed due to quality problems and either additional operations such as rework or repair should be done to correct the product or the product is wasted as scrap. Any unnecessary movement of products, materials, inventory, tools etc. is defined as the transportation waste. Transportation does not add any value to the product. Overprocessing means doing more than what the customer requires and it is a waste since the customer did not want these processes and they have no value for the customer. When production is done more than, faster than or earlier than required, it leads to the waste of overproduction. Any inventory more than needed to satisfy a smooth production flow is considered as the waste of inventory. Inventory is just products staying idle in the system and has no value for the customer. Waiting is another type of Muda and any machine or worker staying idle in the system waiting for production is considered as waste. Finally, any motion of people such as walking, lifting, bending, reaching, etc. does not add value to the product and is a waste.

What are the advantages of JIT production?

self review 3

JIT approach creates a system that coordinates the production such that every part is completed when the next process needs it. In this system, inventories are eliminated since no part is done before needed. Eliminating inventories makes the problems in the system to be more visible. The problems can be better identified and solved in a JIT production system. When inventories are eliminated, there will be no need to transport them, thus transportation waste is also decreased in a JIT system. JIT also eliminates the waste of overproduction since production is done at the same pace as the customer demand.

What are the main benefits of applying one-piece flow strategy compared to batch production?

self review 4

In a one-piece flow system, each part is immediately moved to the next station when it is completed at the current station instead of making production in batches. Note that when a defect occurs, it can generally be identified at the next station. This system helps to identify defects much faster since parts are immediately moved to the next station without waiting others and only the current part would be scrapped while the process can be corrected before the production of other parts. However, in a batch production system, a large batch is produced at each station before being moved to the next one. In a batch production system, the problem can only be identified after all the parts in the batch are already produced, leading to a high number of scraps as waste. One-piece flow prevents this situation. Secondly, one-piece flow strategy decreases the flow time of the products since each part is immediately moved from one station to the next without waiting the completion of others, contrary to the case in batch production systems. One-piece flow strategy also helps to satisfy customer orders in a faster manner since waiting times between stations are minimized. Finally, one-piece flow decreases WIP or finished goods inventory compared to batch production systems.

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Chapter 8 Supply Chain Management

After completing this chapter, you will be able to;

Learning Outcomes

1. Understand the basic concepts in supply chain management
2. Analyze supply chain management decisions
3. Explain the relationship between supply chain and logistics
4. Understand different supply chain structures and coordination in supply chains
5. Explain sustainability in supply chains

Chapter Outline

Introduction
Basic Concepts in Supply Chain Management
Supply Chain Management Decisions
Supply Chain and Logistics
Supply Chain Structure and Coordination
Sustainability in Supply Chains

Key Terms

Supply Chain
Supply Chain Strategy
Production
Logistics
Supply Chain Coordination
Sustainability

INTRODUCTION

Products pass through a long stream of operations before being bought by the customers. In a general setting, customers buy the products from retailers but when the products at the retail shops are depleted, they order new ones from distribution centers or warehouses. These products arrive to these distribution centers from manufacturing plants at different locations. Manufacturers need raw materials in order to make production and they obtain these raw materials from their suppliers. A supply chain is composed of all of these parties involved, directly or indirectly, in satisfying the customer needs. Suppliers, manufacturers, transporters, warehouses, distribution centers, retailers and even customers are considered to be the main components of supply chains. However, some of these stages may not exist in all supply chains.

Traditionally, companies mainly focused on their internal operations and the relations with their suppliers and customers were not considered to be as important. However, with the increasing competition in global markets and the advancement in information technologies, relations with other members in the supply chain started to become much more important and attract much more attention over the years. Competition between the companies extended to become competitions between supply chains. Thus, companies started to focus more on their relations with other members of the supply chain and the operations over the whole supply chain in addition to their internal operations. All the functions and entities in a supply chain affect its performance and they all need to work together to ensure success.

Supply chains include movement of products from suppliers to customers, but they also include movement of information, funds, and products in both directions. Supply chain operations include all operations over the life cycle of the product, beginning with the supply of raw materials, including all the production, distribution and marketing operations, continuing with after-sales and recycling processes, and finally completed when the product is disposed by the end user. In addition, all functions within each company, involved in satisfying a customer request (e.g. product development, marketing, operations, distribution, finance, customer service) are also considered to be parts of the supply chain (Chopra & Meindl, 2007). It should also be noted that any service delivery system can be viewed as a chain or network of activities, which involves different number of participants. Thus, service industries can also be considered as supply chains, just like manufacturing supply chains.

BASIC CONCEPTS IN SUPPLY CHAIN MANAGEMENT

Supply chain management (SCM) aims to integrate different parties in the supply chain in order to satisfy the customer needs with maximum profitability. There are different definitions for supply chain management. According to the Council of Supply Chain Management Professionals (CSCMP), *supply chain management* encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management. It also includes coordination and collaboration with channel partners, which may be suppliers, intermediaries, third-party service providers, or customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply chain management is also defined as a set of approaches utilized to efficiently integrate the supply chain members in order to maximize total supply chain profitability. Supply chain management aims to produce and distribute the products to the right locations, at the right time, at the right quantities, in order to maximize systemwide profitability while satisfying customer service levels. (Simchi-Levi, Kaminsky & Simchi-Levi, 2008).

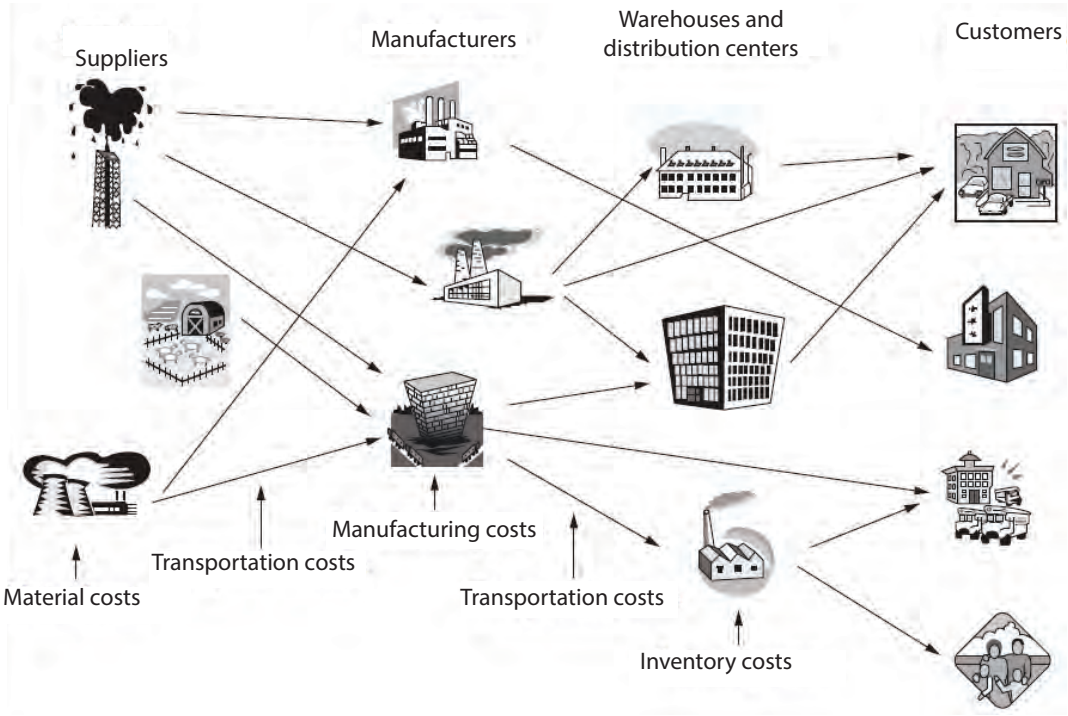


Figure 8.1 A Typical Supply Chain (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008)

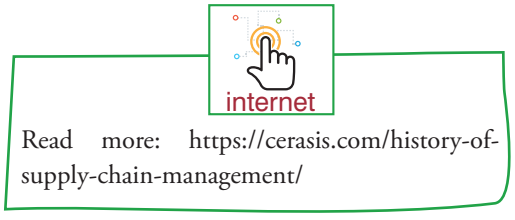
A typical supply chain is shown in Figure 8.1. In this figure, to satisfy the customer needs, raw materials are procured from suppliers and products are manufactured at manufacturing facilities. Then, they are sent to warehouses or distribution centers in order to be delivered to retailers and customers. Every facility that has a role in satisfying customer needs and has an impact on cost needs to be taken into consideration in supply chain management. These facilities range from supplier and manufacturing facilities through warehouses and distribution centers to retailers and stores. It might also be necessary to consider the suppliers' suppliers and the customers' customers in the system if they have an impact on supply chain performance.

Supply chain management encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management.

Development of Supply Chain Management

Supply chain management has attracted increasing attention and analyzed in further detail starting in 1990s, however its roots go back many years, back to industrial revolution and mass production operations. The first applications of supply chain management was related to logistics operations, which prove its importance and were analyzed deeply starting with World War II. In 1940s and 1950s, managers mostly focused on their transportation and logistics operations to improve their businesses. In 1960s, inventory management and cost control became to be the main focus. In 1970s, materials requirement planning (MRP) systems start to emerge and operations management tactics started to be used in businesses. In 1980s, MRP systems became much more advanced and MRP II systems began to be used. Globalization increased at this era and many organizations started to integrate global sources into their business. The supply chain management term was first used at this era in 1982. With the advances in Japan, Just-in-Time philosophy and lean production systems also emerged at this period and companies started to modify their businesses accordingly. In 1990s, companies began to focus on their core competencies and specialization became the main focus. With these developments, the relations with other companies became much more important and the supply chains of the companies extended

beyond the company walls. Companies started to integrate their purchasing, manufacturing, distribution, financials etc., with the help of growing Enterprise Resource Planning (ERP) systems. Also, integrating other companies into core operations of the businesses led to SCM systems to emerge in this era. In 2000s, the definition of SCM has broadened to include things like supply chain strategy, co-innovation and supply chain design, and was named as SCM 2.0. In addition, with the development of Internet and e-businesses, different supply chains and management techniques developed in this period. Real-time decision support systems, synchronized and collaborative extended supply chain networks are a few of the developments in this era. Lately, in today's world, environmental and social considerations are becoming much more important and managers are trying to increase sustainability in their supply chains and decrease their carbon footprints. Supply chain managers are trying to integrate the collection of end-of-life products, recycling and remanufacturing operations into their traditional supply chains. Thus, concepts like reverse logistics, green supply chains, remanufacturing, closed-loop supply chains are widely being researched. In addition, social considerations such as worker rights, child workers, working environments etc. are also being widely considered in supply chain decisions.



Read more: https://cerasis.com/history-of-supply-chain-management/

Views of Supply Chain Processes

Supply chain systems are analyzed via different views. Cycle View and Push/Pull View are two of the most commonly used ways to view the processes in a supply chain:

Cycle View: In every supply chain there are different relations between the supply chain members. A supply chain can be analyzed as a combination of these relations. According to the cycle view of supply chains as shown in Figure 8.2, processes between two successive supply chain stages are analyzed as a cycle. This view of supply chains specifies the roles and responsibilities of each member and the desired outcome of each process. According to this view, the operations between the customers and the retailers are named as the Customer Order Cycle. In this cycle, customers place the orders and the retailers aim to satisfy these orders. Customer Relationship Management (CRM) approaches are mostly utilized at this cycle. In order to satisfy the customer orders, the retailer needs to replenish the inventories from the distributors. The relation between the retailers and distributors is analyzed through the Replenishment Cycle. Distributors obtain the products from the manufacturers and this relation is named as the Manufacturing Cycle. Finally, manufacturers need raw materials in order to produce their products and they obtain these raw materials from the suppliers. The operations between the suppliers and manufacturers are analyzed via the Procurement Cycle. Supplier Relationship Management (SRM) approaches are widely utilized in this cycle.

Cycle view of supply chains analyze the processes between two successive stages in a supply chain as a cycle.

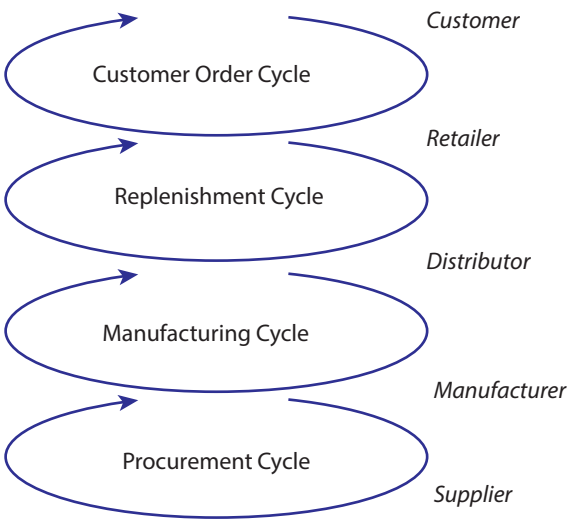


Figure 8.2 Cycle View of Supply Chains (Chopra, & Meindl, 2007)

Push/Pull View: According to push/pull view, processes in a supply chain are divided into two groups depending on whether they are executed in response to a customer order (pull) or in anticipation of a customer order (push). A pull system is a reactive one and execution is initiated in response to a customer order. On the other hand, a push system is a speculative one and execution is initiated in anticipation of customer orders. A make-to-order system in which manufacturing is done according to customer orders is an example of a pull system. In this system, first the customer makes the order and specifies the product characteristics and then the manufacturing processes start. The product is delivered to the customer after a certain time period, called as the lead time. On the other hand, a retail store that places the products on the shelves and waits customers to come and buy them is an example of a push system. In this system, products are manufactured and delivered to retail stores first, and then the customers arrive to the system and buy the products. Both systems have their advantages and disadvantages. In a pull system, customers need to wait for some time in order for their products to be prepared and they can only get the product after a certain time. However, they can specify the product characteristics as they want and customized production can occur. In addition, companies do not carry any finished goods inventory and they do not have any risk of unsold products. Thus inventory and wastage costs are minimized. On the other hand, in a push system, customers can obtain the product immediately since products are already produced and ready for sale at the stores. However, customers might not find exactly what they are looking for and they need to select among the alternatives in the store. Due to the uncertainty in demand, some of the products might be unsold leading to losses for the supply chain and some of the products might be out of stock if there is higher demand than expected, leading to high inventory and wastage costs.

A pull system is a reactive one and execution is initiated in response to a customer order. On the other hand, a push system is a speculative one and execution is initiated in anticipation of customer orders.

Every supply chain needs to design its processes according to their customers' expectations. For example, since customers will not be willing to wait to buy products like bread, detergent, drinks etc., these products are produced in a push setting such that they are ready to be sold at the stores. However, custom-made furniture manufacturers operate in a pull setting such that customers first specify the characteristics of the furniture that they want and the furniture is manufactured afterwards according to customer needs. Customers in this system are willing to wait for some time in order to obtain exactly what they want. Similarly, in a business-to-business setting, when manufacturers order parts from their suppliers with certain specifications, these parts are not ready at the suppliers and suppliers start to produce these parts only after they get the orders. Such businesses are examples of pull systems. It is also possible that a portion of the supply chain operates in a push setting and the other portions on a pull setting. Push/pull boundary separates push processes from pull processes in the supply chain.

Strategic Fit in Supply Chains

In today's global competitive environment, companies and supply chains need to develop different competencies and strategies in order to differentiate themselves from others and to gain advantage in this competition. An attribute of a company that differentiates itself from others is defined as the core competency of the company. Every company also needs to develop a competitive strategy that defines the customer needs to satisfy through its products and services. Based on the competitive strategy, they then need to build a product development strategy that specifies the portfolio of products that the company will develop. Marketing and sales strategy of the company specifies how the market will be segmented, products will be positioned, priced and promoted. Finally the supply chain strategy determines how materials will be procured, transported, manufactured and distributed. All these strategies should be in line with each other and support each other in order for the supply chain to be successful. Supply chains need to be designed to satisfy the customer expectations (the target customers that the company intends to serve), and supply chain management decisions need to support this issue.

The consistency between customer expectations and supply chain capabilities and supply chain strategies is defined as the *strategic fit* (Chopra & Meindl, 2007).

Strategic fit is the consistency between customer expectations and supply chain capabilities and supply chain strategies.

Companies need to understand the customer expectations and their supply chain capabilities in order to design the appropriate strategy and to achieve strategic fit. Customer's expectation is the main building block of the competitive strategy of a supply chain. The performance of supply chain will be closely related with the supply chain strategy in responding to the established competitive strategy. A company's competitive strategy is its basic method of satisfying more of the customer's expectations than its competitors. The competitive strategy of a company includes its target customers and their specific needs, such as the product type, orders, information, special services, and so on. To achieve strategic fit, a company must ensure that its supply chain capabilities support its ability to satisfy the targeted customer segments (Chaharsooghi and Heydari, 2011).

To understand the customer expectations, a company needs to identify the needs of the customer segment that they serve. For example, when customers go to a fancy restaurant, they go there for the quality and variety of the food, freshness of the ingredients and quality of service, and they do not necessarily look for the lowest price. However, for a fast food restaurant, low price is very important. The customers may be willing to tolerate less variety or lower quality in taste. Every company needs to analyze and understand the characteristics of their customers and decides on several attributes based on their expectations. For example, the price and quality of the product should match the customer expectations. If the company is targeting low-end customers, then they should decrease the price even if the quality of the product also needs to be decreased. However, if the target customers are high-end customers, then highest quality products should be served at a higher price. Similarly, the innovation level of the products, product varieties, service levels and quantity of inventories in store should be decided by considering customer expectations. If the customers are looking for custom-made products and willing to tolerate some waiting times, the supply chain can be designed in a pull setting and custom-made products can be served. However, if customers want to obtain the products immediately, high level of finished goods might be required and the supply chain should be designed in a push setting to satisfy these customer expectations.

Uncertainties in demand also have a significant effect on supply chain strategies. If the demand uncertainty is low, then the company can easily estimate how much product of each type they can sell and can manufacture these products before the actual demand happens. The customers can obtain their products immediately and there is a low risk of unsold items or stock-outs. A push strategy might be more appropriate in this case. However, if the demand uncertainty is high, the company would have a hard time in estimating which products to manufacture at which quantities. There will be a high risk of unsold items and stock-outs in that case. If the customers would be willing to tolerate some waiting times, manufacturing the products after the customer orders in a pull setting and operating in make-to-order fashion might be more appropriate in that case.

In addition to customer expectations, companies also need to understand their supply chain capabilities and build the strategy such that its competitive strategy and supply chain strategy are aligned. Supply chains want to minimize their costs but they also want to be responsive to demand. According to Chopra and Meindl (2007, p.30), supply chain responsiveness is defined as the supply chain's ability to

- respond to wide ranges of quantities demanded
- meet short lead times
- handle a large variety of products
- build highly innovative products
- meet a high service level
- handle supply uncertainty

The supply chain is said to be more responsive if it has more of these abilities. However, increasing responsiveness requires a higher cost. For example,

to build highly innovative products, higher expenses need to made for research and development which increases the costs of the company. Besides being responsive, companies also want to minimize their costs and want to be efficient. Supply chain efficiency can be defined as the cost of making and delivering the product to the customer. The definition of efficiency does not say anything about improving customer service or effectiveness of the supply chain. A supply chain might be very efficient that minimizes costs but if it leads to unhappy customers and if it does not meet customer expectations, it will not be an effective supply chain. Effectiveness of a supply chain is about how well the supply chain is meeting the expectations and demands of the customers.

important

A supply chain's responsiveness is measured by its ability to respond to wide ranges of quantities demanded, meet short lead times, handle a large variety of products, build highly innovative products, meet a high service level and handle supply uncertainty.

Companies generally need to position themselves at a certain point between extremely efficient and extremely responsive standings. Increasing responsiveness results in higher costs that lower efficiency. Depending on the customer expectations and supply chain capabilities, companies need to find the best position for them in order to achieve strategic fit. There is no single right strategy for every supply chain but instead there is a right strategy for a supply chain depending on the needs of its target customers, characteristics of the products and the capabilities of the supply chain.

Figure 8.3 shows the zone of strategic fit with respect to uncertainty of demand. As stated above, if demand uncertainty is low, customer expectations can be almost known in certainty beforehand and decisions can be made much easily that will minimize the costs and an efficient supply chain would be a better fit for this system. However, as the demand becomes more uncertain, the supply chain needs to be more responsive and more flexible to handle the changes in demand. In order to satisfy the customer demand and meet customer expectations, higher varieties might be produced, higher capacities might be built and a more flexible production system might be developed. Of course, these strategies lead to higher costs and thus a responsive supply chain strategy rather than an efficient one might be more appropriate in that case to meet customer expectations. Similarly, if target customers expect low prices, costs become more important and an efficient supply chain strategy might be more suitable. On the other hand, if target customers expect highly innovative products, higher service levels or larger varieties of products in a short time, then a responsive supply chain strategy might be more appropriate.

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There is no single right strategy for every supply chain but instead there is a right strategy for a supply chain depending on the needs of its target customers, characteristics of the products and the capabilities of the supply chain.

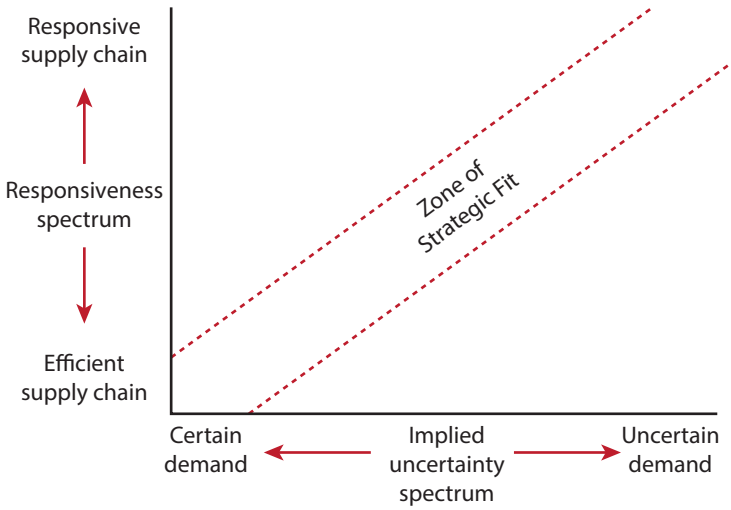

Figure 8.3 Zone of Strategic Fit (Chopra, & Meindl, 2007)

Learning Outcomes

1 To understand the basic concepts in supply chain management

Self Review 1	Relate	Tell/Share
What are the main factors that define the right supply chain strategy?	Associate responsiveness and efficiency with each other.	Tell some of the products you use and the facilities in the supply chain of those products.

SUPPLY CHAIN MANAGEMENT DECISIONS

The objective of supply chain management is generally to maximize profitability across the entire system. Supply chain managers aim to maximize total systemwide profitability which is mainly the difference between the revenues from sales and the system costs which include material costs, transportation and distribution costs, manufacturing costs and inventory costs among others. Thus, supply chain management does not simply aim to minimize transportation cost or reduce inventories but instead requires a systems approach that includes all operations and related revenue and cost factors in the supply chain.

important

Supply chain management requires a systems approach that includes all operations and related revenue and cost factors in the supply chain.

There are various decisions that need to be made for effective supply chain management, such as the structure of the supply chain, relations between facilities, the number of facilities, their function and capacity, type of operations at each facility, locations of these facilities, locations and quantity of inventory, customers to be served from each facility, transportation arrangements etc. There are also various cost factors associated with these decisions throughout the supply chain. Supply chain management encompasses the company's activities and decisions at many levels. These decisions can be classified as strategic, tactical and operational level decisions depending on their significance and the time span that they cover.

Strategic Level Decisions: These decisions are long-term (over several years) decisions and they are generally about the structure of the supply chain. Locations and capacities of facilities, products to be manufactured, information systems to be used, modes of transportation are some examples of such decisions. These decisions are mostly made by the top level managers. Since these decisions are about the structure of the supply chain, it is difficult to change them once they are implemented. When a strategic decision is made, it would be in use for the next several years, and it would be very costly to reverse them in the short run. Thus, these decisions need to be analyzed carefully considering future uncertainties. For example, when a facility is built at a certain location, that location will be used for many years and changing that location would not be easy in the short term. These decisions also need to be made such that they support the strategic objectives of the supply chain.

Strategic level decisions are long-term decisions that are generally about the structure of the supply chain and made by top level managers.

Tactical Level Decisions: Tactical decisions in supply chains are a set of policies that govern medium term (generally between 6 months and 2 years) decisions and they are constrained by the

strategic decisions. Which locations will supply which markets, inventory policies, when and how market promotions will be made, subcontracting and backup decisions are a few examples of tactical decisions. Companies need to consider the factors like demand uncertainty, competition and changes in the system over time when making these decisions. Generally, medium level managers are involved in these decisions.

Operational Level Decisions: Operational decisions are generally daily or weekly decisions that need to be made to operate daily activities. When making these decisions, strategic and tactical decisions are fixed and operating policies are already determined. The main goal is to implement the operating policies as effectively as possible. Deciding order due dates, setting production and delivery schedules, assigning jobs and workers to machines, allocating orders to inventory or production, allocating an order to a particular shipment, generating pick lists at a warehouse, placing replenishment orders are some examples of operational decisions. Since these decisions are short term decisions, there is much less uncertainty in the system when they are made. These decisions are generally made by low level managers.

Facility decisions, manufacturing decisions, inventory decisions, transportation decisions, information decisions, sourcing decisions, pricing and marketing decisions are just some of the decisions that need to be considered by supply chain managers. Each of these decisions will be based on the supply chain strategy as explained below.

Facility Decisions: Facility decisions are among the most important decisions in supply chains. Where to locate the facilities, what should be their capacities, what is going to be done at these facilities are some of the most critical decisions in supply chains. Global companies that produce multiple products decide to produce some items at one location while producing others at other locations. Which products should be produced at which facility, which customers should be supplied from which facilities are a few of the most critical strategic level decisions. Location and capacity decisions about the facilities also should be in line with the supply chain strategy. For example, a company might need to decide between these two alternatives: building many distribution centers with small capacities or building only one distribution center with a high capacity. Each alternative has advantages and disadvantages. If there are many distribution centers at different locations, then these locations will be closer to the customers and products can be delivered to the customers in shorter times, leading to a more responsive supply chain. However, operating multiple facilities will cause higher costs. On the other hand, if these multiple facilities are combined as a single larger facility, the operating and fixed costs of these facilities will be decreased due to economies of scale, and a more efficient supply chain can be obtained. However, since there will be only one facility, this facility can be very far away from some customers and delivery times of the products will increase and the responsiveness of the supply chain will decrease.

Manufacturing Decisions: Manufacturing is one of the main operations in a supply chain and there are various decisions around it. Which products to manufacture for the target customers, how should the products be designed, when, where and how much to produce, what type of machines and manufacturing methods will be used, what should be the production plan and production schedule, how will the demand be forecasted, what should be the quality control, maintenance, research procedures to be used for production are some of the most critical decisions that need to be made in supply chains. Manufacturing decisions are affected by the supply chain strategy such that depending on the target customers, the types, quantities and qualities, the innovation level in products, operating procedures might change. In a responsive supply chain which target high-end customers, highly innovative products with better quality control, and faster and highly automated production methods can be chosen. However, for an efficient supply chain that aims to minimize costs, standard products with lower quality might be acceptable.

Inventory Decisions: Companies in a supply chain keep inventories mainly because of the reasons stated as below:

- **Uncertainties in demand and supply:** Companies keep inventories as a precaution for unexpected changes in demand and supply. Inventory kept above the expected level of demand is defined as the safety inventory and is used to satisfy the demand if demand happens to be above expectations.

- **Economies of scale:** Materials and products are bought at large quantities due to fixed order and transportation costs and to benefit from quantity discounts. The inventory used to satisfy demand between receipts of supplier shipments is defined as the cycle inventory.
- **Production smoothing:** If demand varies at different periods, companies sometimes produce more than the demand at low demand seasons and use the remaining inventory at high demand seasons if production capacity is insufficient. The inventory built up at low demand seasons and used up at high demand seasons is defined as the *seasonal inventory*.
- **Anticipations about price changes:** Companies sometimes buy more than what they need if they anticipate a price increase in the near future.

Companies need to decide when, how much and which materials to order or produce for replenishing their inventories to satisfy customer demand at minimum cost. Inventory decisions are also affected by the supply chain strategy. If a supply chain aims to be a responsive one, then higher amounts of inventory should be kept at closer locations to customers to increase customer service levels. However, keeping inventory brings a cost to the company. Thus, a company that aims to be an efficient one might choose to work with lower levels of inventories.

Seasonal inventory is the inventory built up at low demand seasons and used up at high demand seasons.

Transportation Decisions: Decisions about the movement of products between the facilities in the supply chain are in scope of the transportation decisions. Which mode of transportation (air, truck, rail, ship, pipeline or electronic transportation) to use, which routes should be selected, what should be the logistics network between the facilities, should the products be shipped directly to the customers or should different distributors be used, should a third party logistics company be utilized or should logistics operations be done with in-house vehicles, are some of the decisions that need to be made related to transportation operations. Each of these decisions are also related with the supply chain's strategy. For example, if responsiveness is more important for the company then airways can be used as a mode of transportation which is much faster than the other modes but also more costly. On the other hand, if efficiency is more important, to decrease the costs, railways, ships or trucks can be used rather than using airways, since they are cheaper but delivery takes a longer time.

Information Decisions: Information systems have a significant effect in the coordination between different parties in the supply chain. A healthy and fast communication between the members of the supply chain is critically important for smooth completion of the operations. In order to make good decisions, companies need to have the necessary information as quickly and as correctly as possible. Information systems is the backbone of the supply chains. What type of information systems to use, which companies should share what kind of information with the others, how should the information be communicated are some of the critical decisions related to information systems in supply chains. A good information system can help the supply chains to be responsive and efficient at the same time. With the growing technology in today's world, there are different information systems that are utilized by the companies. Electronic Data Interchange (EDI) systems, Internet, Enterprise Resource Planning (ERP) systems, Supply Chain Management (SCM) systems, Barcode and Radio Frequency Identification (RFID) systems are some of the mostly used information systems in supply chains that help companies make better decisions and continue their operations in a better and faster manner.

Sourcing Decisions: Sourcing can be defined as the processes to obtain or buy goods or services. Sourcing is concerned with what needs to be purchased, where it should be purchased from, when and why it should be purchased. There are various decisions related to sourcing in supply chains. Supplier selection and evaluation, outsourcing, supplier contracts, single or multiple sourcing are some of these decisions. Quality, timeliness in delivery, price, reliability, past performances, technical competency, research and innovation capabilities, guarantee and return policies, production capacity and flexibility are some of the

major factors that affect supplier selection. Supply chain members need to evaluate their suppliers and make decisions regarding which suppliers to work with for what types of products, what types of contracts to make with them and how to improve the relations with suppliers. Suppliers are an integral part of the supply chain and a good relationship with the suppliers is critically important for the success of the supply chain. Supply chain decisions are also related with the supply chain strategy. If responsiveness is more important for the supply chain, then suppliers which are faster and more flexible in delivery might be chosen even if they are more expensive. However, if efficiency is more important, then lower price suppliers can be more suitable to work with. In addition, some companies choose to work with a few number of suppliers and build strong relationships with them, while others choose to buy from many different suppliers at the same time to distribute the risk. Supplier selection is one of the most critical decisions for a company and the choice of a wrong supplier might hurt the supply chain significantly.

Quality, timeliness in delivery, price, reliability, past performances, technical competency, research and innovation capabilities, guarantee and return policies, production capacity and flexibility are some of the major factors that affect supplier selection.

Pricing and Marketing Decisions: Pricing is an important decision that affects the customers whether to buy the product or not. Pricing decisions will directly affect the demand and the sales of the company, which later on affect all the other production, distribution, inventory or sourcing related decisions. Pricing and marketing decisions can be used as very effective strategies to increase supply chain profitability. Depending on the customer expectations and supply chain capabilities, prices can be increased or decreased at different times in order to match supply and demand. For example, if demand is higher than the production capacity, then prices can be increased to obtain more profit from sales. On the other hand, if demand is lower than expected and if there is excess inventory at hand, prices can be decreased in order to sell the inventory at hand and obtain some revenue. This is a general procedure that can be observed in fashion retail stores. It is commonly seen that there are certain discounts at certain unsold items especially at the end of the sales season. Promotions also affect the customer behaviors and companies commonly use these strategies to attract customers at certain periods. Different pricing and revenue management strategies are commonly used by different companies in order to increase their profits. Dynamic pricing approaches used by airlines or hotels are just a few examples of such strategies. Companies devise their own strategies depending on their supply chain strategy. For example, some companies, like BİM and A101 markets in Turkey, employ everyday low pricing strategy but they generally have low product availability. Other companies might use other strategies like high-low price strategy but they generally have higher product availability with higher varieties.

Most of the decisions stated above are actually related with each other. A decision about one of the factors might affect the decisions about others. Improving one part of the system without considering others might lead to unwanted results. For example, if the prices are decreased in order to increase sales, it might lead to higher revenues at first, however, it will also require higher inventories and higher manufacturing and transportation costs. In addition, the production capacity might not be enough to satisfy the increased demand, leading to stock-outs and unhappy customers in the system. Thus, a supply chain system need to analyze all of these decisions together in an interrelated setting using a systems approach. For example, the facility location decisions should also consider transportation, distribution and inventory decisions as well among others, since different routes and distribution strategies will be required depending on the facility locations. Similarly, if the pricing strategy is changed, the production inventory and sourcing decisions will all be affected. A supply chain manager needs to understand the effects of the decisions on all parts of the supply chain and make these decisions accordingly in order for the supply chain to be successful.

Learning Outcomes

2 To analyze supply chain management decisions

Self Review 2	Relate	Tell/Share
What are the main reasons to keep inventories in supply chains?	Build a relationship between strategic, tactical and operational level decisions.	Tell some of the decisions that are made in a real life company that you observe.

SUPPLY CHAIN AND LOGISTICS

The concepts of supply chain and logistics are commonly mistaken for each other. Even though logistics is in relation with the sourcing, manufacturing, marketing and finance departments among others, it is mainly related with the distribution and transportation of products or services between facilities. However, supply chain management is a much larger concept that deals with all the operations from the sourcing of raw materials until the delivery of the product or service to the end-user and it includes logistics activities. Supply chain management includes all the sourcing, manufacturing, information and marketing decisions in addition to logistics or distribution decisions.

According to CSCMP, *logistics management* is defined as the part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to

meet customers' requirements. Logistics operations are about the transportation and distribution of raw materials, semi-finished goods and finished goods between the facilities up to the customers. Harrison and Van Hoek (2008) define logistics as the task of coordinating material flow and information flow across the supply chain.

Logistics management is the part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.

The part of the logistics operations that are about supplying the materials needed for manufacturing from the suppliers to the manufacturers are called inbound logistics and the part that are about delivering the finished goods from the manufacturers to the customers are called outbound logistics. The logistics operations that are performed inside the manufacturing facility are called manufacturing logistics.

Logistics decisions aim to satisfy customer expectations at minimum cost. Broadly speaking, its mission is to provide the right materials at the right place and at the right time, while optimizing a given performance measure subject to a given set of constraints. Logistics costs are mainly composed of transportation, warehousing, inventory, order processing and administrative costs.

The mission of logistics is to provide the right materials at the right place and at the right time, while optimizing a given performance measure subject to a given set of constraints.

Logistics is directly related with the distribution costs in a supply chain and also affects customer service levels and profitability in the supply chain. In order to increase responsiveness of the supply chain and to decrease response times, the number of manufacturing and distribution facilities need to be increased. Since these facilities will be closer to the customers, outbound transportation costs will also decrease. However, as the number of facilities increase, the inbound transportation costs from the suppliers and the operating costs of these facilities will increase as well. In addition, more inventory need to be kept in total at these facilities which will cause increased inventory costs. Thus, based on their supply chain strategy, companies need to determine the optimal number and locations of these facilities in order to minimize their total costs while satisfying customer expectations.

Supply chain managers need to design their logistics and distribution networks according to their supply chain strategy. There exists different distribution network designs used for delivering the products to customers. Some of the mostly used network designs as classified by Chopra and Meindl (2007) can be explained as below:

Manufacturer Storage with Direct Shipping: In this system, all the products are stored at the manufacturing facilities. Customers give their orders through retailers or online order systems and manufacturers ship exactly what the customer wants from the manufacturing site directly to the customer. Since there is no distribution center in this system, facility operating costs are minimized. In addition, customized production can be done and the company does not need to keep high levels of inventory. Different varieties of products can be supplied to customers depending on their orders. Generally this system is used for high value products with low demand and high variety. However, this system also has several disadvantages. First of all, since every customer order is shipped separately from the manufacturer site directly to the customer, it causes very high transportation costs. In addition, customers have to wait certain times in order to obtain their products leading to high response times. Customers should be willing to tolerate these response times in order for this system to be usable.

Manufacturer Storage with Direct Shipping and In-Transit Merge: This system is just like the above one except that pieces of customer orders coming from different manufacturing sites are merged on the way by the shippers or cargo carriers so that the customer gets a single delivery even if his order is composed of multiple pieces produced at different locations. *Cross-docking* procedures can

also be utilized in this system. Cross-docking is a logistics system in which materials from incoming vehicles are directly redistributed to outbound vehicles with minimum handling or storage in between. This system helps to decrease the transportation costs since customer orders are combined and each customer order is delivered in a single shipment rather than each piece being delivered separately. However, processing the orders and merging the shipments require some time and some extra cost for the carrier.

Cross-docking is a logistics system in which materials from incoming vehicles are directly redistributed to outbound vehicles with minimum handling or storage in between.

Distributor Storage with Carrier Delivery: In this system, products are stored at distribution centers or at retailer warehouses and package carriers deliver these products from these locations to customers. The distribution centers are generally built closer to customers so that response times are much shorter and outbound transportation costs are much lower than manufacturer storage networks. In addition more economic modes of transportation can be used between manufacturer and distributor locations. However, higher levels of inventory need to be kept at distributor facilities in order to satisfy customer demand and customized production may not be possible in this case. In addition, higher facility costs will be inquired to operate these warehouses. Distributor or manufacturer storage and related e-business systems started to be increasingly used especially with the developments in Internet technologies in today's world.

Retail Storage with Customer Pick-up: This is the most traditional network design in which products are kept at retail stores and customers go to these retail stores in order to buy the products. The response time is shortest in this setting so that customers can immediately buy the product when they come to the store. In addition, the company does not need to pay any transportation cost to deliver the product to the customer. However, distributing the products from the manufacturers to retailers will require a certain transportation cost. In addition, a high number of retail stores are required and thus high facility operating costs are incurred. Since each retail store needs to carry a certain level of inventory, high inventory costs will be realized and there is a risk of customers not being able to find exactly what they are looking for at each store. Also a limited amount or product varieties can be kept at each store. Generally this system is used for fast moving consumer goods with high demand, low variety and low uncertainty or if customers want to obtain the product immediately.

Further Reading

How Amazon Is Changing Supply Chain Management

Amazon builds reputation through bold strategies and technology

Amazon.com has changed the face of retail through its use of bold supply chain strategies and its deployment of innovative technologies. In this article, we explore some of the ways that Amazon has shaped its supply chain, leaving competitors scrambling to catch up.

Rapid Growth: In 2004, ten years after Amazon was founded, its annual revenue was just under $7 billion. According to Statista, in 2016, however, revenue reached almost $136 billion. In fact, Amazon is the fastest company to reach $100 billion in sales revenue, taking only 20 years. From its inception, Amazon has been growing approximately 20 percent per year. Currently, it enjoys 6.4 percent of gross global e-commerce sales. One of the major secrets behind Amazon's massive transformation from a simple online bookseller to the most dominant and formidable force in the retail industry is its innovative and highly efficient supply chain. Amazon's continuous efforts to deliver products to the customers in the quickest possible time are causing intense pressure other giant players in the retail industry across the globe and thus changing the way supply chain management works.

Amazing Supply Chain Management Practices: Amazon enjoys a cult following. It is a favorite choice for customers due to one crucial reason: quick and efficient supply chain management. The combination of sophisticated information technology, an extensive network of warehouses, multi-tier inventory management and excellent transportation makes Amazon's supply chain the most efficient among all the major companies in the world.

Outsourcing Inventory Management and Insourcing Logistics: Amazon's supply chain heavily depends on outsourcing of its inventory management. Especially the products that are not frequently purchased or ordered are not stored in regular Amazon warehouses. It may come as a surprise to you that nearly 82 percent of Amazon's sales comprise of third-party sellers. That amounted to $22.9 billion in 2016. Amazon's one-hour or same day shipping is possible due to its dependence on its own logistics. Just because it sells third-party products does not mean it uses third-party logistics to deliver the products. Amazon understands too well that depending on third-party logistics would just lengthen the product delivery time. That's why Amazon mostly uses its own delivery vehicles for same day delivery or one-hour delivery options.

Delivery Options To Customers: Amazon has different warehouses for different kinds of products and customer preferences for delivery options. Prime customers delivery, one-day delivery, first class delivery, and free super saver delivery are some of the common delivery options available to Amazon customers. Amazon's continuous efforts to make product delivery in the fastest possible time make it a logistics giant and not just the leader in the retail industry.

Push/Pull Strategy for Supply Chain Success: Amazon's own warehouses are strategically placed, moving closer and closer to main metropolitan areas and city centers. As a result, it uses a pure push strategy for the products it stores in its warehouses. On the other hand, it uses a pure pull strategy when it sells the products from the third party sellers.

Classes and Zones: Amazon boasts over 70 fulfillment centers in the U.S. and greater than 90,000 full-time employees. To make good on increasingly fast delivery promises, the company has positioned many new warehouses in proximity to local urban markets. (Wal-Mart's online strategy in China now similarly makes use of a closer to the customer fulfillment model, operating a network of mini-warehouses.) The location, size, and the number of warehouses are important factors in Amazon's supply chain success. Its warehouses are divided into five storage areas. Its library prime storage stores

books and magazines. Next, its pallet prime storage stores full case products that have very high demand. Next, case flow prime storage stores high demand products picked in less-than-case quantities. Its reverse storage accommodates irregularly shaped and low demand products. Finally, its random storage area stores modern demand, smaller items.

Automation: Back in 2012, Amazon acquired a provider of automated and robotic warehouse solutions called Kiva Systems. And in 2015, that company was rebranded as Amazon Robotics. The robots of Amazon Robotics can pick and pack without needing any human assistance, enabling Amazon to complete warehouse activities super-fast. Over the years, Amazon has significantly increased its army of warehouse robots. Its warehouse robots, in fact, have grown at the rate of 15,000 per year from 2015. As of January 2017, Amazon had more than 45,000 warehouse robots, and the robot invasion continues. To date, Amazon's robotics have been aimed at bringing goods to people for the picking of orders. The next generation of robots will see them picking the orders on their own to reduce the need for human order pickers. Amazon is also investing in a drone-based delivery system which is a major indicator that Amazon is well ahead of other players in the retail industry and it is doing everything possible to leverage all of the latest supply chain technologies to maintain their position as the clear market leader.

Supply Chain Cost: Due to the huge economies of scale and a bundle of industry-leading supply chain strategies, Amazon has been able to keep its overall per unit supply cost to a bare minimum. As a result, it has been difficult for other companies with far lower sales volumes and only their own warehouses to compete.

Manufacturing Sector: Amazon is not just a retail giant anymore as it produces a wide variety of products including batteries, backpacks, Bluetooth speakers, iPhone chargers, dog poop bags and more. In fact, in the near future Amazon would include more and more product categories in its manufacturing product arsenal. Amazon somehow understood that many of the third-party products it is selling to customers could be produced at much lower prices. With the massive volume in which Amazon operates deals, it is dealing with high volume situations which lend themselves to low-cost production. As a result, the manufacturing sector of Amazon is making it financially stronger while grabbing market share from many manufacturing companies. This combination of manufacturing to support its retail operations provides Amazon with an important revenue growth opportunity.

Amazon's unique supply chain strategies and continuous technological innovations have already changed the way supply chain management works. With impending advances in robotics, drones and other autonomous vehicles, one can only guess what the future holds for Amazon.

Source: R Leblanc, 2019, June 25.

Learning Outcomes

3 To explain the relationship between supply chain and logistics

Self Review 3	Relate	Tell/Share
What are the product, customer and system characteristics required for manufacturer storage with direct shipping to be appropriate to use?	Associate logistics with supply chain management.	Tell some of the distribution network designs for the products that you buy.

SUPPLY CHAIN STRUCTURE AND COORDINATION

A supply chain is generally composed of many different facilities located at different places all over the world. Traditionally, each company in the supply chain aims to maximize its own profitability. Thus, most companies have been focusing on the activities inside their own organization. However, the increasing competition between the companies and the complex customer demand have made companies realize that only coordinating the internal processes is insufficient (Jayaram et al. 2010). Companies need to consider their relations with their supply chain partners and need to achieve some levels of coordination in their supply chain structure.

Supply Chain Structure

The structure of the supply chain defines the length, width and dimensions of the chain as well as the number of facilities in the chain and their relations with each other. From a company's point of view, supply chain operations can be divided into three parts: supply operations, internal manufacturing operations and distribution operations, as shown in Figure 8.4. In a supply chain network, the supplier that sends materials directly to the company is called a first tier supplier, while the supplier of the first tier supplier is called a second tier supplier, and it goes on as such. Similarly, the customer that buys products directly from the company is called a first tier customer, while the facility that buys products from the first tier customer is called a second tier customer, and so on.

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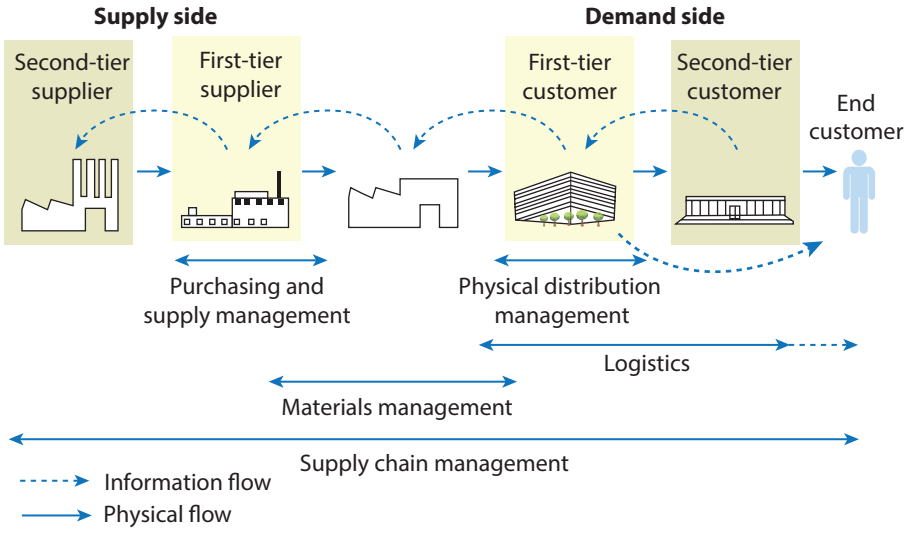

Figure 8.4 A Supply Chain Network Structure (Slack, Chambers, Harland, Harrison, & Johnston, 2013)

The supply chain structure might vary from a simple serial supply chain to a broad network of supply chain facilities. Figure 8.5 shows different supply chain structures. For each company in a supply chain, facilities that provide materials into that company is called upstream while facilities that take materials from the company are called downstream. For example, for the distribution centre in the serial structure in Figure 8.5, manufacturer is an upstream facility while retailer is a downstream facility. In a general setting, most companies procure many products from different suppliers, thus the supply chain converges as it gets closer to the company in focus and they sell many products to different customers, leading to a divergent structure on the demand side of the analyzed company.

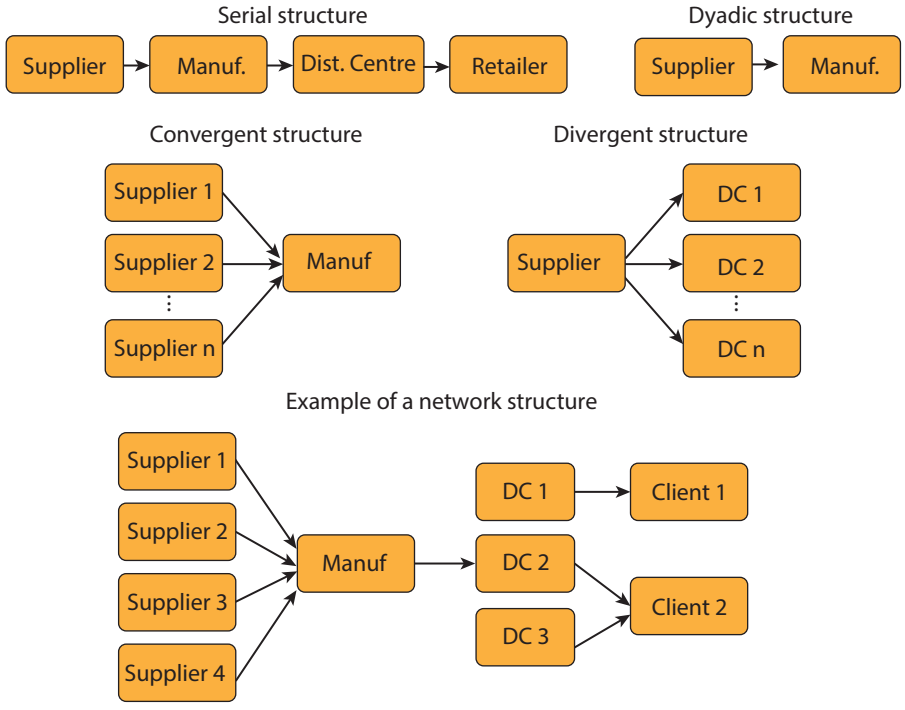

Figure 8.5 Different Supply Chain Structures (Montoya-Torres, & Ortiz-Vargas, 2014)

Supply chain structures of real life companies can be very complicated. For example, the supply chain of General Motors (GM) spans over 18,000 businesses around the world. GM spent approximately $97 billion in 2018 for raw materials, parts, supplies, freight, transportation, and other services. They operate 133 manufacturing facilities in 16 countries (General Motors Sustainability Report, 2018). Operating and coordinating all of these activities require a significant amount of effort. On the other hand, some supply chain structures can be very simple, too. For example, if a manufacturer sells its products directly to customers, the supply chain can be much shorter without all the distributors and retailers in between.

The structure of the supply chain is affected by many factors, such as the customer demand and characteristics, transportation options and costs, economic factors, market culture, financial system etc. Some supply chains can be very short, while some others can be very long. Similarly, some companies prefer a narrow supply chain, in which the materials are supplied only from a few suppliers and products are distributed through a small number of parallel channels. In this case, the company would have more control over its supply chain. On the other hand, some companies work with much more parallel suppliers and use very different distributors and sales channels at the same time. In this case, even though it might be much harder to control the whole supply chain, lower costs and higher service levels can be obtained. Every company needs to structure its own supply chain depending on its needs and customer requirements.

Coordination and Collaboration in Supply Chains

Supply chains can be classified as centralized and *decentralized supply chains* based on the collaboration between supply chain members. If each party in a supply chain makes their own decisions in order to maximize their own profitability, it's called a decentralized supply chain. On the other hand, in a centralized supply chain, the members of the supply chain act in a collaborative manner such that all the decisions of different entities are made by a central agency in order to maximize total supply chain profitability.

A supply chain in which independent companies make their own decisions in order to maximize their own profitability is called a **decentralized supply chain.**

In a decentralized supply chain, companies might have different objectives that might conflict with each other. For example, retailers want the manufacturers to be flexible and be able to produce a lot of varieties of the product in order to satisfy the customer demand. However, manufacturing different varieties and keeping stocks of different items at the same time will bring a high cost to manufacturers and thus manufacturers want to produce high amounts of the same products with as little variety as possible in order to minimize costs. Manufacturer's objective of making large production runs might also conflict with the distributor's objective of minimizing inventory and minimizing inventory might imply an increase in transportation costs. Similarly, suppliers want manufacturers to order large quantities in stable volumes with long delivery dates. However, manufacturers generally want their suppliers to be flexible and want to order small quantities and want to have them in very short times in order to satisfy changing customer demand.

As seen in the above examples, when different companies have different objectives, optimizing just one company's objective might hurt the supply chain as a whole. Thus, supply chain companies need to coordinate their activities in order to obtain the best possible outcome for the supply chain. In today's competitive markets, most companies have to integrate their supply chain in order to remain in the market due to the increasing pressure from the customers and their supply chain partners.

One approach to achieve coordination is *contract mechanisms*. Under these mechanisms, relationships between suppliers and buyers are established through contracts that define the quality and specifications of the product, pricing and discounting structures, delivery lead times, return procedures etc. Contracts help to align the objectives of independent parties in decentralized supply chains with the objective of the whole supply chain. It is observed that contracts used between two members of a supply chain can benefit both parties and improve the supply chain performance. In addition, under certain circumstances, supply chain contracts used in a decentralized supply chain can provide the same performance as if the entire supply chain performance is optimized by a centralized agency. Wholesale price contracts, revenue sharing contracts, cost sharing contracts, franchising contracts, sales rebate contracts, capacity contracts, quantity discount and quantity flexibility contracts are some of the mostly used contracts in real life. Interested readers are referred to Cachon (2003) for further details about supply chain contracts.

Another approach used for supply chain coordination is *strategic partnerships* between companies. Strategic partnerships can help both members increase their profitability. It is commonly seen in the real world that many manufacturers build strategic partnerships with their suppliers and logistics providers. Manufacturing companies share critical information with their strategic partner suppliers, like their demand data or production schedules so that suppliers can make their own plans in a better manner, leading to timely deliveries of materials with lower cost. Suppliers also share their production capabilities, inventories, production costs and schedules with the manufacturers so that manufacturers can plan their own production according to supplier constraints. This strategic partnership will benefit both the supplier and the manufacturer since the supplier can produce the required items at the right time with a lower cost, and the manufacturer will benefit from this system since they can obtain the materials exactly when they need and can smooth out their production without needing to keep high amounts of raw material inventory. Thus, information sharing and common operational planning are critical components for strategic partnerships. Information sharing also allows suppliers and manufacturers to control the variability in supply chains, also known as the bullwhip effect. However, questions such as "which information should be shared", "how should the information be used in partnerships", "what type of partnerships should be made with which companies" etc. need to be analyzed considering supply chain characteristics.

Bullwhip Effect

One of the most interesting dynamics observed in supply chains is called the *Bullwhip Effect*. It is observed that small changes in customer demand at the end of the supply chain propagate to the beginning of the supply chain with significantly increased order variations. As seen in Figure 8.6,

even though the consumer sales vary only slightly over time, retailer's and wholesaler's orders to manufacturer and manufacturer's orders to supplier have highly inflated variations. This variation in orders make the production planning much more difficult leading to high levels of inventories and increased costs in the system.

The phenomena that small changes in customer demand at the end of the supply chain propagate to the beginning of the supply chain with significantly increased order variations is called the **Bullwhip Effect.**

Figure 8.6 Bullwhip Effect (Lee, Padmanabhan, & Whang, 1997)

Hugos (2011) state five major factors that are attributed to the cause of the bullwhip effect. These factors are stated as demand forecasting, order batching, product rationing, product pricing and performance incentives.

Demand Forecasting: Companies at the lower stages of the supply chain, like suppliers, cannot observe the actual customer demand and can only forecast the demand through orders that they receive from their immediate customers. When they use the order data to forecast the demand, they just add another distortion into the actual demand, leading to much higher variations than there actually exists. This distortion in forecasts are also passed on to the supplier of that company, leading to much higher distortions.

Order Batching: Companies generally give orders to their suppliers at periodic intervals by combining the demand in those periods. Batching the orders in this manner causes variations from the actual demand values and this variation is magnified as it goes to the beginning of the supply chain.

Product Rationing: *Product rationing* is the practice of controlling the distribution of a scarce product. When companies are faced with more demand than they have in stock, they allocate the existing inventory among its customers and backorder the rest. When the retailers or distributors get less than what they order, in the next periods they artificially increase their orders, thinking that only a portion of their order will be satisfied. When all of this order is satisfied, then they have excess inventory and order much less than the demand in the upcoming periods. This leads to increased variations in orders which is very much different than actual demand variation.

Product Pricing: When product prices fluctuate, demand also fluctuates, leading to variations in sales across periods. These fluctuations cause much increased variations through the end of the supply chain, leading to increased costs and inefficiencies in the system.

Product rationing is the practice of controlling the distribution of a scarce product.

Performance Incentives: Generally companies provide several incentives to their workers if they meet certain objectives. However, these incentives do not always work in the best interest of the supply chain. For example, when an incentive is given to the sales force on sales made each period, the sales force would make some discounts or increase their efforts as the end of the period approaches in order to meet the quotas. This behaviour leads to changes in the demand structure and causes variations in demand. Performance incentives might also conflict with company objectives. For example, a transportation manager might try to decrease the transportation costs in order to obtain the performance incentive, however these actions might lead to additional inventory costs and loss in customer service levels, which are not wanted by the supply chain.

The solution to decrease the bullwhip effect is thought to be better sharing of data and information between the companies in the supply chain. Companies need to coordinate their activities by sharing information with each other in order to overcome such unnecessary complications in the system to increase supply chain profitability. In addition, collaborative forecasting of demand and strategic partnerships are seen to be very effective in decreasing the bullwhip effect.

Learning Outcomes

4 To understand different supply chain structures and coordination in supply chains

Self Review 4	Relate	Tell/Share
What are the main approaches used to achieve coordination in supply chains?	Build a relationship between a manufacturer's and a retailer's objectives in a supply chain.	Tell a contract mechanism that you see in real life between two companies.

SUSTAINABILITY IN SUPPLY CHAINS

Economic, environmental and social considerations are three main pillars of sustainability and maintaining the balance between them is the key issue to achieve sustainability. In today's world, there is a growing consideration for environmental and social issues in addition to the financial objectives. Customers are becoming more concerned about the environmental and social policies of the companies and thus, sustainability of the supply chains are becoming more important. Supply chain managers need to modify their operations to meet the changing customer expectations.

important

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Waste electrical and electronic equipment (WEEE) directive applied by the European Environment Agency promotes reuse, recycle and other forms of recovery of WEEE items in order to reduce the quantity of such waste to be disposed and to improve the environmental performance of the economic operators involved in the treatment of WEEE. The WEEE Directive forces the electronic companies to collect at least a certain portion of their products back from the customers at the end of their useful lives and sets the criteria for the collection, treatment and recovery of waste electrical and electronic equipment. In addition, the regulations in different countries concerning CO_2 emissions, working hours and worker rights create new challenges for the companies in their operations. Companies are becoming to be bound

by the emission rules and emission regulations. Governmental policies like carbon caps, carbon taxes and carbon trade policies are some of the legislative issues that will force the companies to consider their emissions.

The emission scandal of Volkswagen company that arose in 2015 is one of the most dramatic examples that show the importance of emission considerations. The company lost millions of dollars when the United States Environmental Protection Agency (EPA) announced that the company violated the Clean Air Act. The image of the Volkswagen Group dropped sharply in the eyes of their customers after the scandal. In today's world, customers are looking for products that are environmentally-friendly and want to work with the companies that are socially conscious. Most of the companies today are investing on decreasing their carbon footprints, and making their operations more environmentally and socially friendly, from the design stage up to the end-of-life usage of the product.

Companies are trying to find new ways to manage their operations with decreased emissions and aim to move in the direction of more sustainable operations (e.g. Eguia et al., 2013). In addition, transporters are bound by the legislations enforcing driver working hours, and unbalanced working times are seen to create problems among the workers and against the company (e.g. Gagnon et al., 2010). Thus, supply chain companies need to focus on their environmental and social objectives as well as the financial ones.

Read more: https://www.mckinsey.com/business-functions/sustainability/our-insights/ starting-at-the-source-sustainability-in-supply-chains

Closed-loop supply chain management, product recovery, recycling, refurbishing, *remanufacturing* and reverse logistics concepts received considerable attention in the last years and are becoming especially important in the context of sustainable development (e.g. Guide et al., 2003). Kaya (2010) states that companies engage in recycling and remanufacturing processes either because of legislations in their countries or because of economical reasons. In Europe, recycling of materials is driven by legislations, and original equipment manufacturers (OEMs) are legally responsible for collecting their end-of-life products. However, there are several companies in US and other countries, who are not legally bound to collect back their products but do so to reap economic benefits from this process through remanufacturing.

Traditional supply chains are generally forward supply chains and deal with the forward movement of products from the supplier to the end customer. On the other hand, reverse supply chain activities consider the collection of used products from the customer and deal with backward movement of products from the customer to the related facilities. Closed-loop supply chain (CLSC) management refers to the integration of forward and reverse supply chain activities and improves the sustainability of supply chains (Banasik et al. 2017). In a CLSC, forward flows are used to satisfy demands for new products, while reverse flows represent collection, repairing, remanufacturing or recycling activities as seen in Figure 8.7. Closing the loop refers to the integration and coordination of the operations related to both new and used products in both forward and reverse channels. In addition to the forward movement and distribution of new products, collected products are tested, sorted, then reused in the supply chain and redistributed to the customers as repaired, recycled or remanufactured products. Collected products that are not re-usable at all are sent to disposal sites. Some CLSC systems are composed of dedicated facilities such that there are different facilities for each of the activities. However in some cases, hybrid facilities can also be used, in which some of the operations (e.g. manufacturing and remanufacturing; or distribution and collection) are performed at the same facility concurrently.

Closed-loop supply chain management refers to the integration of forward and reverse supply chain activities and improves the sustainability of supply chains.

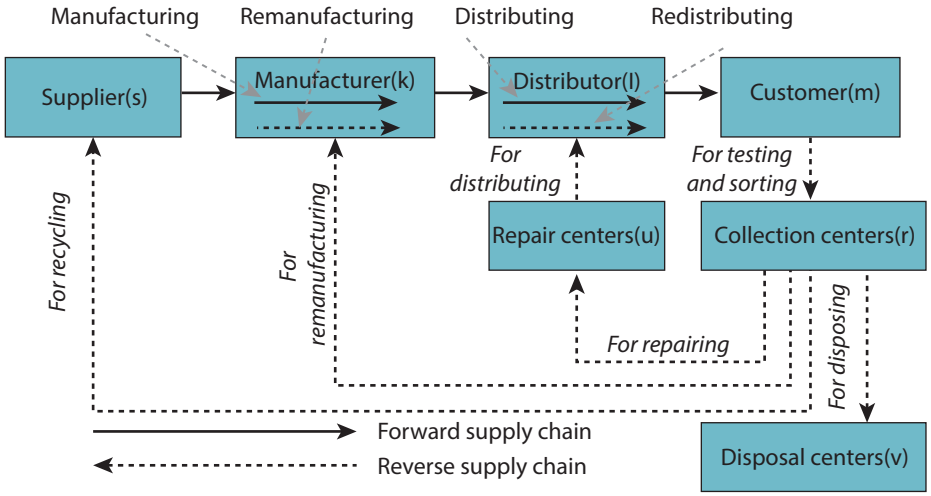

Figure 8.7 A Closed-Loop Supply Chain (Xu, Pokharel, Elomri, & Mutlu, 2017)

Source: Xu, Z., Pokharel, S., Elomri, A., & Mutlu, F. (2017). Emission policies and their analysis for the design of hybrid and dedicated closed-loop supply chains. Journal of Cleaner Production, 142, 4152-4168.

Collection of used products from the customers is one of the most important tasks that affects all the other activities in the reverse supply chain. Some companies collect the used products directly from end customers, but there are also independent third parties that handle used product collection for OEMs in some industries. Financial incentives offered to product holders or buy-back campaigns influence the quantity of returns and thus, many companies offer financial incentives to collect more used products. Offering the correct amount of incentive is of great importance for a company to ensure a sufficient number of used products for remanufacturing. In addition, several companies are locating more and more collection centers to be close to the customers and collect more used products (Kaya, 2010).

Remanufacturing is the process of collecting used items, extracting the useful parts and reusing these parts in the production of new products. Remanufacturing has both economical and environmental consequences. In addition to saving from direct material costs, companies also save from disposal and energy costs through remanufacturing (Kaya, 2010). Studies have shown that the unit cost of remanufacturing can be about 40–60% of the unit manufacturing cost of an original product in some industries. This means that the remaining value in used products may reach significant levels. In addition to 14 million tons of material savings per year worldwide, an estimated 120 trillion BTUs/year of energy are saved from remanufacturing globally, accounting for about 16 million barrels of crude oil and about $500 million in energy costs (Giuntini and Gaudette, 2003). Xerox obtained over $80 million with the implementation of a remanufacturing program in 1997 (Maslennikova and Foley, 2000) and is a successful example of the benefits that can be achieved by remanufacturing and closed-loop supply chain management.

Remanufacturing
is the process of collecting used items, extracting the useful parts and reusing these parts in the production of new products.

Closed-loop supply chain management activities help to use less resources, both in terms of materials and energy, and less emission is produced since they utilize already existing products and it is not required to manufacture every piece from scratch. In addition, less number of products are sent for disposal in the world since end-of-life products are collected and re-used instead of going to waste. These activities help to improve the sustainability of the operations and to preserve the world by decreasing the carbon footprints of the supply chain companies. For this reason, these operations are also called green supply chain management activities in different sources.

Learning Outcomes

5 To explain sustainability in supply chains

Self Review 5	Relate	Tell/Share
What are the main activities that do not exist in traditional forward supply chains, but are considered in closed-loop supply chain management?	Build a relationship between forward and reverse supply chain management activities.	Tell some of the recycled or remanufactured products that are used in real life.

Summary

LO 1 Understand the basic concepts in supply chain management.

A supply chain is composed of many different facilities that work together in order to satisfy the customer needs. Supply chain management deals with the planning and management of all activities involved in the operations at these facilities and the movements of materials, information and finances from the supplier to the end customer. Coordination and collaboration among the supply chain members is aimed at integrating the operations and decisions to improve supply chain profitability.

Different views are used to analyze the processes in supply chains. Cycle view considers the relations at the interfaces between two successive stages. Customer order cycle, replenishment cycle, manufacturing cycle and procurement cycle are the main cycles analyzed in this view. On the other hand, push/pull view of supply chains analyzes the processes based on the timing of processes with respect to customer orders. In a push system, production is made before the orders arrive and finished goods are stored in the inventory waiting for the customers to buy. However, in a pull system, production is started after the customer orders. Production is done according to the order specifications and customer needs. In a supply chain, push/pull boundary separates push processes from pull processes.

Supply chain strategy determines how operations will be performed in a supply chain. It is said that there will be a strategic fit between the supply chain strategy and customer expectations and supply chain capabilities if they are consistent with each other. Supply chain strategy should be designed based on the competitive strategy of the company considering the target customers and their expectations. A responsive supply chain can be designed in order to respond to high demand with large varieties, meet high service levels in a short time, build highly innovative products and handle uncertainty in supply. A responsive supply chain can meet these customer expectations, however, increasing these abilities require increased costs in the system. If supply chain efficiency, which is the cost of making and delivering the product, is more important, then an efficient strategy should be designed. Supply chain managers need to determine the best position for their supply chains across the responsiveness-efficiency spectrum based on their customer expectations and supply chain capabilities in order to achieve strategic fit.

LO 2 Analyze supply chain management decisions.

Supply chain management assumes a systems approach that analyzes all the relations and decisions in the supply chain in an integrated manner. There are various decisions that need to be made in supply chains and these decisions can be classified as strategic, tactical and operational level decisions depending on their effects and the time span they cover. Strategic level decisions are top level decisions and are mostly related to the supply chain structure and design. Tactical decisions span a period between 6 months to 2 years and are generally made by medium level managers. These decisions are generally related to operational procedures and rules to be followed. Lastly, operational decisions are daily or weekly decisions made by low level managers and are mostly related to day-to-day operations.

Depending on the supply chain strategy, different decisions related to facilities, manufacturing, inventory, transportation, information, sourcing, pricing and marketing etc. need to be made in a supply chain. These decisions are mostly related with each other and a decision about one of these factors generally affects the others. For effective supply chain management, the relations between different factors and decisions need to be understood and an integrated approach needs to be used.

LO 3 Explain the relationship between supply chain and logistics.

Logistics is a part of supply chain management that mainly deals with the distribution and movement of products, information and services in the supply chain. Logistics management aims to provide the right materials at the right place at the right time with minimum cost. From the viewpoint of a company, logistics operations can be classified as inbound logistics, manufacturing logistics and outbound logistics. Inbound logistics are about the movement of materials from the suppliers to the company, while outbound logistics is about the distribution of products from the company to the customers. Manufacturing logistics are related to the internal logistics operations within the company.

Logistics and distribution networks are designed based on the customer expectations and the supply chain strategy. Manufacturer storage with direct shipping, manufacturer storage with direct shipping and in-transit merge, distributor storage with carrier delivery and retail storage with customer pick-up are some of the mostly used distribution network structures.

LO 4 Understand different supply chain structures and coordination in supply chains.

The number of companies in a supply chain and their relations with each other are defined by the structure of the supply chain, which can vary from a simple serial supply chain to a broad network of entities. Some companies prefer a short and narrow supply chain in order to have more control over the supply chain activities, while others might to choose to work in a long and wide chain to decrease costs and increase service levels. The structure of the supply chain should be designed based on customer needs and the employed supply chain strategy.

There are different companies in a supply chain with varying relations with each other. It is not enough for each company just to focus on their internal operations, but they also need to coordinate their activities with their supply chain members in order to satisfy customer expectations and stay competitive in the market. Different supply chain members might have conflicting objectives with each other and supply chain performance without a proper coordination between these members might be lacking.

Contract mechanisms and strategic partnerships are two of the mostly used approaches to achieve coordination in supply chains. Contract mechanisms are used in decentralized supply chains in order to align supply chain members' objectives with each other and the whole supply chain. They are seen to be effective in increasing the profits of all involved parties and improving the supply chain performance as a whole. Strategic partnerships also help different companies to improve their profits by sharing critical information with each other and making decisions in a collaborative manner.

Bullwhip effect is a phenomena that tries to explain the increased variability in orders propagated to the front of the supply chain, as a result of small changes in customer demand. Demand forecasting, order batching, product rationing, product pricing and performance incentives are the major factors that are attributed to the cause of the bullwhip effect. Information sharing and strategic partnerships help to decrease this order variability, leading to better supply chain performances.

Summary

LO 5 Explain sustainability in supply chains.

In today's world customer expectations are changing and companies are expected to consider environmental and social effects of their decisions in addition to financial outcomes in order to achieve sustainability. Supply chains need to be managed with decreased emissions and supply chain operations need to be modified considering the new environmental and social regulations and legislations that arose throughout the world.

Traditional supply chains are generally forward looking and consider the distribution of products to the end customers. With the increased environmental concerns, companies started to engage in the collection of end of life products from the end users and aim to reuse them through repairing, remanufacturing and recycling operations. Closed-loop supply chain management aims to integrate the forward and reverse operations in supply chains. These operations can also provide financial benefits to the companies in addition to improving the sustainability in the supply chain and decreasing the carbon footprints.

1 Which of the following cycles is **not** one of the cycles considered in the cycle view of supply chains?

a. Customer Order Cycle
b. Replenishment Cycle
c. Manufacturing Cycle
d. Logistics Cycle
e. Procurement Cycle

2 Which one the followings is an advantage of a push system as compared to a pull system in supply chains?

a. Higher variety of products are produced.
b. Customers obtain the products in a short time.
c. Customized production is easier to be done.
d. Inventory costs are small.
e. Wastage risks of products are small

3 Which of the followings is **not** considered to be one of the abilities of responsive supply chains?

a. Meet short lead times
b. Handle a large variety of products
c. Minimize costs
d. Meet a high service level
e. Build highly innovative products

4 Which one of the followings is a strategic level decision in a supply chain?

a. Where should a manufacturing facility be built?
b. When should the company make a promotion?
c. How much inventory should be built for a product?
d. Which worker should be assigned to the manufacturing of a product?
e. What should be the due date for an order?

5 I- Logistics only deals with the distribution of products from the manufacturers to customers

II- Logistics coordinates material flow and information flow across the supply chain

III- Logistics is only a part of supply chain management

Which of the above statements related to logistics are correct?

a. Only I
b. Only II
c. I and II
d. II and III
e. I, II and III

6 Which one of the following distribution networks would be more appropriate to use for fast moving consumer products with high demand and low uncertainty?

a. Manufacturer storage with direct shipping
b. Manufacturer storage with direct shipping and in-transit merge
c. Distributor storage with carrier delivery
d. Distributor storage with direct shipments
e. Retail storage with customer pick-up

7 Which one of the followings **is not** a benefit that can be obtained with supply chain coordination?

a. Increase supply chain profitability
b. Decrease inventory costs
c. Increase production capacity
d. Decrease the bullwhip effect
e. Increase customer service levels

Test Yourself

8 Which one of the following approaches will **not** improve supply chain performance?

a. Decentralization
b. Strategic partnerships
c. Information sharing
d. Supply chain contracts
e. Collaborative forecasting

9 Which of the following are the main considerations for sustainability in supply chains?

a. Environmental considerations
b. Environmental and Social considerations
c. Economic and Environmental considerations
d. Economic and Social considerations
e. Economic, Environmental and Social considerations

10 Which one of the following entities does only exist in reverse supply chains?

a. Supplier
b. Manufacturer
c. Distributor
d. Recycler
e. Customer

1. d	If your answer is wrong, please review the "Basic Concepts in Supply Chain Management" section.
2. b	If your answer is wrong, please review the "Basic Concepts in Supply Chain Management" section.
3. c	If your answer is wrong, please review the "Basic Concepts in Supply Chain Management" section.
4. a	If your answer is wrong, please review the "Supply Chain Management Decisions" section.
5. d	If your answer is wrong, please review the "Supply Chain and Logistics" section.
6. e	If your answer is wrong, please review the "Supply Chain and Logistics" section.
7. c	If your answer is wrong, please review the "Supply Chain Structure and Coordination" section.
8. a	If your answer is wrong, please review the "Supply Chain Structure and Coordination" section.
9. e	If your answer is wrong, please review the "Sustainability in Supply Chains" section.
10. d	If your answer is wrong, please review the "Sustainability in Supply Chains" section.

self review 1

What are the main factors that define the right supply chain strategy?

Supply chain strategy determines how operations such as material procurement, transportation, manufacturing, distribution etc. will be done in the supply chain. This strategy is firstly defined by the expectations of target customers and their specific needs. For example, if customers want their product in a short time, faster transportation and distribution methods need to be used. Secondly, supply chain capability is a main factor in defining the supply chain strategy. Supply chain managers need to consider what can and can not be done within the supply chain constraints. Otherwise, the strategy can not be implemented and will not be of any use. Finally, characteristics of the products is another main factor. Depending on the product properties, different strategies might be used. For example, if the product is perishable in a short time, lower amounts of inventory might be required, in order to decrease wastage costs. The supply chain strategy should be designed to meet the target customer expectations, within the supply chain capabilities, considering the product characteristics.

Suggested Answers for "Self Review"

self review 2

What are the main reasons to keep inventories in supply chains?

Companies aim to satisfy customer demand at minimum cost, and for this purpose they sometimes need to keep certain levels of inventories. Firstly, due to uncertainties in demand, it can not be exactly known how many units will be required and thus companies keep inventories more than the average level to protect themselves against unexpected demand. In addition, there might be problems in the production process and as a precaution to such supply disruptions, extra inventory is carried in order to satisfy the demand during that period. Another reason for carrying inventory is economies of scale. Every time a company orders materials from its suppliers, there will be some ordering and transportation cost. Thus, it would not be economical to give very small orders due to these fixed costs. Companies generally buy in larger quantities to save from ordering and transportation costs, but this leads to inventory accumulation. A third reason to carry inventories is to smooth the production levels. If the demand varies across time periods, companies can change their production rate, however this requires a change in the number of workers and machine utilization. Instead, it might be more economical to produce at the same average rate at all periods without changing the number of workers. The inventory will be built up during low demand periods and it will be used when demand increases and exceeds the production rate. Finally, some companies carry inventory considering expected price changes in the future. If they expect a price increase in the near future, they buy more than what they need, leading to inventory accumulation.

self review 3

What are the product, customer and system characteristics required for manufacturer storage with direct shipping to be appropriate to use?

Manufacturer storage with direct shipping would be appropriate to use mainly for customized products with high demand uncertainty. The manufacturer can produce different varieties of the product according to customer needs, however this requires a certain time period. Customers should be willing to wait for some time to obtain their orders. In addition, since every order is shipped separately, transportation or cargo costs should be relatively small with respect to the value of the product. Companies generally need to have advanced information systems to handle online sales and transactions. However, they save from facility and inventory costs in this setting.

What are the main approaches used to achieve coordination in supply chains?

self review 4

Contract mechanisms and strategic partnerships are two of the mostly used approaches to achieve coordination in supply chains. Contract mechanisms define the relationship between members of a supply chain through written agreements. Parameters used in contracts aim to coordinate the decisions of the supply chain members such that the resulting performance is improved and both parties obtain higher profits. Strategic partnerships are developed between supply chain members in order to coordinate their activities with the aim of improving the supply chain performance. Strategic partners are expected to share critical information with each other and make operational decisions collaboratively, such that these decisions will benefit both parties.

What are the main activities that do not exist in traditional forward supply chains, but are considered in closed-loop supply chain management?

self review 5

Collection of used products, product recovery, repairing, recycling, remanufacturing and disposal operations are the main activities that receive considerable attention in the last years in the context of closed-loop supply chain management. Traditional forward supply chains are mainly interested about the distribution of products from the supplier side to the end customer and do not consider collection or re-use of these products. However, closed-loop supply chain management includes collection and re-use (or disposal if they can not be re-used) of these products once their lives are completed at the end customer. Closed-loop supply chain management aims to integrate the forward and reverse supply chain operations in order to improve the sustainability and the profitability of the supply chain.

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