Introduction to Operations Management

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Contents

Acknowledgements

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1. Introduction to Operations Management

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Learning Objectives

- What is Operations Management?
- Describe the transformation process and some categories.

- Why should a business student study Operations Management?
- What are some of the Professional Organizations involved in Operations Management?
- Describe each of the three phases of Operations Management history.
- Discuss how producing goods is different from performing services.

This chapter is an adaptation of two courses, Saylor's BUS 300 (Operations Management) and The Open University's Understanding Operations Management.

Operations management is a vast topic but can be bundled into a few distinct categories, each of which will be covered in later units. (It should be noted that entire courses could be devoted to each of these topics individually). Since most people do not work in a formal operations department, we will begin with an overview of operations management itself.

The top manager of an operations department is usually called the **Director of Operations**.

Most operations departments will report to a **Chief Operating Officer** (COO), who reports to the **Chief Executive Officer** (CEO).

The COO is often considered the most important figure in a firm, next to the CEO.

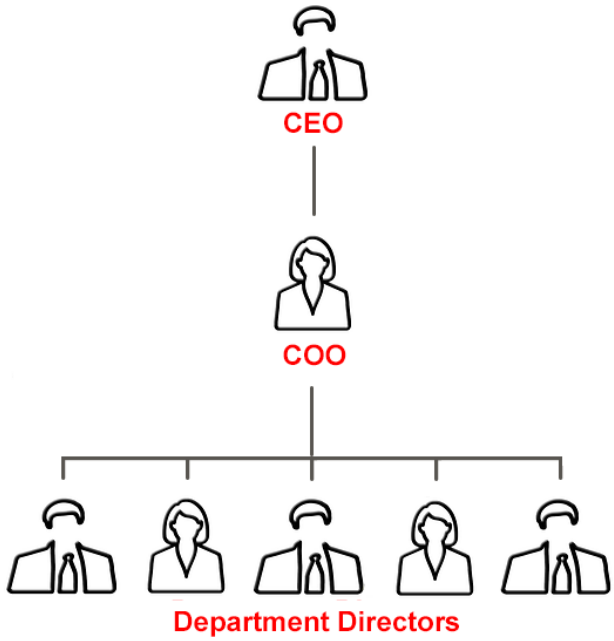

Figure 1.1: A diagram of corporate hierarchy.

The history of operations management can be traced back to the industrial revolution when production began to shift from small, local companies to large-scale production firms. One of the most significant contributions to operations management came in the early 20th century when Henry Ford pioneered the assembly line manufacturing process. This process drastically improved productivity and made automobiles affordable to the masses. Understanding the motivations behind innovations of the past can help us identify factors that may motivate individuals in the future of operations management.

What is Operations Management?

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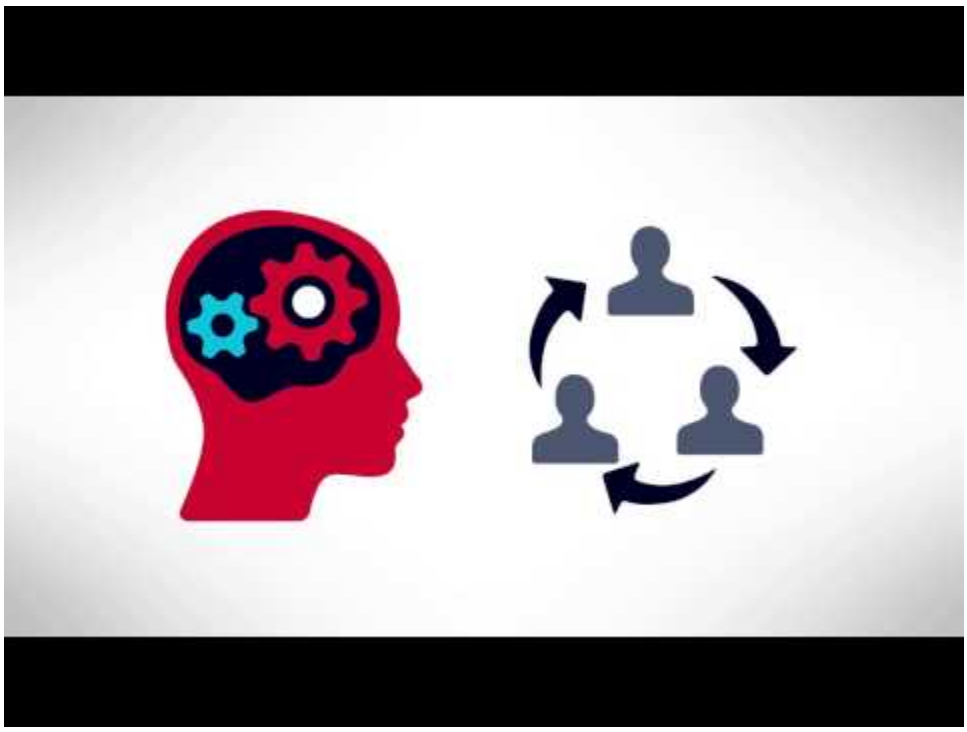
Operations management is the management of the processes that transform inputs into the goods and services that add value for the customer. Consider the ingredients of your breakfast this morning. Unless you live on a farm and produced them yourself, they passed through a number of different processing steps between the farmer and your table and were handled by several different organizations.

Every day, you use a multitude of physical objects and a variety of services. Most of the physical objects have been manufactured and most of the services have been provided by people in organizations. Just as fish are said to be unaware of the water that surrounds them, most of us give little thought to the organizational processes that produce these goods and services for our use. The study of operations deals with how the goods and services that you buy and consume every day are produced.

The following video shows some of the basic strategic areas in operations management. We will cover some of these areas in addition to some tools and techniques used in operations management.



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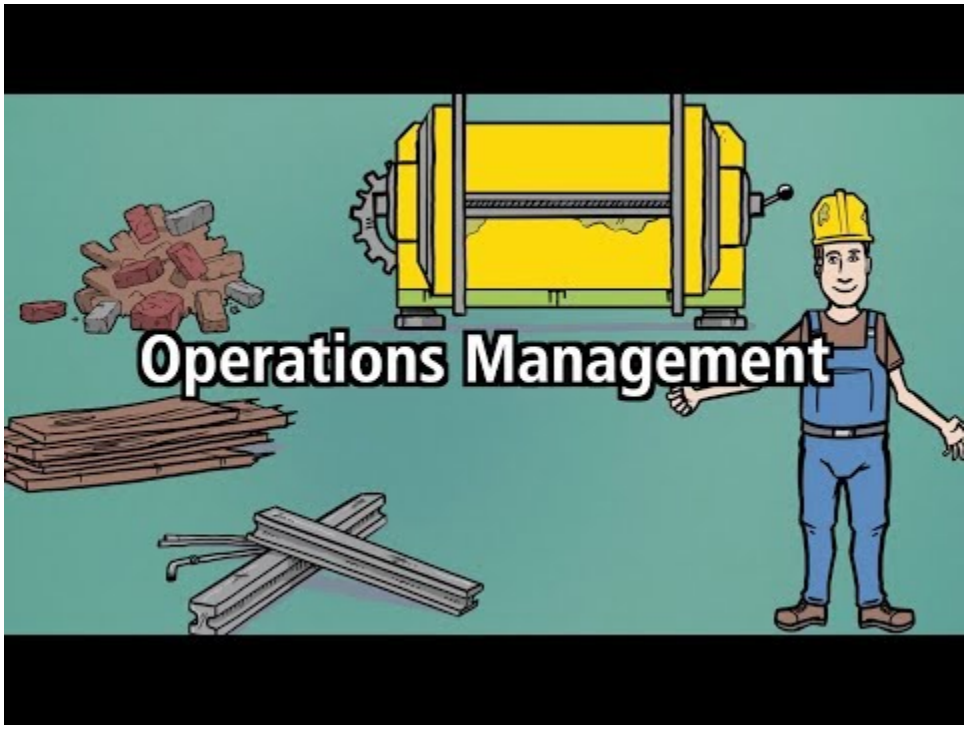
Transformation Processes



A YouTube element has been excluded from this version of the text. You can view it online here: *https://pressbooks.senecacollege.ca/operationsmanagement/?p=44*

A **transformation process** is any activity or group of activities that takes one or more inputs, transforms and adds value to them, and provides outputs for customers or clients. Where the inputs are raw materials, it is relatively easy to identify the transformation involved, such as when milk is transformed into cheese or butter. Where the inputs are information or people, the nature of the transformation may be less obvious. For example, a hospital transforms ill patients (the input) into healthy patients (the output).

Examples of Transformation Processes

- changes in the physical characteristics of materials or customers
- changes in the location of materials, information or customers
- changes in the ownership of materials or information
- storage or accommodation of materials, information or customers
- changes in the purpose or form of information
- changes in the physiological or psychological state of customers

Often all three types of **input** – materials, information and customers – must be transformed by a single organisation. For example, withdrawing money from a bank account involves information about the customer's account, materials (such as cheques and currency), and the customer. Treating a patient in hospital involves not only the "customer's" state of health, but also any materials used in treatment and information about the patient.

As Figure 1.2 demonstrates, transformation processes can be categorized into four groups: manufacture (the physical creation of products, e.g. automobiles), service (the treatment of customers or storage of products, e.g. hospitals or warehouses), supply (a change in ownership of goods, e.g. retail), and transport (the movement of materials or customers, e.g. taxi service).

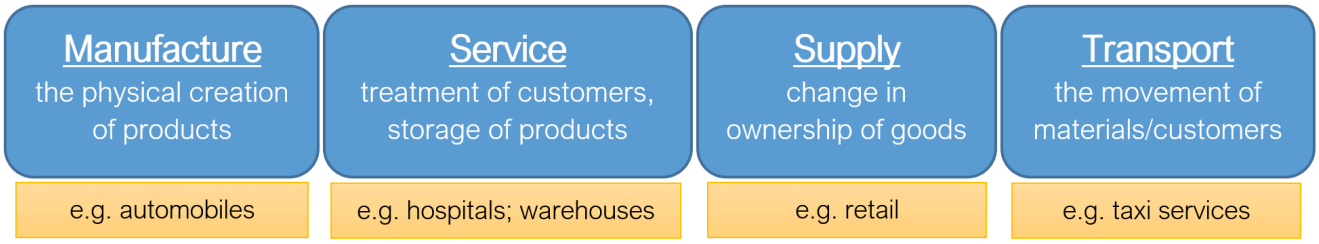


Figure 1.2: Categories of transformation processes.

Several different transformations are usually required to produce a good or service. The overall transformation can be described as the **macro operation**, and the more detailed transformations within this macro operation as **micro operations**. For example, the macro operation in a brewery is making beer (Figure 1.3). The micro operations include:

- milling the malted barley into grist
- mixing the grist with hot water to form wort
- cooling the wort and transferring it to the fermentation vessel
- adding yeast to the wort and fermenting the liquid into beer
- filtering the beer to remove the spent yeast
- decanting the beer into casks or bottles.

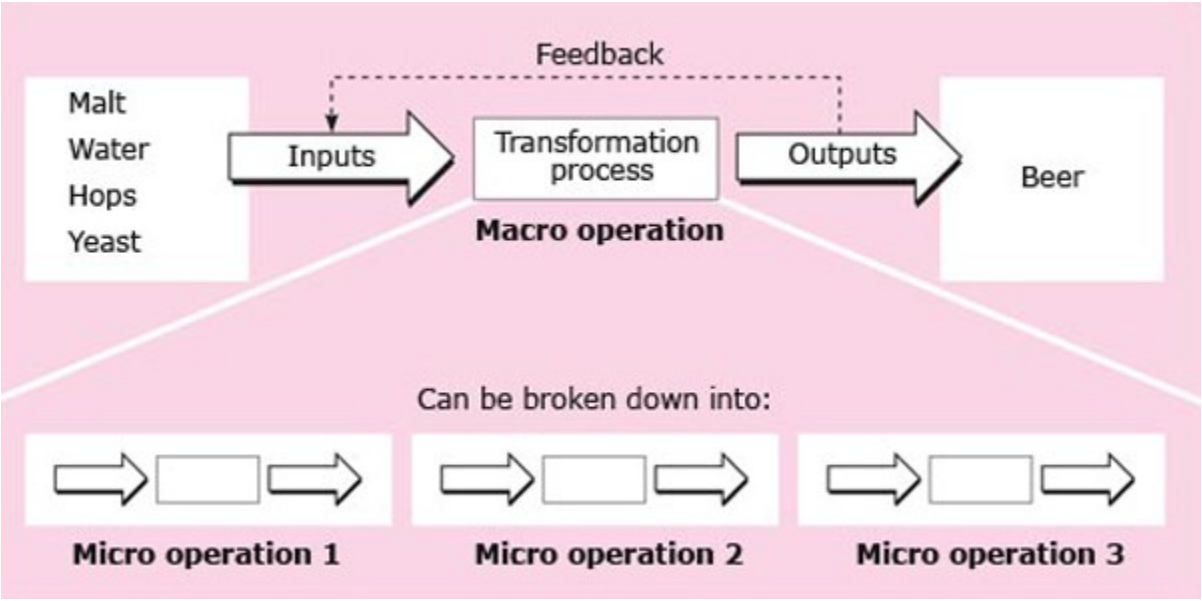


Figure 1.3: Macro and micro operations (transformation processes); Credit: The Open University / open.edu

The Operations Function

Every organization has an operations function, whether or not it is called 'operations'. The goal or purpose of most organizations involves the production of goods and/or services. To do this, they have to procure resources, convert them into outputs and distribute them to their intended users. The term **operations** embraces all the activities required to create and deliver an organization's goods or services to its customers or clients.

Within large and complex organizations, operations is usually a major functional area, with people specifically designated to take responsibility for managing all or part of the organization's operations processes. It is an important functional area because it plays a crucial role in determining how well an organization satisfies its customers. In the case of private-sector companies, the mission of the operations function is usually expressed in terms of profits, growth and competitiveness; in public and voluntary organizations, it is often expressed in terms of providing value for money.

Operations management is concerned with the design, management, and improvement of the systems that create the organization's goods or services. The majority of most organizations' financial and human resources are invested in the activities involved in making products or delivering services. Operations management is therefore critical to organizational success.

Other functions of the Business :

A typical organization has four distinct basic functional areas; operations, marketing and sales, finance, and human resources. Operations is the area that is responsible for directly creating the product or service for which the customer will pay. The other three departments ensure that the operations of the business has everything needed in order to do the work.

Marketing – ensures that operations is producing the right product or service in a way that provides customers with all the features or characteristics that they value.

Finance – ensures that the funds for materials, supplies, payroll and equipment are available when needed.

Human Resources – ensures that the correct employees, with the adequate skills and experience are recruited, hired and trained. They are responsible for compensation, collection of income taxes, administration of benefits, succession planning and more. Without HR, there would be no employees in the operations department.

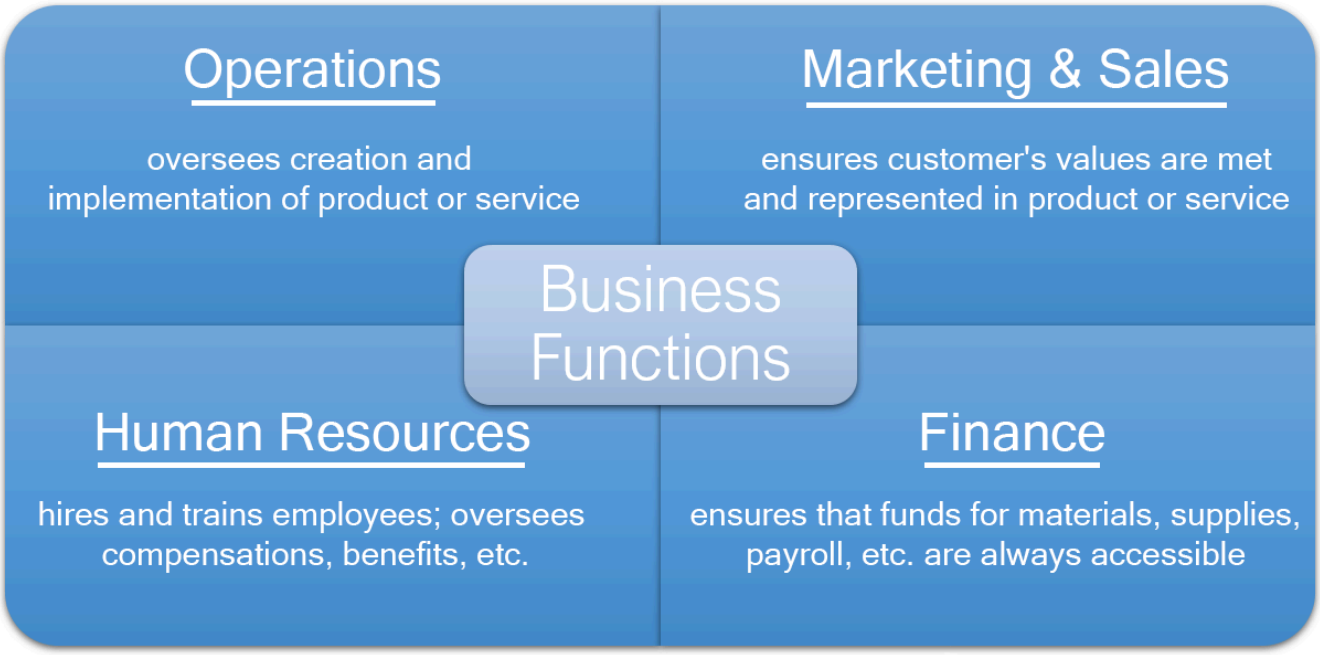


Figure 1.4: Business functions of departments.

Why should I study Operations Management?

In most organizations, operations tends to be the largest department in terms of the number of employees. For a new graduate, you may be smart to look for a position within the operations of a business. In a larger company these jobs are far more plentiful than those in smaller departments. If you have a passion for working for a large organization, you might want to focus more on which organization you go to work for, and less focus on the actual job title. Soon enough, if you're punctual, energetic and proactive, you will likely apply or get promoted into the job you desire.

Operations is where the largest share of the firm's dollars are spent. It is a huge focus of top management.

All other departments in the organization are interrelated with operations. In finance, marketing and human resources, you will be interacting with operations on a regular basis. You should understand the businesses' core transformation process regardless of the department in which you work.

Major innovations are made through operations. If you look at successful companies such as Toyota, Amazon, or Dell, you will find that the keys to their success came from innovations to the operations processes of their businesses.

Operational innovation means coming up with entirely new ways of filling orders, developing products, providing customer service, or doing any other activity that an enterprise performs.
As a new grad in an organization, you will find that every business is looking for new ideas, tools, and improvement suggestions in order to improve on the effectiveness and the efficiency of the business.

- **Effectiveness** refers to making the right actions and plans in order to improve the business and add value for the customer. It is helping to get the business doing the right things for the customer.
- **Efficiency** is different. To be efficient means doing things well at the lowest cost possible. To be efficient, we look for ways to reduce unnecessary or redundant activities that add unnecessary cost and could be avoided.

Often, decisions that must be made will involve a trade-off between effectiveness and efficiency. Consider the decision to hire an extra full time server in a restaurant. The service may be faster and customers will feel as though their server was more attentive to their table. However, this comes at a higher cost, which is a reduction in efficiency.
We think of value as the relationship between quality and price. If we can provide the customer with a better quality product at the same price point, then that is adding value. If we are able to provide the same product but at a lower price, then the customer wins again.

Resources for Operations Management learners and professionals:

- Supply Chain Management Association (SCMA)
- Canadian Institute of Traffic and Transportation (CITT)
- Association for Supply Chain Management (APICS)
- American Society for Quality (ASQ)
- Project Management Institute (PMI)

Activity:

Look at ONE of the Associations above and answer the following questions:

1. Is this organization Canadian, or multinational?
2. Is there an opportunity for students to join? If yes, is there a fee, and how much?
3. Are there opportunities for networking and to meet professionals?
4. Do they offer job search assistance?
5. Would you consider joining either of these organizations? Why or why not?

Development of Operations Management

Operations in some form have been around as long as human endeavor itself but, in manufacturing at least, it has changed dramatically over time, and there are three major phases – craft manufacturing, mass production and the modern period. Let's look at each of these briefly in turn.

Craft manufacturing

Craft manufacturing describes the process by which skilled craftspeople produce goods in low volume, with a high degree of variety, to meet the requirements of their individual customers. Over the centuries, skills have been transmitted from masters to apprentices and journeymen, and controlled by guilds. Craftspeople usually worked at home or in small workshops. Such a system worked well for small-scale local production, with low levels of competition. Some industries, such as furniture manufacture and clock-making, still include a significant proportion of craft working.

Mass production

In many industries, craft manufacturing began to be replaced by **mass production** in the 19th century. Mass production involves producing goods in high volume with low variety – the opposite of craft manufacturing. Customers are expected to buy what is supplied, rather than goods made to their own specifications. Producers concentrated on keeping costs, and hence prices, down by minimizing the variety of both components and products and setting up large production runs. They developed aggressive advertising and employed sales forces to market their products.

An important innovation in operations that made mass production possible was the system of standardized and interchangeable parts known as the "American system of manufacture" (Hounshell, 1984), which developed in the United States and spread to the United Kingdom and other countries. Instead of being produced for a specific machine or piece of equipment, parts were made to a standard design that could be used in different models. This greatly reduced the amount of work required in cutting, filing and fitting individual parts, and meant that people or companies could specialize in particular parts of the production process.

A second innovation was the development by Frederick Taylor (1911) of the system of 'scientific management', which sought to redesign jobs using similar principles to those used in designing machines. Taylor argued that the role of management was to analyze jobs in order to find the 'one best way' of performing any task or sequence of tasks, rather than allowing workers to determine how to perform their jobs. By breaking down activities into tasks that were sequential, logical and easy to understand, each worker would have narrowly defined and repetitious tasks to perform, at high speed and therefore with low costs (Kanigel, 1999).

A third innovation was the development of the moving assembly line by Henry Ford. Instead of workers bringing all the parts and tools to a fixed location where one car was put together at a time, the assembly line brought the cars to the workers. Ford thus extended the ideas of scientific management, with the assembly line controlling the pace of production. This completed the development of a system through which large volumes of standardized products could be assembled by unskilled workers at constantly decreasing costs – the apogee of mass production.

The modern period

Mass production worked well as long as high volumes of mass-produced goods could be produced and sold in predictable and slowly changing markets. However, during the 1970s, markets became highly fragmented, product life cycles reduced dramatically, and consumers had far greater choice than ever before.

An unforeseen challenge to Western manufacturers emerged from Japan. New Japanese production techniques, such as total quality management (TQM), just-in-time (JIT) and employee involvement were emulated elsewhere in the developed world with mixed results. More recently, the mass production paradigm has been replaced, but there is yet no single approach to managing operations that has become similarly dominant. The different approaches for managing operations that are currently popular include:

- **Flexible specialization** (Piore and Sabel, 1984) in which firms (especially small firms) focus on separate parts of the value-adding process and collaborate within networks to produce whole products. Such an approach requires highly developed networks, effective processes for collaboration and the development of long-term relationships between firms.
- **Lean production** (Womack et al., 1990) which developed from the highly successful Toyota Production System. It focuses on the elimination of all forms of waste from a production system. A focus on driving inventory levels down also exposes inefficiencies, reduces costs, and cuts lead times.
- **Mass customisation** (Pine et al., 1993) which seeks to combine high volume, as in mass production, with adapting products to meet the requirements of individual customers. Mass customisation is becoming increasingly feasible with the advent of new technology and automated processes.
- **Agile manufacturing** (Kidd, 1994) which emphasizes the need for an organization to be able to switch frequently from one market-driven objective to another. Again, agile manufacturing has only become feasible on a large scale with the advent of enabling technology.

In various ways, these approaches all seek to combine the high volume and low cost associated with mass production with the product customization, high levels of innovation and high levels of quality associated with craft production.

	CRAFT MANUFACTURING (PRIOR TO LATE 1800)	MASS PRODUCTION (LATE 1800-1970)	THE MODERN PERIOD (1970-PRESENT)
PRODUCTION	Low volume	High volume	High volume
VARIETY	Maximal	Minimal	Dependant on company's goals
FOCUS	Meet specific requirements of customers	Low costs and prices, standardization of materials and production	Low costs, adaptability within market, innovation, high quality
WORKERS	Highly skilled and specialized individuals	Many (usually unskilled) individuals with narrowly defined tasks	Dependant on company's goals
FACILITY	Home or small workshops	Fixed locations with assembly lines	Dependant on company's goals
COMPETITION	Low	High	Very high

Figure 1.5: A chart summarizing characteristics of craft manufacturing, mass productions, and the modern period.

Producing Goods and Services

The production and goods and the performance of services are both part of operations management. There are however some key differences in the two.

In the production of goods the result is the creation of a tangible product such as a vehicle, an article of clothing, a cell phone or a shovel. A service on the other hand is an intangible such as a car repair, a haircut, or a medical treatment. There are some key differences in managing these two types of businesses.

1. Services have a much higher amount of customer contact. The customer will generally come to the service provider for the service to take place, or the service provider will come to the customer.
    - In manufacturing the customer rarely comes to our facility. The purchase generally takes place at a different location than the one where the manufacturing occurred. That simplifies matters quite a bit.
2. Services have a higher amount of labour content than manufacturing organizations.
3. Services have a much higher degree of input variability than do manufacturing companies. Each customer often arrives to a service with a unique set of circumstances that may require extra time and skills on the part of the service provider.
4. Measurement of quality is much more straight-forward in a manufacturing setting. There are many technical ways of deciding if manufactured goods have the required quality level.
    - In services many factors will affect the customers impression of the quality of the service received.
5. Measurement of productivity is very straight-forward in a manufacturing operation due to high degree of standardization in the inputs and outputs used.
    - In services it is more difficult to measure productivity.
6. Inventory can be stored in the case of a manufacturing organization. If goods are not sold in the intended week, then they can be put into storage to be sold at a later date.
    - In services, once the time period has passed, the opportunity to use that capacity is gone.

Chapter Key Terms:

Agile manufacturing – Emphasizes the need for an organization to be able to switch frequently from one market-driven objective to another.

Craft manufacturing – The production of goods in low volume, but with a high degree of variety, performed by skilled, specialized craftspeople to meet the requirements of their individual customers.

Effectiveness – Making the right actions and plans in order to improve the business and add value for the customer.

Efficiency – Doing things well at the lowest cost possible and reducing activities which add unnecessary costs.

Flexible specialization – Firms (especially small firms) focus on separate parts of the value-adding

process and collaborate within networks to produce whole products. Such an approach requires highly developed networks, effective processes for collaboration and the development of long-term relationships between firms.

Lean production – Focuses on the elimination of all forms of waste from a production system, especially from the perspective of keeping inventory levels down to exposes inefficiencies, reduces costs, and cuts lead times.

Macro operations – The overall process within a company's transformation processes, e.g. in a brewery, the macro operation is making beer.

Mass customisation – Seeks to combine high volume, as in mass production, with adapting products to meet the requirements of individual customers.

Mass production – The production of goods in high volume with low variety by using standardized parts, a system of scientific management, and assembly lines; rose in popularity in the 19th century.

Micro operations – The detailed transformations that must occur, usually in a specific sequence, for a company to complete their macro operation.

Operations management – The design, management, and improvement of the systems and processes that create the organization's goods or services.

Transformation process – Any activity or group of activities that takes one or more inputs, transforms and adds value to them, and provides outputs for customers or clients, e.g. milk (input) being transformed into cheese or butter (outputs).

2. Operations Strategy and Competitiveness

Learning Objectives

- Explain each of the key purchasing criteria.
- Differentiate between order qualifiers and order winners.
- Understand the four competitive priorities and common strategies firms use to achieve these priorities.
- Describe the term ‘core competency.’
- Describe the three levels of strategy.
- Know the six categories of operations strategy categories.
- Calculate productivity measures including partial, multi-factor and total productivity.

Competitiveness

We have all competed in various types of activities, perhaps in sports, or school. There may have been prizes or rewards for ranking high in these competitions. Business is no different. We define **competitiveness** as the ability and performance of a firm to sell and supply goods and services in a given market, in relation to the ability and performance of other firms.[1] In other words, how will one firm win over customers in order to become the product or service of choice.

Competitive Advantage and Key Purchasing Criteria

Competitive advantage is the leverage a business has over its competitors. This can be gained by offering clients better and greater value. Advertising products or services with lower prices or higher quality piques the interest of consumers. This is the reason behind brand loyalty, or why customers prefer one particular product or service over another.[2]

Each organization needs to have a deep understanding of their customers and what drives their customers to make purchases. We refer to these as **key purchasing criteria**. They are the factors which customers evaluate and consider when making a product choice.

It is important to keep in mind that the customer is not always a consumer purchasing a good at a store. The customer in many instances may be another business. The city of Toronto may be purchasing heavy duty trucks to use in the landscaping of city parks or Toyota may be searching for a new supplier for automobile glass.

Key Purchasing Criteria include:

Price – Firms need to understand how much the customer will pay for an item. If products are seen to be very similar to one another, the customer will choose based on price.

Quality – Many customers are willing to spend more in order to obtain a product with specific characteristics or brand reputation. Not only are we considering a product with a great design, but also, one that is long lasting and defect free.

Variety – There is a part of the market that value the opportunity to choose from a wide variety of products. They look for options to change the style, colour, dimensions or technical characteristics.

Timeliness – Some customers care greatly about how long it will take to obtain the product or service. For companies' in the transportation business, this will be a key necessity in order to gain new customers. This can also be related to the capability of the company to deliver at the time that they had promised.

1. Wikipedia contributors. (2019). Competition (companies). In *Wikipedia, The Free Encyclopedia*. Retrieved on January 6, 2020, from https://en.wikipedia.org/w/index.php?title=Competition_(companies)&oldid=920132676
2. Wikipedia contributors. (2019). Competitive advantage. In *Wikipedia, The Free Encyclopedia*. Retrieved on January 6, 2020, from https://en.wikipedia.org/w/index.php?title=Competitive_advantage&oldid=923650944

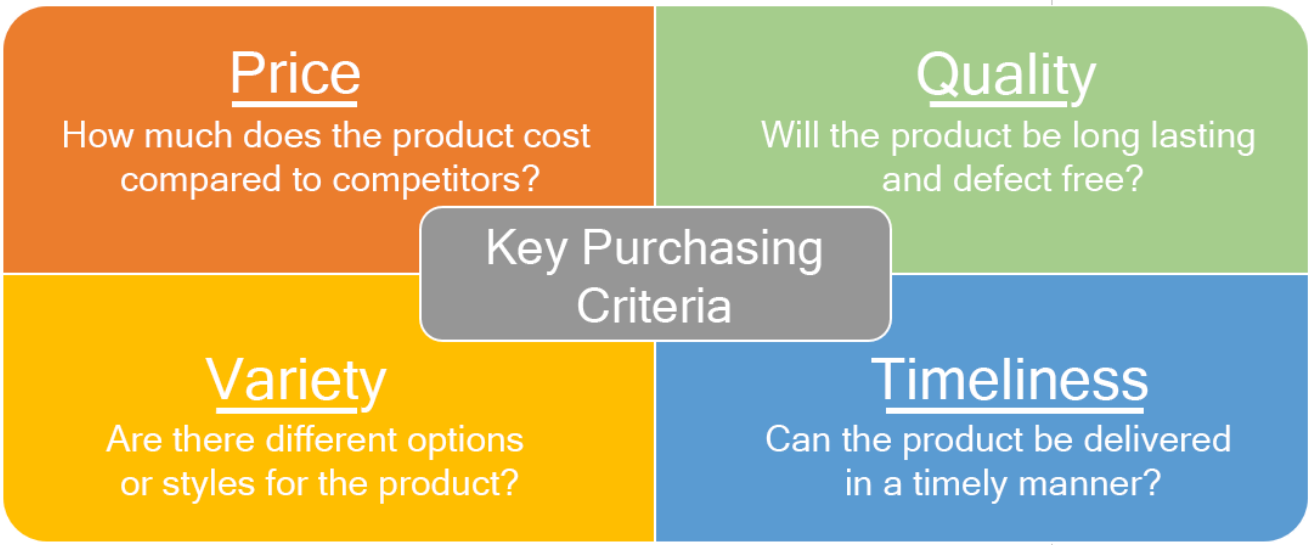


Figure 2.1: Categories of key purchasing criteria.

Order qualifiers versus order winners

Two concepts related to key purchasing criteria are order qualifiers and order winners, first introduced by Terry Hill.[3] For important purchases, the customers will consider which characteristics are absolutely necessary (nonnegotiable) and which characteristics can actually lead them to make their decision.

Order qualifiers are those characteristics that are "the nonnegotiable requirements" of the customer. Unless these characteristics are part of the product or service package, the customer will look elsewhere. Order qualifiers for a car may include and minimum safety features, and air conditioning.

An **order winner** is the characteristic that wins the order. Often it may be a new technical feature that is desirable. It could be a great warranty package or service agreement, or a better price.

Order qualifiers and order winners change over time. What was an order winner some years ago, may now become an order qualifier and vice versa. In 1989, air conditioning in a car might have been considered an order winner. It was new and desirable. In 2020 however, few customers purchasing a new car would consider buying a car without air conditioning. It has therefore changed from an order winner to an order qualifier.

Marketing must understand what the order qualifiers and order winners are for their customers. Operations must respond promptly to ensure that they are making these options and features available to customers.

Competitive Priorities

The competitive priorities are the ways in which the Operations Management function focuses on the characteristics of cost, quality, flexibility and speed. The firm's customers will determine which of the competitive priorities are emphasized.

3. Hill, T. (2000). *Manufacturing Strategy: Text and Cases*. 3rd ed. New York: McGraw-Hill.

Cost – Firms whose customers prioritize price will be very interested in having processes that enable them to keep their costs low. These companies are typically paying close attention to identifying and eliminating waste within their operations. By reducing defects, they will reduce costs. These firms will closely monitor and seek to improve their productivity. Factors such as resource utilization and efficiency will be important.

Quality – Firms whose customers prioritize quality focus on creating both excellent product and process design. Marketing and Engineering collaborate to design products that meet customers' requirements. Manufacturing must ensure that the process is able to produce the products defect-free. It is only by having excellent design quality and excellent process quality that the organization can ensure that customers will have their expectations satisfied.

Flexibility – Firms whose customers prioritize variety must prioritize the ability to change rapidly. Firms who value flexibility usually do so by carefully choosing equipment that is general-purpose and able to perform multiple functions. They will often strive to keep a small amount of spare capacity in case it is needed. Multi-skilled employees who are able to work in various areas of the firm or operate multiple types of technology are valued. These firms want to ensure that they can get new products to market quickly and transition from making one product to another quickly. Keeping machine set-ups fast is a critical way to do this. They also strive to be able to abruptly modify the volume of their output in case the need or opportunity arises.

Delivery (reliability and speed) – Firms whose customers prioritize speed of product/service delivery must be very efficient and quick at providing their products and services. McDonald's and Amazon are examples of this.

Below is a table summarizing the relationship between a customer's priority and a firm's strategy.[4][/footnote]

Customer's priority	Firm's strategy
Cost	Minimizing product costs and waste, maximizing productivity
Quality	Designing superior, durable products, minimizing defects
Flexibility	Adaptability in product design and output, utilizing general-purpose machinery and multi-skilled workers
Delivery	Maintaining reliable and speedy delivery services

It is a long-held understanding that each major decision that needs to be made within the operations of an organization will include a trade-off because it is impossible for any one organization to excel on all the competitive priorities at once! An example is a manufacturer who competes on the basis of cost. In order to reduce defects, they may choose to change one of their input components for one with a better quality. This however will increase their costs. Cost and quality are common trade-offs. Flexibility and speed are also considered trade-offs. When organizations increase their number of options and varieties, it adds operational complexity. This will slow down their operations.

4. [footnote]Garo Junior, W., & Guimarães, M. (2018). COMPETITIVE PRIORITIES AND STRATEGIC ALIGNMENT AS MEDIATORS IN THE RELATIONSHIP BETWEEN COMPANIES IN THE BRAZILIAN AUTOMOTIVE SUPPLY CHAIN. The South African Journal of Industrial Engineering, 29(1), 184-194. doi:https://doi.org/10.7166/29-1-1791

Core Competency (Core Capabilities)

Core competency is a management theory that originated in a 1990 Harvard Business Review article, "The Core Competence of the Corporation."

Core competencies are the resources and capabilities that comprise the strategic advantages of a business. A modern management theory argues that a business must define, cultivate, and exploit its core competencies in order to succeed against the competition.

- Core competencies are the defining characteristics that make a business or an individual stand out from the competition.
- Identifying and exploiting core competencies are as important for a new business making its mark as for an established company trying to stay competitive.
- A company's people, physical assets, patents, brand equity, and capital all can make a contribution to a company's core competencies.

A successful business has identified what it can do better than anyone else, and why. Its core competencies are the "why."

Defining Core Competencies

In the article, C.K. Prahalad, and Gary Hamel review three conditions a business activity must meet in order to be a core competency:

- The activity must provide superior value or benefits to the consumer.
- It should be difficult for a competitor to replicate or imitate it.
- It should be rare.

Some examples of core competencies:

- McDonald's has standardization. It serves nine million pounds of French fries every day, and every one of them has precisely the same taste and texture.
- Apple has style. The beauty of its devices and their interfaces gives them an edge over its many competitors.
- Walmart has buying power. The sheer size of its buying operation gives it the ability to buy cheap and undersell retail competitors.[5]

5. Twin, A. (2019). Core Competencies. Retrieved on January 6, 2020, from https://www.investopedia.com/terms/c/core_competencies.asp

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.senecacollege.ca/operationsmanagement/?p=41

Strategy

The Strategy Hierarchy

In most corporations, there are several levels of management. Strategic management is the highest of these levels in the sense that it is the broadest and applies to all parts of the firm while also incorporating the longest time horizon. It gives direction to corporate values, corporate culture, corporate goals, and corporate missions. Under this broad corporate strategy there are typically business-level competitive strategies and functional unit strategies.[6]

6. Francis, A. (2011). Business Strategy Hierarchy. Retrieved on January 6, 2020, from https://www.mbaknol.com/strategic-management/business-strategy-hierarchy/

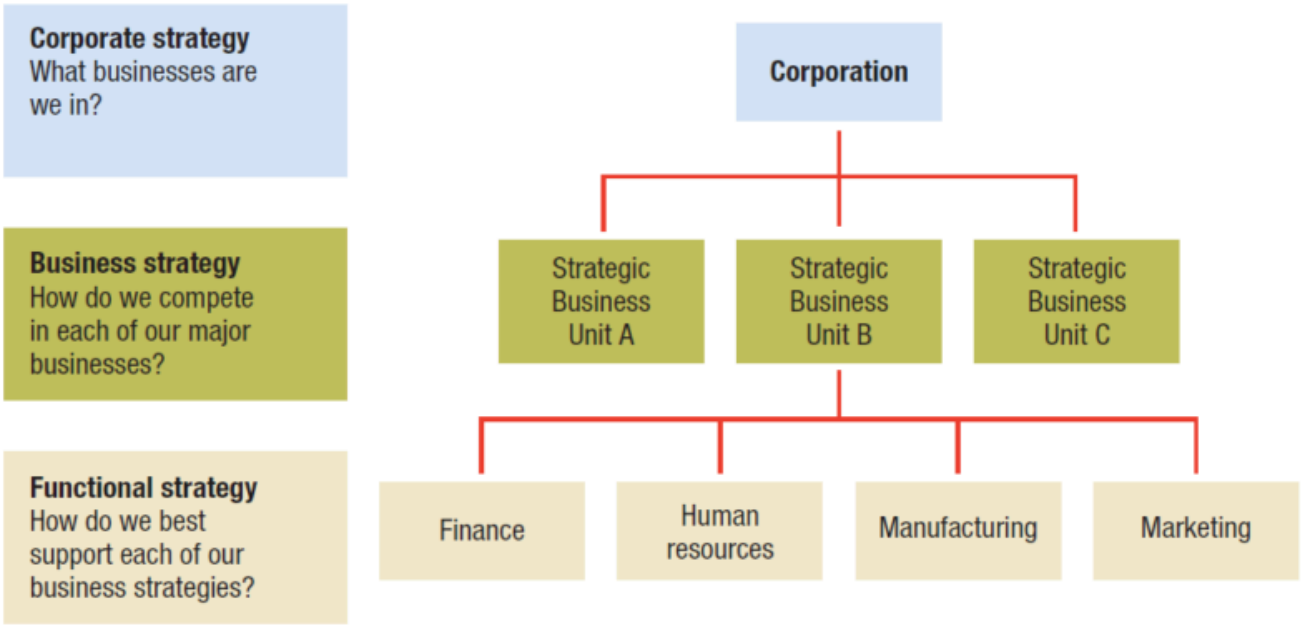


Figure 2.2: A hierarchical diagram detailing different strategies within a corporation; Credit: Abey Francis; https://www.mbaknol.com/strategic-management/business-strategy-hierarchy/

Corporate strategy refers to the overarching strategy of the diversified firm. Such a corporate strategy answers the questions of "in which businesses should we compete?" and "how does being in these businesses create synergy and/or add to the competitive advantage of the corporation as a whole?"

Business strategy refers to the aggregated strategies of a single business firm or a strategic business unit (SBU) in a diversified corporation. According to Michael Porter, a firm must formulate a business strategy that incorporates either cost leadership, differentiation or focus in order to achieve a sustainable competitive advantage and long-term success in its chosen arenas or industries.

Functional strategies include marketing strategies, new product development strategies, human resource strategies, financial strategies, legal strategies, supply-chain strategies, and information technology management strategies. The emphasis is on short- and medium-term plans and is limited to the domain of each department's functional responsibility. Each functional department attempts to do its part in meeting overall corporate objectives, and hence to some extent their strategies are derived from broader corporate strategies.

Many companies feel that a functional organizational structure is not an efficient way to organize activities, so they are reengineered according to processes or SBUs. A **strategic business unit** is a semi-autonomous unit that is usually responsible for its own budgeting, new product decisions, hiring decisions, and price setting. An SBU is treated as an internal profit centre by corporate headquarters.

An additional level of strategy called **operational strategy** was encouraged by Peter Drucker in his theory of Management By Objectives (MBO). It is very narrow in focus and deals with day-to-day operational activities

such as scheduling criteria. Operational level strategies are informed by business level strategies which, in turn, are informed by corporate level strategies.[7]

Operations strategy categories can be broken down into many types of areas that must be addressed. The decisions made in these areas will determine whether the business strategy is executed. Below is a list of 10 critical decisions in operations management[8]:

1. **Design of Goods and Services** – The actual design of the product or service will have the largest impact on the cost to produce and the quality to achieve.
2. **Quality** – The way in which the organization will ensure that the product specifications are met. This may include the use of statistical process control, total quality management or Six Sigma.
3. **Process and Capacity Design** – The type of product along with its volume and variety will have the major impact on which type of process to be chosen.
4. **Location** – Important decisions such as how many locations and where to locate them are critical to organization success. This will be a major factor in terms of how quickly the transformation process can take place, and how quickly goods can be shipped to customers.
5. **Layout Design and Strategy** – Consider the placement of work centres, movement of goods, people and information How materials are delivered and used.
6. **Human Resources and Job Design** – Decisions regarding training for employees, how to motivate employees to achieve operational success.
7. **Supply Chain Decisions** – Decisions in terms of where suppliers are located and the level of supplier collaboration are major considerations that impact cost and delivery speed.
8. **Inventory** – How will inventories be used and controlled in the business and the supply chain
9. **Scheduling** – includes both how to schedule production, resources and employees in order to be effective, efficient and meet commitments to customers.
10. **Maintenance**– This involves maintaining equipment and machinery as well as keeping quality high and processes stable.

Common Operations Strategies

There are many types of Operations strategies; two of the most common are quality-based strategies and time-based strategies.

Quality-based strategies are commonly used when companies wish to elevate their reputation in the marketplace. Improving on their product design and the reduction of errors are the backbone of these initiatives. Firms will often use programs such as ISO9001, Six Sigma, and Total Quality Management in their efforts.

Time-based strategies are used to reduce lead time, which is the amount of time elapsed from the receipt of the customer's order until the products are shipped. Firms that can produce faster will often have lower costs. These companies may use lean production methods to improve the velocity of their processes.

7. Business Strategy/Approaches to Strategic Management. (2017). *Wikibooks, The Free Textbook Project*. Retrieved on January 6, 2020, from https://en.wikibooks.org/w/index.php?title=Business_Strategy/Approaches_to_Strategic_Management&oldid=3337918
8. Kettering University. (2018). 10 Critical Decisions of Operation Management. Retrieved on January 6, 2020, from https://online.kettering.edu/news/2018/05/11/10-critical-decisions-operations-management

Productivity

In operations, we love to measure. One of the key ways we judge our operational performance is by using a simple wholistic measure, which is productivity.

Productivity is referred to as a relative measure. It has little meaning in isolation but does tell a story when it is compared to the previous period, or to a similar department or organization. The key thing we pay attention to is whether the productivity has improved or declined or stayed the same. Let's look at several types of productivity measures, and how to calculate the percent change.

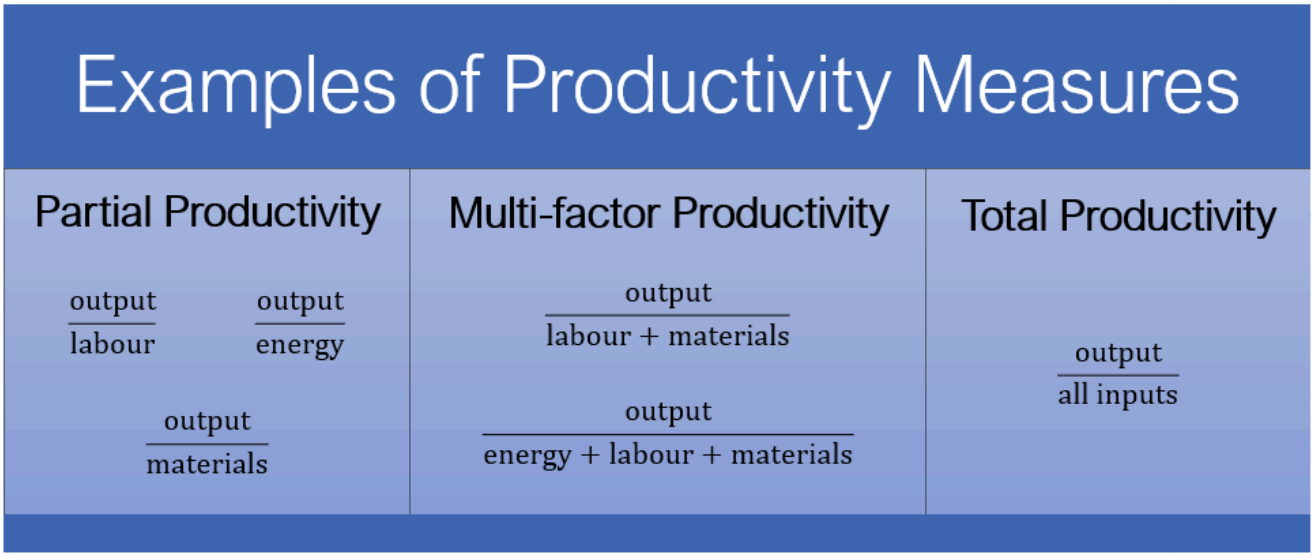


Figure 2.3: Examples of equations for productivity measures.

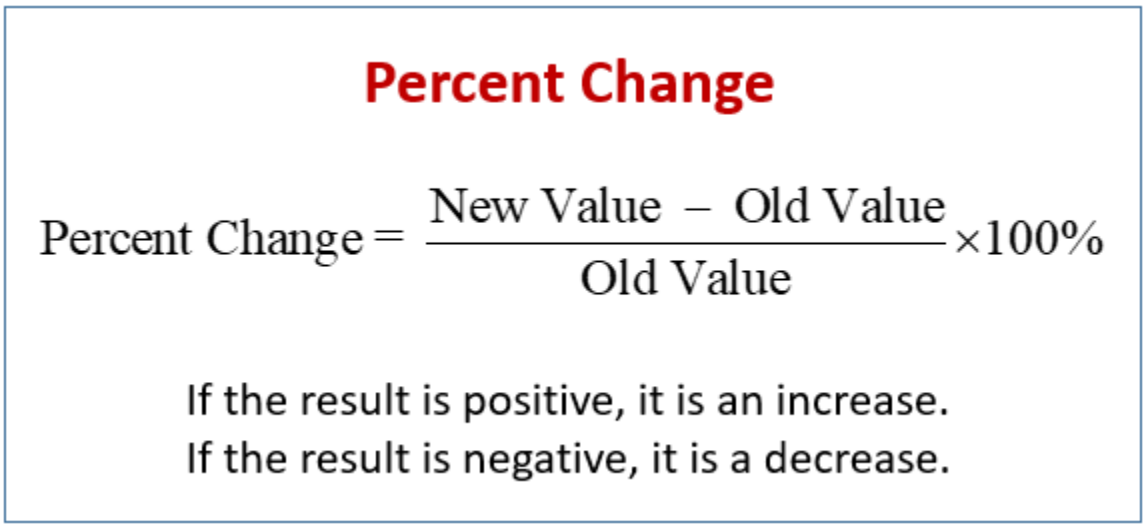


Figure 2.4: Percent change calculation; Credit: onlinemathlearning.com/percent-change-algebra.html

Output is always a reflection of how much the firm was able to produce. If the product is homogenous, meaning it has very little variations, then expressing output as the number of units produced may be reasonable. If, however, the firm makes a variety of products with different levels of labour and material costs, then the output would likely be described by the dollar value of all the goods produced within a certain time period.

For **inputs**, dollars spent are typically used as the measure. Several exceptions might be labour hours, gallons of water, or kilowatts of electricity. Firms will typically measure the productivity for the things which represent significant expenditures. A farmer might measure the pounds of meat produced as the output and the pounds of feed consumed as the input. Some other common productivity measures can be found below.

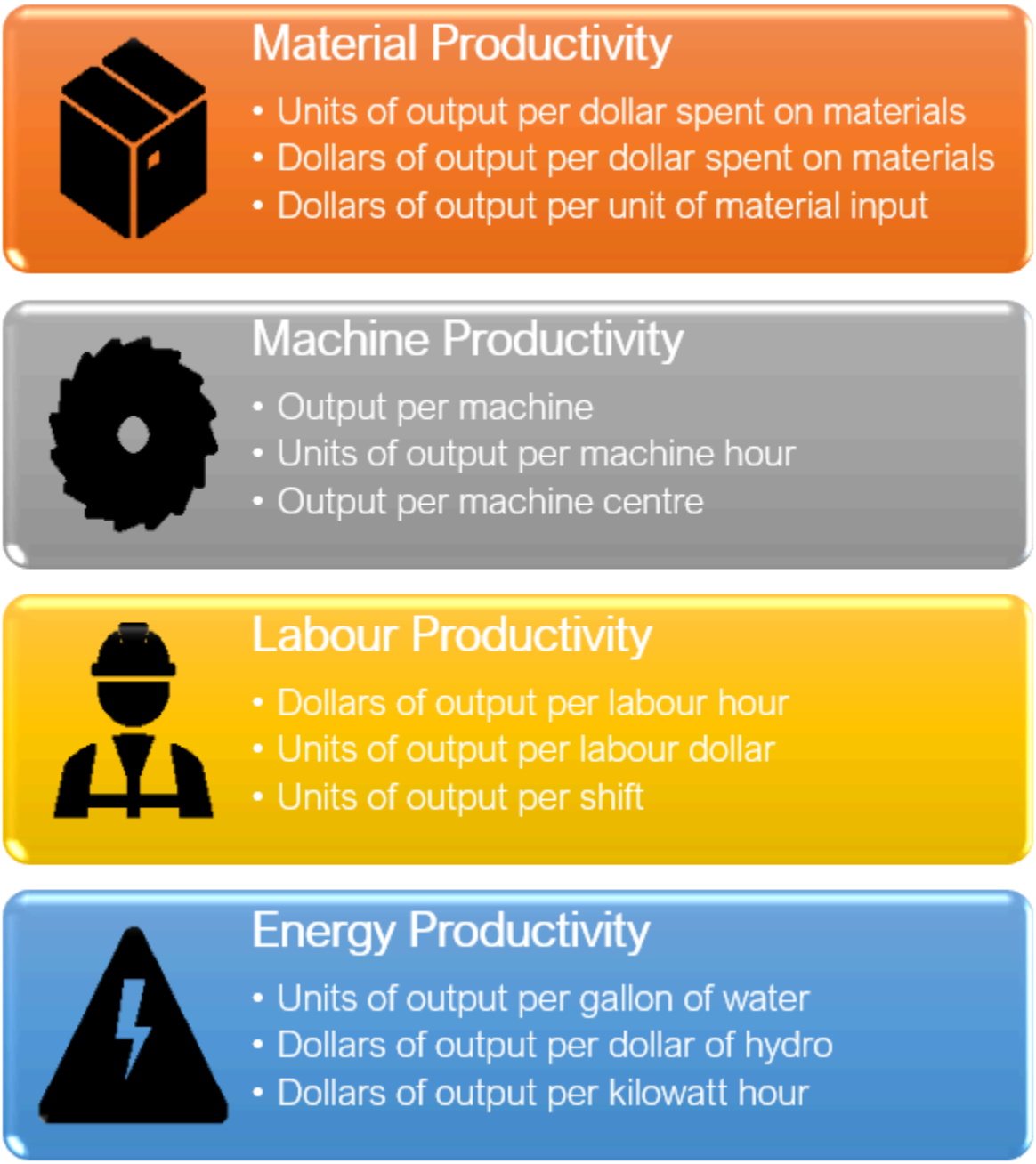


Figure 2.5: Examples of productivity measures.

End of Chapter Problems

Problem #1

Billco Windows and Doors is preparing their monthly productivity report. Their monthly costs are shown below. Calculate the **a)** labour productivity (output / labour hours), **b)** machine productivity (output / machine hours), and **c)** the multifactor productivity (output / labour cost + material cost + energy cost) of dollars spent on labour, materials, and energy. Average labour rate is $18.00.

Units produced: 1800

Labour hours: 1975

Machine hours: 425

Materials cost: $81000

Energy cost: $21600

Solution

a) Labour productivity (output / labour hours)
= 1800 / 1975
= .91 units per labour hour

b) Machine productivity (output / machine hours)
= 1800 / 425
= 4.23 units per machine hour

c) Multifactor productivity (output / labour cost + material cost + energy cost)
= 1800 / (1975 x $18 + $81000 + $21600)
= .013 units per dollar spent

Problem #2

A company makes seasonal jams and jellies. Yesterday they produced 420 jars of jam with five workers who each worked an 8-hour day. What was the labour productivity?

Solution

= 420 / (5 workers x 8 hours)
= 10.5 jars per worker hour

Problem #3

A greeting card company manufactured 3500 cards in one day. Labour cost was $1200, material cost was $90, and overhead was $450. What is the multifactor productivity?

Solution

= 3500 / ($1200 + $90 + $450)
= 2.01 cards per dollar of input

Problem #4

Joe has purchased a pizza franchise and is learning how to measure productivity. Calculate the **a)** food cost productivity, **b)** labour productivity, and **c)** total productivity. Also calculate the percent change for each measure.

	June	July
Sales	$52500	$59650
Food cost	$15750	$16702
Labour cost	$11550	$14912
Overhead cost	$3500	$3500

Solution

	June	July	% Change
a) Food cost productivity	52500 / 15750 = **$3.33**	59650 / 16702 = **$3.57**	(3.57 – 3.33) / 3.33 x 100 = **+7.21%**
b) Labour productivity	52500 / 11550 = **$4.55**	59650 / 14912 = **$4.00**	(4.00 – 4.55) / 4.55 x 100 = **-12.09%**
c) Total productivity	52500 / (15750 + 11550 + 3500) = **$1.70**	59650 / (16702 + 14912 + 3500) = **$1.70**	(1.70 – 1.70) / 1.70 x 100 = 0**%**

3. Forecasting

Learning Objectives

- What is forecasting and why is it important?
- Understand the differences between qualitative and quantitative forecasting.
- Describe types of demand patterns exhibited in product demand.
- Calculate forecasts using time series analysis and seasonal index.
- Determine forecast accuracy.

Forecasting is the process of making predictions of the future based on past and present data. This is most commonly by analysis of trends. A commonplace example might be estimation of some variable of interest at

some specified future date. Prediction is a similar, but more general term. Both might refer to formal statistical methods employing time series, cross-sectional or longitudinal data, or alternatively to less formal judgmental methods. Usage can differ between areas of application: for example, in hydrology, the terms "forecast" and "forecasting" are sometimes reserved for estimates of values at certain specific future times, while the term "prediction" is used for more general estimates, such as the number of times floods will occur over a long period.

Risk and uncertainty are central to forecasting and prediction; it is generally considered good practice to indicate the degree of uncertainty attached to specific forecasts. In any case, the data must be up to date in order for the forecast to be as accurate as possible. In some cases, the data used to predict the variable of interest is itself forecasted.[1]

As discussed in the previous chapter, functional strategies need to be aligned and supportive to the higher level corporate strategy of the organization. One of these functional areas is marketing. Creating marketing strategy is not a single event, nor is the implementation of marketing strategy something only the marketing department has to worry about.

When the strategy is implemented, the rest of the company must be poised to deal with the consequences. An important component in this implementation is the **sales forecast**, which is the estimate of how much the company will actually sell. The rest of the company must then be geared up (or down) to meet that demand. In this module, we explore forecasting in more detail, as there are many choices that can be made in developing a forecast.

Accuracy is important when it comes to forecasts. If executives overestimate the demand for a product, the company could end up spending money on manufacturing, distribution, and servicing activities it won't need. Data Impact, a software developer, recently overestimated the demand for one of its new products. Because the sales of the product didn't meet projections, Data Impact lacked the cash available to pay its vendors, utility providers, and others. Employees had to be terminated in many areas of the firm to trim costs.

Underestimating demand can be just as devastating. When a company introduces a new product, it launches marketing and sales campaigns to create demand for it. But if the company isn't ready to deliver the amount of the product the market demands, then other competitors can steal sales the firm might otherwise have captured. Sony's inability to deliver the e-Reader in sufficient numbers made Amazon's Kindle more readily accepted in the market; other features then gave the Kindle an advantage that Sony is finding difficult to overcome.

The firm has to do more than just forecast the company's sales. The process can be complex, because how much the company can sell will depend on many factors such as how much the product will cost, how competitors will react, and so forth. Each of these factors has to be taken into account in order to determine how much the company is likely to sell. As factors change, the forecast has to change as well. Thus, a sales forecast is actually a composite of a number of estimates and has to be dynamic as those other estimates change.

A common first step is to determine market potential, or total industry-wide sales expected in a particular product category for the time period of interest. (The time period of interest might be the coming year, quarter, month, or some other time period.) Some marketing research companies, such as Nielsen, Gartner, and others, estimate the market potential for various products and then sell that research to companies that produce those products.

1. Wikipedia contributors. (2019). Forecasting. In Wikipedia, The Free Encyclopedia. Retrieved November 4, 2019, from https://en.wikipedia.org/w/index.php?title=Forecasting&oldid=933732816

Once the firm has an idea of the market potential, the company's sales potential can be estimated. A firm's sales potential is the maximum total revenue it hopes to generate from a product or the number of units of it the company can hope to sell. The sales potential for the product is typically represented as a percentage of its market potential and equivalent to the company's estimated maximum market share for the time period. In your budget, you'll want to forecast the revenues earned from the product against the market potential, as well as against the product's costs.[2]

Forecasting Horizons

Long term forecasting tends to be completed at high levels in the organization. The time frame is generally considered longer than 2 years into the future. Detailed knowledge about the products and markets are required due to the high degree of uncertainty. This is commonly the case with new products entering the market, emerging new technologies and opening new facilities. Often no historical data is available.

Medium term forecasting tends to be several months up to 2 years into the future and is referred to as intermediate term. Both quantitative and qualitative forecasting may be used in this time frame.

Short term forecasting is daily up to months in the future. These forecasts are used for operational decision making such as inventory planning, ordering and scheduling of the workforce. Usually quantitative methods such as time series analysis are used in this time frame.

Categories of Forecasting Methods

Qualitative Forecasting

Qualitative forecasting techniques are subjective, based on the opinion and judgment of consumers and experts; they are appropriate when past data are not available. They are usually applied to intermediate- or long-range decisions.

In the following, we discuss some examples of qualitative forecasting techniques:

Executive Judgement (Top Down)

Groups of high-level executives will often assume responsibility for the forecast. They will collaborate to examine market data and look at future trends for the business. Often, they will use statistical models as well as market experts to arrive at a forecast.

Sales Force Opinions (Bottom up)

The sales force in a business are those persons most close to the customers. Their opinions are of high value.

2. Saylor Academy. (2012). Principles of Marketing. Forecasting. Retrieved on November 4, 2019, from https://saylordotorg.github.io/text_principles-of-marketing-v2.0/s19-03-forecasting.html

Often the sales force personnel are asked to give their future projections for their area or territory. Once all of those are reviewed, they may be combined to form an overall forecast for district or region.

Delphi Method

This method was created by the Rand Corporation in the 1950s. A group of experts are recruited to participate in a forecast. The administrator of the forecast will send out a series of questionnaires and ask for inputs and justifications. These responses will be collated and sent out again to allow respondents to evaluate and adjust their answers. A key aspect of the Delphi method is that the responses are anonymous, respondents do not have any knowledge about what information has come from which sources. That permits all of the opinions to be given equal consideration. The set of questionnaires will go back and forth multiple times until a forecast is agreed upon.

Market Surveys

Some organizations will employ market research firms to solicit information from consumers regarding opinions on products and future purchasing plans.

Quantitative Forecasting

Quantitative forecasting models are used to forecast future data as a function of past data. They are appropriate to use when past numerical data is available and when it is reasonable to assume that some of the patterns in the data are expected to continue into the future. These methods are usually applied to short- or intermediate-range decisions. Some examples of quantitative forecasting methods are causal (econometric) forecasting methods, last period demand (naïve), simple and weighted N-Period moving averages and simple exponential smoothing, which are categorizes as time-series methods. Quantitative forecasting models are often judged against each other by comparing their accuracy performance measures. Some of these measures include Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE).

We will elaborate on some of these forecasting methods and the accuracy measure in the following sections.[3]

Causal (Econometric) Forecasting Methods (Degree)

Some forecasting methods try to identify the underlying factors that might influence the variable that is being forecast. For example, including information about climate patterns might improve the ability of a model to predict umbrella sales. Forecasting models often take account of regular seasonal variations. In addition to climate, such variations can also be due to holidays and customs: for example, one might predict that sales of college football apparel will be higher during the football season than during the off-season.

Several informal methods used in causal forecasting do not rely solely on the output of mathematical

3. Wikipedia contributors. (2019). Forecasting. In Wikipedia, The Free Encyclopedia. Retrieved on November 4, 2019, from https://en.wikipedia.org/w/index.php?title=Forecasting&oldid=933732816

algorithms, but instead use the judgment of the forecaster. Some forecasts take account of past relationships between variables: if one variable has, for example, been approximately linearly related to another for a long period of time, it may be appropriate to extrapolate such a relationship into the future, without necessarily understanding the reasons for the relationship.

One of the most famous causal models is **regression analysis**. In statistical modeling, regression analysis is a set of statistical processes for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed.

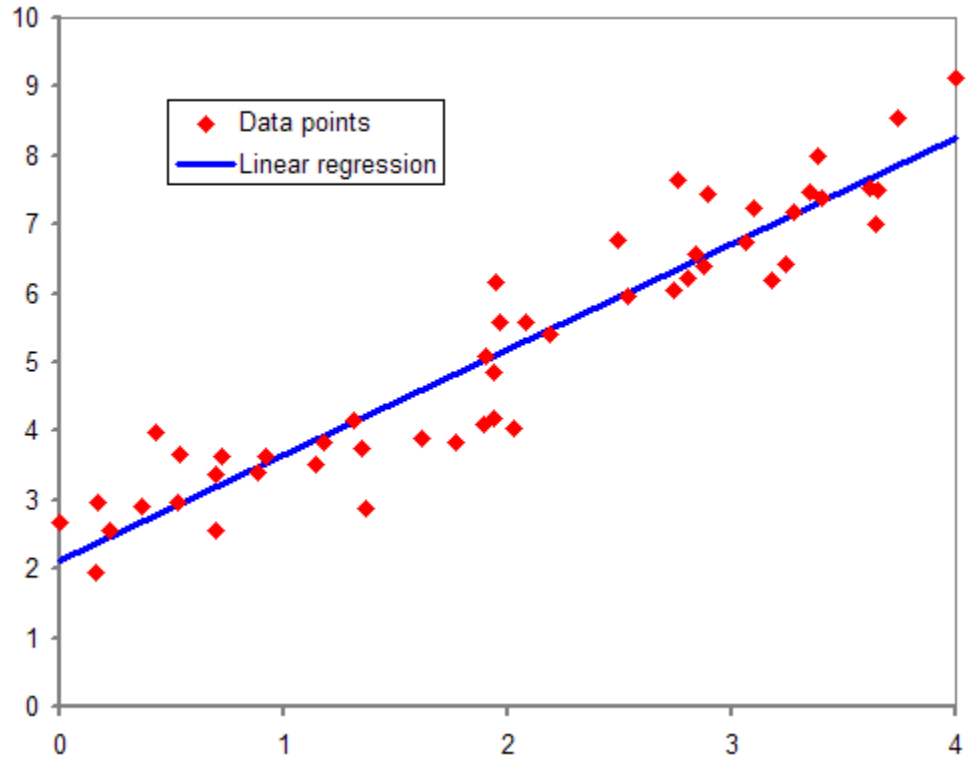


Figure 3.1: Example of regression analysis.

Common Forecasting Assumptions:

1. Forecasts are rarely, if ever, perfect. It is nearly impossible to 100% accurately estimate what the future will hold. Firms need to understand and expect some error in their forecasts.
2. Forecasts tend to be more accurate for groups of items than for individual items in the group. The popular Fitbit may be producing six different models. Each model may be offered in several

different colours. Each of those colours may come in small, large and extra large. The forecast for each model will be far more accurate than the forecast for each specific end item.

3. Forecast accuracy will tend to decrease as the time horizon increases. The farther away the forecast is from the current date, the more uncertainty it will contain.

Demand Patterns

When we plot our historical product demand, the following patterns can often be found:

Trend – A trend is consistent upward or downward movement of the demand. This may be related to the product's life cycle.

Cycle – A cycle is a pattern in the data that tends to last more than one year in duration. Often, they are related to events such as interest rates, the political climate, consumer confidence or other market factors.

Seasonal – Many products have a seasonal pattern, generally predictable changes in demand that are recurring every year. Fashion products and sporting goods are heavily influenced by seasonality.

Irregular variations – Often demand can be influenced by an event or series of events that are not expected to be repeated in the future. Examples might include an extreme weather event, a strike at a college campus, or a power outage.

Random variations – Random variations are the unexplained variations in demand that remain after all other factors are considered. Often this is referred to as noise.

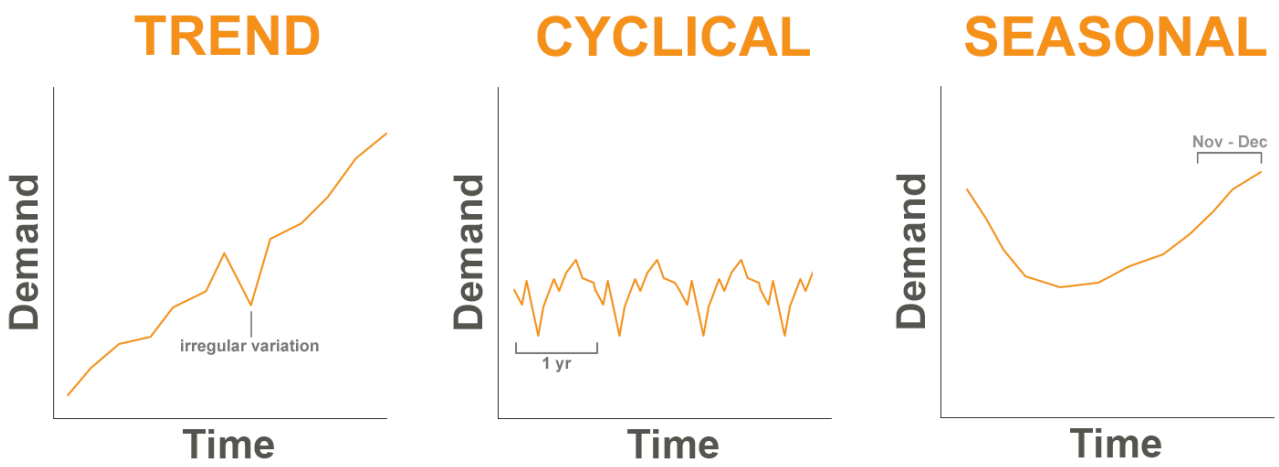


Figure 3.2: Diagram of trend, cyclical, and seasonal demand patterns.

Time Series Methods

Time series methods use historical data as the basis of estimating future outcomes. A time series is a series of data points indexed (or listed or graphed) in time order. Most commonly, a time series is a sequence taken at

successive equally spaced points in time. Thus, it is a sequence of discrete-time data. Examples of time series are heights of ocean tides, counts of sunspots, and the daily closing value of the Dow Jones Industrial Average.

Time series are very frequently plotted via line charts. Time series are used in statistics, signal processing, pattern recognition, econometrics, mathematical finance, weather forecasting, earthquake prediction, electroencephalography, control engineering, astronomy, communications engineering, and largely in any domain of applied science and engineering which involves temporal measurements.[4]

In the following, we will elaborate more on some of the simpler time-series methods and go over some numerical examples.

Naïve Method

The simplest forecasting method is the naïve method. In this case, the forecast for the next period is set at the actual demand for the previous period. This method of forecasting may often be used as a benchmark in order to evaluate and compare other forecast methods.

Simple Moving Average

In this method, we take the average of the last "n" periods and use that as the forecast for the next period. The value of "n" can be defined by the management in order to achieve a more accurate forecast. For example, a manager may decide to use the demand values from the last four periods (i.e., n = 4) to calculate the 4-period moving average forecast for the next period.

Example

Some relevant notation:
D_t = Actual demand observed in period t
F_t = Forecast for period t

Using the following table, calculate the forecast for period 5 based on a 3-period moving average.

Period	Actual Demand
1	42
2	37
3	34
4	40

Solution

Forecast for period 5 = F5 = (D4 + D3 + D2) / 3 = (40 + 34 + 37) / 3 = 111 / 3 = 37

Here is a video explaining simple moving averages.

4. Wikipedia contributors. (2019). Time series. In *Wikipedia, The Free Encyclopedia*. Retrieved on November 4, 2019, from https://en.wikipedia.org/w/index.php?title=Time_series&oldid=934671965

https://www.linkedin.com/learning/forecasting-using-financial-statements/simple-moving-average

Weighted Moving Average

This method is the same as the simple moving average with the addition of a weight for each one of the last "n" periods. In practice, these weights need to be determined in a way to produce the most accurate forecast. Let's have a look at the same example, but this time, with weights:

Example

Period	Actual Demand	Weight
1	42	
2	37	0.2
3	34	0.3
4	40	0.5

Solution

Forecast for period 5 = F5 = (0.5 x D4 + 0.3 x D3 + 0.2 x D2) = (0.5 x 40+ 0.3 x 34 + 0.2 x 37) = 37.6

Note that if the sum of all the weights were not equal to 1, this number above had to be divided by the sum of all the weights to get the correct weighted moving average.

Here is a video explaining weighted moving averages.

https://www.linkedin.com/learning/forecasting-using-financial-statements/weighted-moving-average

Exponential Smoothing

This method uses a combination of the last actual demand and the last forecast to produce the forecast for the next period. There are a number of advantages to using this method. It can often result in a more accurate forecast. It is an easy method that enables forecasts to quickly react to new trends or changes. A benefit to exponential smoothing is that it does not require a large amount of historical data. Exponential smoothing requires the use of a smoothing coefficient called Alpha (α). The Alpha that is chosen will determines how quickly the forecast responds to changes in demand. It is also referred to as the Smoothing Factor.

There are two versions of the same formula for calculating the exponential smoothing.

Here is version #1:

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

Note that α is a coefficient between 0 and 1

For this method to work, we need to have the forecast for the previous period. This forecast is assumed to be

obtained using the same exponential smoothing method. If there were no previous period forecast for any of the past periods, we will need to initiate this method of forecasting by making some assumptions. This is explained in the next example.

Example

Period	Actual Demand	Forecast
1	42	
2	37	
3	34	
4	40	
5		

In this example, period 5 is our next period for which we are looking for a forecast. In order to have that, we will need the forecast for the last period (i.e., period 4). But there is no forecast given for period 4. Thus, we will need to calculate the forecast for period 4 first. However, a similar issue exists for period 4, since we do not have the forecast for period 3. So, we need to go back for one more period and calculate the forecast for period 3. As you see, this will take us all the way back to period 1. Because there is no period before period 1, we will need to make some assumption for the forecast of period 1. One common assumption is to use the same demand of period 1 for its forecast. This will give us a forecast to start, and then, we can calculate the forecast for period 2 from there. Let's see how the calculations work out:

If $\alpha = 0.3$ (assume it is given here, but in practice, this value needs to be selected properly to produce the most accurate forecast)

Assume $F_1 = D_1$, which is equal to 42.

Then, calculate $F_2 = (1 - \alpha)\ F_1 + \alpha\ D_1 = (1 - 0.3) \times 42 + 0.3 \times 42 = 42$

Next, calculate $F_3 = (1 - \alpha)\ F_2 + \alpha\ D_2 = (1 - 0.3) \times 42 + 0.3 \times 37 = 40.5$

And similarly, $F_4 = (1 - \alpha)\ F_3 + \alpha\ D_3 = (1 - 0.3) \times 40.5 + 0.3 \times 34 = 38.55$

And finally, $F_5 = (1 - \alpha)\ F_4 + \alpha\ D_4 = (1 - 0.3) \times 38.55 + 0.3 \times 40 = 38.985$

Period	Actual Demand	Forecast
1	42	42 (assumed = D_1)
2	37	(1 – 0.3) x 42 + 0.3 x 42 = 42
3	34	(1 – 0.3) x 42 + 0.3 x 37 = 40.5
4	40	(1 – 0.3) x 40.5 + 0.3 x 34 = 38.55
5		(1 – 0.3) x 38.55 + 0.3 x 40 = 38.985

Figure 3.3: Solution for Exponential Smoothing Version 1

Accessible format for Figure 3.3

Here is a video explaining exponential smoothing using EXCEL.

https://www.linkedin.com/learning/search?keywords=exponential%20smoothing&u=2169170

Here is version #2:

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

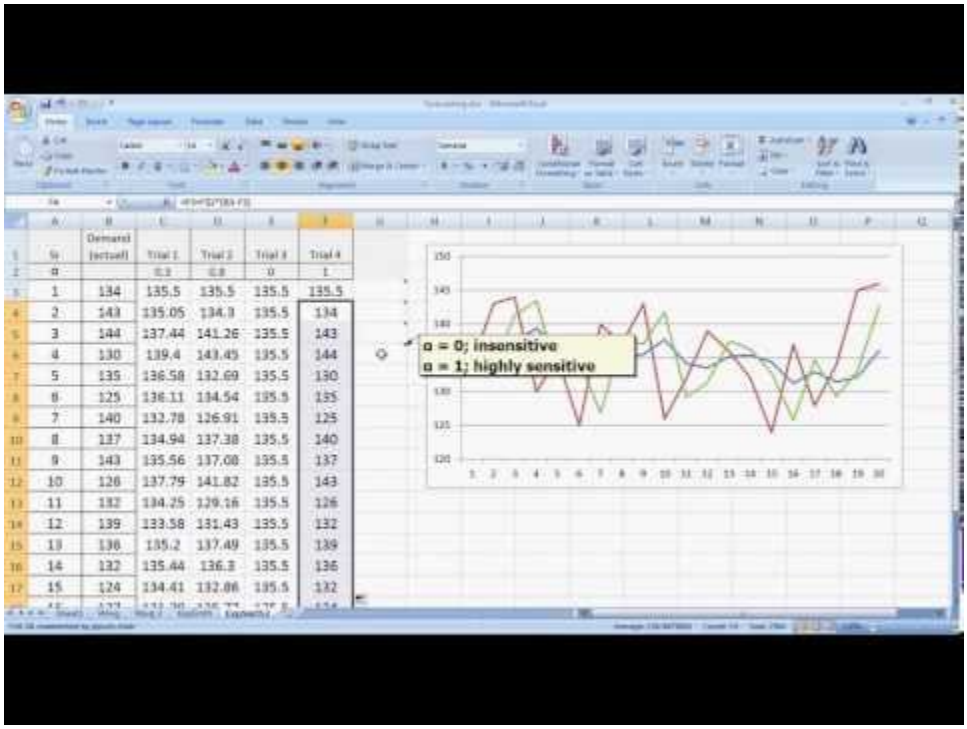
Example

Assume you are given an alpha of 0.3, $F_{t-1} = 55$

Period	Actual Demand	Forecast
1	60	55 (assumed = α)
2	55	55 + 0.3 x (60 – 55) = 56.5
3	51	56.5 + 0.3 x (55 – 56.5) = 56.05
4	58	56.05 + 0.3 x (51 – 56.05) = 54.53
5		54.54 + 0.3 x (58 – 54.53) = 55.64

Figure 3.4: Solution for Exponential Smoothing Version 2

Accessible format for Figure 3.4



A YouTube element has been excluded from this version of the text. You can view it online here:
https://pressbooks.senecacollege.ca/operationsmanagement/?p=73

Seasonal Index
Many organizations produce goods whose demand is related to the seasons, or changes in weather throughout the year. In these cases, a seasonal index may be used to assist in the calculation of a forecast.

Example

Season	Previous Sales	Average Sales	Seasonal Index
Winter	390	500	390 / 500 = .78
Spring	460	500	460 / 500 = .92
Summer	600	500	600 / 500 = 1.2
Fall	550	500	550 / 500 = 1.1
Total	2000		

Using these calculated indices, we can forecast the demand for next year based on the expected annual demand for the next year. Let's say a firm has estimated that next year annual demand will be 2500 units.

Season	Anticipated annual demand	Avg. Sales / Season (2500/4)	Seasonal Factor	New Forecast
Winter		625	0.78	.78 x 625 = 487.5
Spring		625	0.92	.92 x 625 = 575
Summer		625	1.2	1.2 x 625 = 750
Fall		625	1.1	1.1 x 625 = 687.5
	2500			

Forecast Accuracy Measures

In this section, we will calculate forecast accuracy measures such as **Mean Absolute Deviation** (MAD), **Mean Squared Error** (MSE), and **Mean Absolute Percentage Error** (MAPE). We will explain the calculations using the next example.

Example
The following actual demand and forecast values are given for the past four periods. We want to calculate MAD,

MSE and MAPE for this forecast to see how well it is doing.
Note that Abs (e_t) refers to the absolute value of the error in period t (e_t).

Period	Actual Demand	Forecast	e_t	Abs (et)	e_t^2	[Abs (e_t) / D_t] x 100%
1	63	68				
2	59	65				
3	54	61				
4	65	59				

Here are what need to do:

Step 1: Calculate the error as $e_t = D_t - F_t$ (the difference between the actual demand and the forecast) for any period t and enter the values in the table above.

Step 2: Calculate the absolute value of the errors calculated in step 1 [i.e., Abs (et)], and enter the values in the table above.

Step 3: Calculate the squared error (i.e., e_t^2) for each period and enter the values in the table above.

Step 4: Calculate [Abs (e_t) / D_t] x 100% for each period and enter the value under its column in the table above.

Solution

Period	Actual Demand	Forecast	e_t	Abs (et)	e_t^2	[Abs (e_t) / D_t] x 100%
1	63	68	-5	5	25	7.94%
2	59	65	-6	6	36	10.17%
3	54	61	-7	7	49	12.96%
4	65	59	6	6	36	9.23%

Calculations for Accuracy Measures:

MAD = The average of what we calculated in step 2 (i.e., the average of all the absolute error values)
= (5 + 6 + 7 + 6) / 4 = 24 / 4 = **6**
MSE = The average of what we calculated in step 3 (i.e., the average of all the squared error values)
= (25 + 36 + 49 + 36) / 4 = 146/4 = **36.5**
MAPE = The average of what we calculated in step 4
= (7.94% + 10.17% + 12.96% + 9.23%) / 4 = 40.3/4 = **10.075%**

Here is a video on Mean Absolute Deviation using EXCEL

https://www.linkedin.com/learning/search?keywords=mean%20absolute%20deviation%20&u=2169170

End of Chapter Problems

Problem #1

Below are monthly sales of light bulbs from the lighting store.

Month	Sales
Jan	255
Feb	298
Mar	357
Apr	319
May	360
June	

Forecast sales for June using the following

1. Naïve method
2. Three- month simple moving average
3. Three-month weighted moving average using weights of .5, .3 and .2
4. Exponential smoothing using an alpha of .2 and a May forecast of 350.

Solution

1. 360
2. (357 + 319 + 360) / 3 = 345.3
3. 360 x .5 + 319 x .3 + 357 x .2 = 347.1
4. 350 + .2(360 – 350) = 352

Problem #2

Demand for aqua fit classes at a large Community Centre are as follows for the first six weeks of this year.

Week	Demand
1	162
2	158
3	138
4	190
5	182
6	177
7	

You have been asked to experiment with several forecasting methods. Calculate the following values:

1. a) Forecast for weeks 3 through week 7 using a two-period simple moving average
2. b) Forecast for weeks 4 through week 7 using a three-period weighted moving average with weights of .6, .3 and .1
3. c) Forecast for weeks 4 through week 7 using exponential smoothing. Begin with a week 3 forecast of 130 and use an alpha of .3

Solution

Week	Demand	a)	b)	c)
1	162			
2	158			
3	138	(162 + 158) / 2 = **160**		**130**
4	190	(158 + 138) / 2 = **148**	138 x .6 + 158 x .3 + 162 x .1 = **146.4**	130 + .3 x (138 – 130) = **132.4**
5	182	(138 + 190) / 2 = **164**	190 x .6 + 138 x .3 + 158 x .1 = **171.2**	132.4 + .3 x (190 – 132.4) = **149.7**
6	177	(190 + 182) / 2 = **186**	182 x .6 + 190 x .3 + 138 x .1 = **180**	149.7 + .3 x (182 – 149.7) = **159.4**
7		(182 + 177) / 2 = **179.5**	177 x .6 + 182 x .3 + 190 x .1 = **179.8**	159.4 + .3 x (177 – 159.4) = **164.7**

Problem #3

Sales of a new shed has grown steadily from the large farm supply store. Below are the sales from the past five years. Forecast the sales for 2018 and 2019 using exponential smoothing with an alpha of .4. In 2015, the forecast was 360. Calculate a forecast for 2016 through to 2020.

Year	Sales	Forecast
2015	348	360
2016	372	
2017	311	
2018	371	
2019	365	
2020		

Solution

Year	Sales	Forecast
2015	348	**360**
2016	372	360 + .4 x (348 – 360) = **355.2**
2017	311	355.2 + .4 x (372 – 355.2) = **361.9**
2018	371	361.9 + .4 x (311 – 361.9) = **341.6**
2019	365	341.6 + .4 x (371 – 341.6) = **353.3**
2020		353.3 + .4 x (365-353.3) = **358.0**

Problem #4

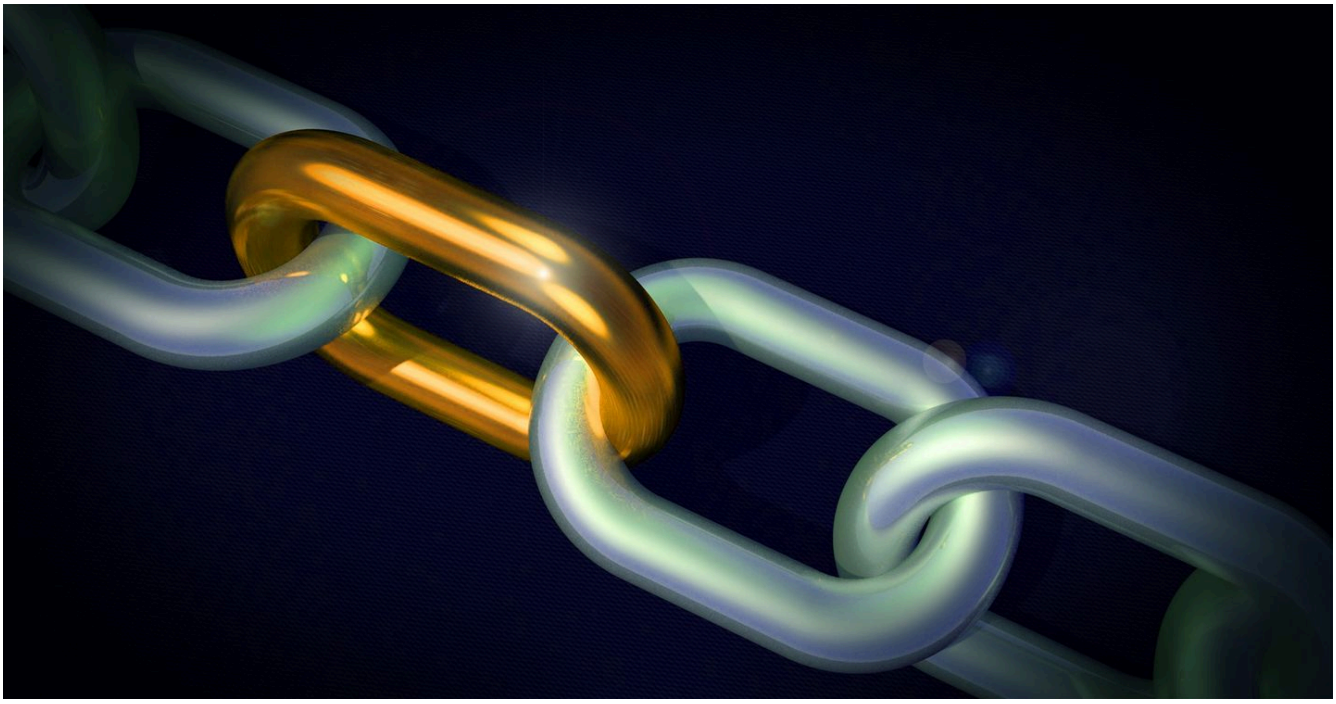
Below is the actual demand for X-rays at a medical clinic. Two methods of forecasting were used. Calculate a mean absolute deviation for each forecast method. Which one is more accurate?

Week	Actual Demand	Forecast #1	Forecast #2
1	48	50	50
2	65	55	56
3	58	60	55
4	79	70	85

Solution

Week	Actual Demand	Forecast #1	|error|	Forecast #2	|error|
1	48	50	2	50	2
2	65	55	10	56	9
3	58	60	2	55	3
4	79	70	9	85	6
		Mean Abs Deviation:	**5.75**	**Mean Abs Deviation:**	**5**

4. Supply Chain



Learning Objectives

Explain the term supply chain, describe its flows, and the organizations that participate in a typical supply chain.

Identify types of inventory in the supply chain and reasons for carrying inventory.

Define the term logistics and give advantages and disadvantages to various forms of transportation.

Describe the various forms of communication and technology in the supply chain.

Calculate inventory turnover and days of supply as measures of supply chain performance.

Supply Chain refers to the group of organizations that are linked together by their participation in order to fulfill a customer order from the sourcing of raw materials through the production of goods to distribution and sale. Each organization has a role to play in adding value for the final customer. The organizations that participate in a supply chain include suppliers, manufacturers, transporters (also known as carriers), distribution centres, wholesalers, retailers and end-consumers.

Every link in this chain of supply is very important. As they say, “a chain is only as strong as its weakest link.” This has implications for the supply chain management in a sense that it is not enough for the companies just to

focus on their own internal operations. They need to regularly check with their supply chain members to make sure that everybody is performing at their best. One weak member in any supply chain will impact everybody else.

For example, if a retail store is not doing a good job at replenishing their inventory on time, the product will not be available to some end-consumers when needed, and as a result, lost sales happen and that supply chain will be affected financially. Let's think about it for a second: fewer products had got ordered from the manufacturer, and thus, fewer raw materials were ordered (by the manufacturer) from higher tiered suppliers. This way, everybody in the supply chain sold less than what they could if the retailer had ordered the right quantity at the right time.

Managing Main Flows in the Supply Chain

There are three types of main flows that happen in any supply chains: flow of materials/goods, flow of money/cash, and flow of information. There is a forward flow of materials/goods for the regular flow that happens all the way from higher tier suppliers (upstream) to the end-consumer (downstream). In addition, if there is any returns for any reason, there will be a reverse flow of materials/goods in the opposite direction to the forward flow.

Flow of money (cash flow) happens from downstream to upstream. For example, the retailer needs to pay the distributor for the goods they have received from them.

Flow of information happens both ways in the supply chain since organizations will need to share different type of information with each other so that the whole supply chain can make better decisions to improve overall performance.

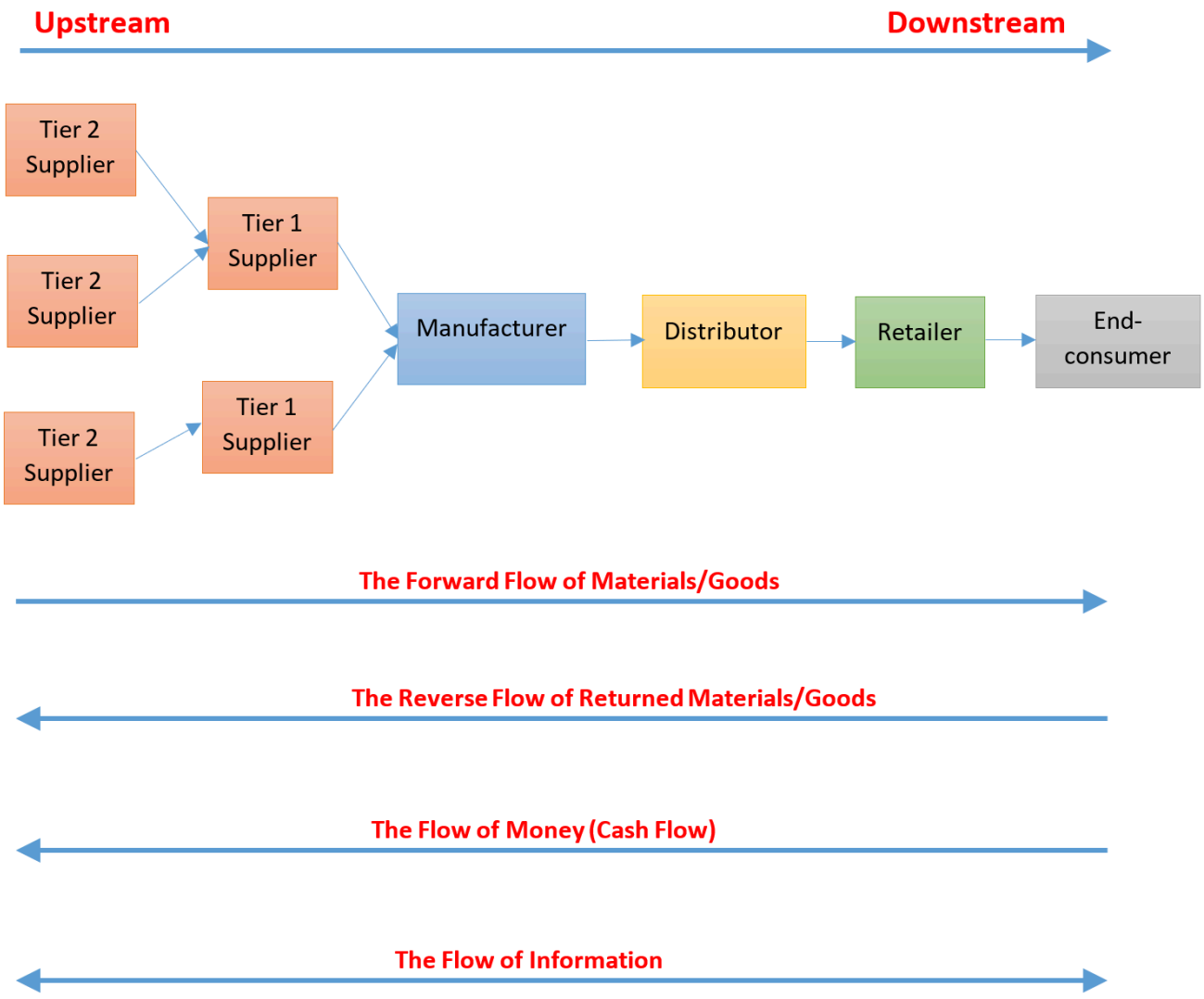
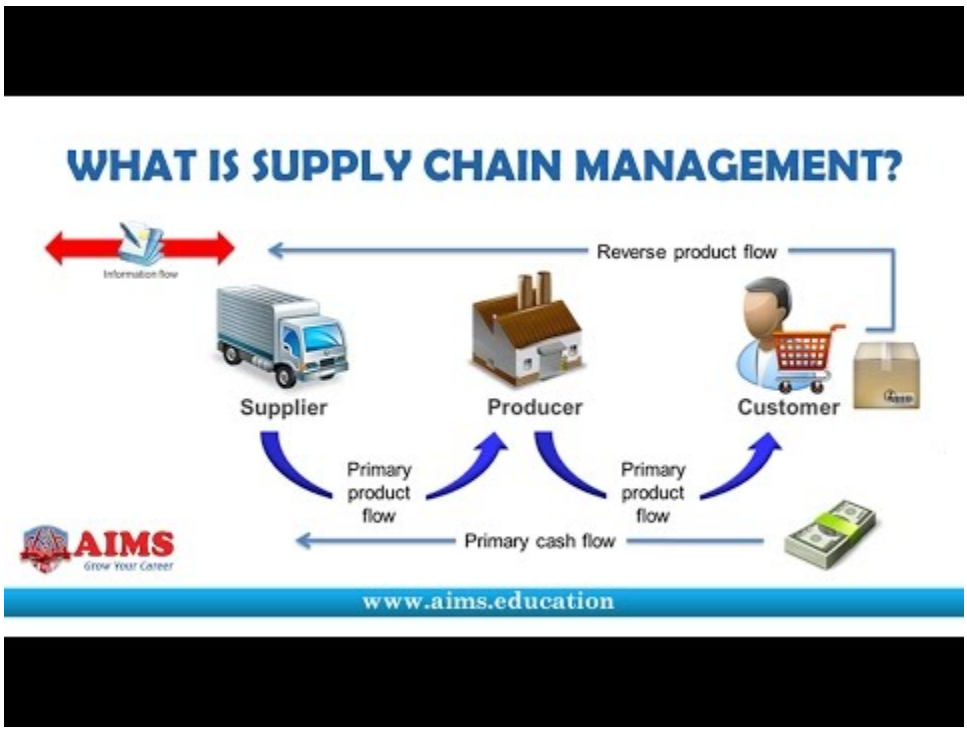


Figure 4.1: Upstream and downstream of a supply chain and its flows.



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Foundational Elements of Supply Chain Management

Each organization in a supply chain needs to manage four key elements. These include supply management, managing the internal operations, distribution management, and managing the integration of all of these so that all parts of the supply chain are working with each other in harmony. The following sections will cover some of the things that are done in relation to each one of these elements. Figure 4.3 depicts the foundational elements.

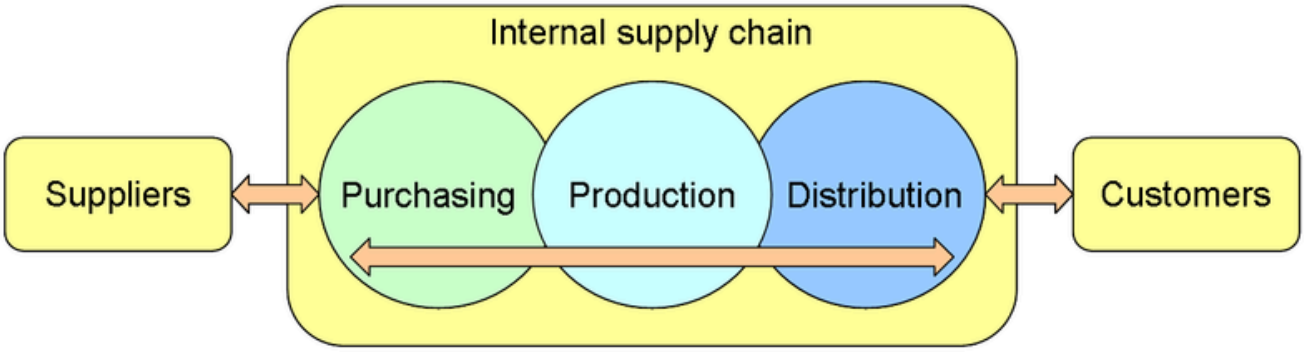

Figure 4.3: Example of a company's supply chain; Credit: Stern / Wikimedia / https://commons.wikimedia.org/wiki/File:A_company%27s_supply_chain_(en).png

Supply Management includes purchasing and managing the suppliers and the relationships with them. **Internal Operations** is consisted of managing whatever the company does to add value. For example, a manufacturer does "Production", along with managing inventory of raw materials and finished goods, human resources, etc. **Distribution Management** deals with managing the customers and the relationships with them. In order to do this, the organization needs to have a deep understanding of its customers and their needs to be able to deliver the right product/service to the right customer at the right time. **Integration Management** uses several technologies such as ERP systems to make the collaboration among the different elements easier and more accurate.

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Supply Chain Design

Supply Chain Design is a strategic decision which determines who needs to take on what role or responsibility in the supply chain and where they should be located. Different companies choose different design or structure for their supply chains. For example, Walmart has always used traditional brick and mortar stores to serve its customers, while Amazon has been using an online platform to get customers' orders and then, ship them directly from their distribution/fulfillment centres.

When designing a supply chain, two main things to consider are Efficiency (cost reductions) and Responsiveness. The balance between these two could be different for different companies. That is, depending on the customers' preferences, the company decides to have a certain structure for their supply chain. For example, if the customers for a particular company are willing to wait for 5-7 days to get their ordered products online, the company can store its inventory in fewer locations and use the longer time of transportation to serve its customers. However, if the customers want to have their products right away, the company may need to open quite a few stores and keep enough inventory in each one to be able to respond faster to its customers' needs.

A company may decide to use other companies for parts of their supply chain or to have their own entities. This includes Vertical and/or Horizontal integration. Vertical integration is a term that is used when a firm owns more than one portion of its supply chain. For example, for a manufacturer company, they may have their own distributors or even retail stores to sell their products to the end-consumers (forward integration) or they may

choose to own one or more of the suppliers that provide the company with certain materials or components (backwards integration).

Horizontal Integration is a situation where a business chooses to increase their holdings by acquiring or merging with another firm in the same market. An example of this was the 2015 merger of Kraft foods and Heinz, or Marriott International's purchase of Starwood hotels in 2016.

Example

A complex surrounding the Highland Park Plant included a power plant, machine shop, and foundry. Ford was starting to bring together the various stages in the manufacture of automobiles, a strategy called vertical integration. By the 1920s, Ford had purchased a rubber plantation in Brazil, coal mines in Kentucky, acres of timberland and iron-ore mines in Michigan and Minnesota, a fleet of ships, and a railroad. These efforts to vertically integrate helped Ford make sure his company would have raw materials and parts when they were needed, guaranteeing a continuously operating assembly line. These efforts also enabled the company to profit from more of the processes involved in producing the automobile.[1]

Example

Netflix is one of the most significant backward vertical integration examples in the entertainment industry. In the past, Netflix was established at the end of the supply chain because it was a platform to distribute films and TV shows created by other content creators. Although this was a profitable means of doing business, Netflix leaders realized that they could generate greater revenue by creating their own original content. This would offset their reliance on outside content creators, and fill what Netflix discovered was a desire among their subscribers for original content. Netflix leaders understood that they could leverage their existing distribution platform to promote original content to a captive audience. This strategy has become vital to Netflix's continuing success because as more and more film studios end their licensing agreements with the streaming giant, the company's original content will become the main attractor for new subscribers.[2]

The Role of Inventory in the Supply Chain

Managing inventory is one of the most important activities in a supply chain. Materials/goods are needed to provide manufacturers with the exact items that they need, in the right order, the right quality, delivered to the right location, and at the right time. Without all of this happening, it will be impossible to produce high quality goods and meet commitments to our customers. In addition, when goods are ready for shipment, the outbound supply chain needs to be organized in such a way that customers receive their requested orders in a cost-efficient manner.

1. Rush, M., Bonner, P. (2019). Case Study on Productivity (Part 2) – Henry Ford and the Model T. Retrieved on November 4, 2019, from https://www.econedlink.org/resources/henry-ford-and-the-model-t-a-case-study-in-productivity-part-2/
2. Quain, S. (2018). Examples of Vertically Integrated Companies. Retrieved on November 4, 2019, from https://smallbusiness.chron.com/examples-vertically-integrated-companies-12868.html

Types of Inventory in the Supply Chain:

- Finished goods
- Raw materials
- Purchased components and operating supplies
- Work-in-process

Reasons for holding inventories:

Many reasons exist for keeping stocks of inventory. Some of the most common include:

- Manufacturers often build up inventories throughout the year because of seasonal demand.
    - An example is a Chocolate manufacturer who does not have the capacity to produce all the product that is needed for Christmas. They may begin building inventory in late spring in order to have enough on hand for orders in November and December.
- At the same time, a manufacturer may carry large amounts of inventory if they have some uncertainty or risk in their supply base**.** If suppliers have some risk of shortages, work stoppages, poor quality or late deliveries then more stock may be carried.
- Firms may be tempted by extra discounts often provided by purchasing large order sizes. Perhaps they may want to minimize transportation costs. There may also be some worry about future price increases that can cause organizations to build up their inventories.
- Retailers carry inventory to ensure that they do not run out of what they anticipate their customers may want. Distributors and retailers may try and balance the cost of keeping large inventories on hand with providing excellent customer service with few or no disappointed customers. However, it is often a challenge to anticipate exact customer behaviour.
- It is a challenge to synchronize incoming flow of materials and goods in order to meet production schedules and ship to customers as promised. As a result, inventory may be stored at many locations along the supply chain. This causes extra cost and inefficiencies for each organization.

Logistics

Logistics refers to the activities of coordinating and moving resources, particularly inputs into the transformation process, and finished goods out to customers. Originally, the term logistics was from the military and referred to moving troops, equipment and supplies. Managing logistics involves making decisions such as the following:

- Choosing to operate and manage the firm's own transportation, or whether to outsource this activity
- Selecting suppliers that have the capability to ship goods safely and securely within the required time frame
- Choosing the correct mode of transportation and the most effective route
- Negotiating the shipping rate

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Modes of Transportation

There are several modes of transportation available to companies. We discuss them in the following:

Trucking

The majority of goods are shipped by truck completely or at some point during the shipping. Trucking is the most flexible of all modes of transportation. Trucking is categorized by "truck-load" (TL) when the entire truck is hired and delivered directly, or "less-than-truckload" (LTL) which generally includes using several orders to increase the utilization of the truck. A serious issue facing Canada at this time is the expected shortage of qualified drivers. Demand for drivers continues to increase every year, and the average age of drivers is increasing. The trucking industry will face challenges to make driving more attractive to entice new workers into trucking jobs.[3]

Railroads

Rail can be a very cost effective means of transporting goods that need to travel long distances. Goods in

3. https://www.conferenceboard.ca/topics/energyenviro/truckdrivers.aspx?AspxAutoDetectCookieSupport=1

containers, or products that are bulky and heavy are ideal for train transport. Canadian rail ships products including cars, fertilizer, food and beverages, forest products, grain, metals and minerals and petroleum products. Often, large manufacturers locate themselves near rail lines to make for easy shipment of raw material into, and finished goods out of their facilities. Compared to trucking, shipping by rail is very energy efficient, and removes many trucks from congested highways. Canada has a very old and well-established rail system.[4]

Airfreight

For goods that are expensive, small and light, air shipping may be a good choice. Air carriers charge by a combination of the weight and size of the shipment. This mode of transport is generally used when speed is more important than cost. Shipping by air is very reliable. Firms may want to consider the environmental impact of regular use of air shipping.

Waterway

This is a very common way of shipping goods. The goods that travel by water include chemicals, stone, cement, sugar, coal and other heavy commodities. Millions of containers travel by ship each year. Do you know what goods travel by ship? Read here.

The Great Lakes St. Lawrence Seaway System is a 3,700 kilometer marine highway that runs between Canada and the United States. Opening in 1959 the seaway is a major trade artery that serves many industries to ship iron ore, coal, limestone, steel, grain and cement. The cost for shipping by waterways is inexpensive. Most low-cost products are shipped by waterways.[5]

Pipelines

Crude oil, natural gas and other petroleum products are shipped by pipelines. Once the pipelines are built, the cost per kilometre for shipping is very inexpensive. There is a lot of opposition and concern over new pipelines because of worry over spills and leaks that may contaminate land and waterways.[6]

Multimodal/Intermodal shipping

This refers to the use of a combination of different types of transportation to move goods from origin to destination. A common example is a combination of truck/ship/train. The goods are shipped under a single contract with a carrier, and can be easily tracked. It also uses several modes of transportation but also uses a container so that freight does not have to be handled each time

4. Palmer, B. (2014). Let's make an effort to move more freight by rail and less by road. Trains are more efficient. Retrieved on November 4, 2019, from https://www.washingtonpost.com/national/health-science/lets-make-an-effort-to-move-more-freight-by-rail-and-less-by-road-trains-are-more-efficient/2014/03/03/d1947278-9d90-11e3-9ba6-800d1192d08b_story.html
5. The St. Lawrence Seaway Management Corporation. (2019). A Vital Waterway. Retrieved on November 4, 2019, from http://www.greatlakes-seaway.com/en/seaway/vital/index.html
6. Green, K., Jackson, T. (2015). Pipelines are the safest way to transport oil and gas. Retrieved on November 4, 2019, from https://www.fraserinstitute.org/article/pipelines-are-safest-way-transport-oil-and-gas

it changes modes. Each mode will have a carrier responsible for the shipment. The use of containers increases the security, reduces loss and damage and increases the speed of shipment.

TRUCKING

- Flexible (truck load vs. less-than-truckload)
- Drivers in demand
- Creates highway congestion

RAILROADS

- Ideal for bulkier products or containers
- Cost effective over distances
- Energy efficient

AIRFREIGHT

- Ideal for small & light products
- Prioritizes speed over cost
- Reliable
- Air pollutant

WATERWAY

- Ideal for low cost, heavy products
- Very common
- Inexpensive

PIPELINE

- Used for crude oil, gas, petroleum
- Once built, very cost effective

MULTIMODAL

- Uses a combination of modes through a carrier
- Products secured

Figure 4.4: Diagram summarizing various modes of transportation.

Distribution Management

Distribution management refers to the process of overseeing the movement of goods from supplier or manufacturer to point of sale. Distribution management is an important part of the business cycle for distributors and wholesalers. The profit margins of businesses depend on how quickly they can turn over their goods. The more they sell, the more they earn, which means a better future for the business. Having a successful distribution management system is also important for businesses to remain competitive and to keep customers satisfied.

Distribution involves diverse functions such as customer service, shipping, warehousing, inventory control, private trucking-fleet operations, packaging, receiving, materials handling, along with plant, warehouse, store location planning, and the integration of information.

The goal is to achieve ultimate efficiency in delivering raw materials and parts, both partially and completely finished products to the right place and time in the proper condition.[7]

The combination of distribution and transportation is **logistics**. The most important factor in any logistics is quickly delivering product in perfect condition. Read here how Amazon has used its supply chain management to fuel its rise to the top.

Crossdocking

A broad definition of **crossdocking** is the transfer of goods and materials from an inbound carrier to an outbound carrier without the products actually entering the warehouse or being put away into storage. Thus, the products "cross the docks" from the receiving dock area to the shipping dock area. It can provide significant inventory savings, and the cost of holding inventory and the costs of handling the inventory are reduced. Crossdocking helps to provide excellent customer service by speeding up customer deliveries.[8]

Communication and Technology in the Supply Chain

Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) is the computer-to-computer exchange of business documents, such as purchase orders and invoices, in a standard electronic format between business partners, such as retailers and their suppliers, banks and their corporate clients, or car-makers and their parts suppliers.

7. Kenton, W. (2019). Distribution Management. Retrieved on November 4, 2019, from https://www.investopedia.com/terms/d/distribution-management.asp
8. Kulwiec, R. (2004). Crossdocking as a Supply Chain Strategy. Retrieved on November 4, 2019, from https://www.ame.org/sites/default/files/target_articles/04-20-3-Crossdocking.pdf

EDI enables the companies to transfer the documents without having any people involved. The documents are automatically transferred from one computer (account) to another. As a result, there are many advantages to using EDI. The primary benefit is the speed and accuracy of the information transmitted. Information is made available in real time and errors that may have previously been caused during the data entry process are eliminated.

Common information exchanged using EDI include:

- Purchase orders
- Invoices
- Advance shipment notices (ASN)
- Customs documents
- Inventory information
- Shipping status
- Payment documents
- Bill of lading
- Sales/price catalogues
- Shipment status messages

Barcodes

Barcodes have been used extensively since the 1970s, and consist of data that is displayed in a machine-readable form that can be scanned by barcode readers. The information contained on the barcode is typically pricing information, product number and description and any other pertinent information. Barcodes have become the norm in retail operations allowing for pricing accuracy and easy price changes. This data provides point-of-sale information to allow retailers to track items being sold, update inventory, identify fast and slow moving products and assist in forecasting.

QR

Quick Response (known as QR) is using bar codes and EDI to make sales data available to vendors so that vendors can quickly replenish goods in the correct quantity. This is thought of as JIT in the retail industry. The goal is to reduce out-of stock incidents, as well as using smaller more frequent deliveries to reduce inventory and operating expenses.

Radio Frequency Identification Device (RFID)

This technology uses radio waves to communicate information contained on a tag attached to an object. The information contained on a tag may include things such as the products origin, date of production, shipment information, pricing info, and any other pertinent info. In order to transfer this info, both a tag and a reader are needed. There are two types of tags, active and passive. An active tag contains a power source such as a battery and can operate a great distance from the reader. Passive tags use energy from the reader. Unlike barcodes, the RFID tag and reader do not require line of site in order to transmit the information.

RFID applications include the following plus many more:

- Retail use to protect from theft
- Toll road payments
- Identification (i.e. tracking of animals and people)
- Passports
- Shipping tracking – to identify location and contents of orders
- Asset tracking (e.g. laptops, expensive tools, medical devices in hospitals)
- Race timing for marathons
- Tracking luggage during travel

Supply Chain Collaboration

Vendor Managed Inventory (VMI)

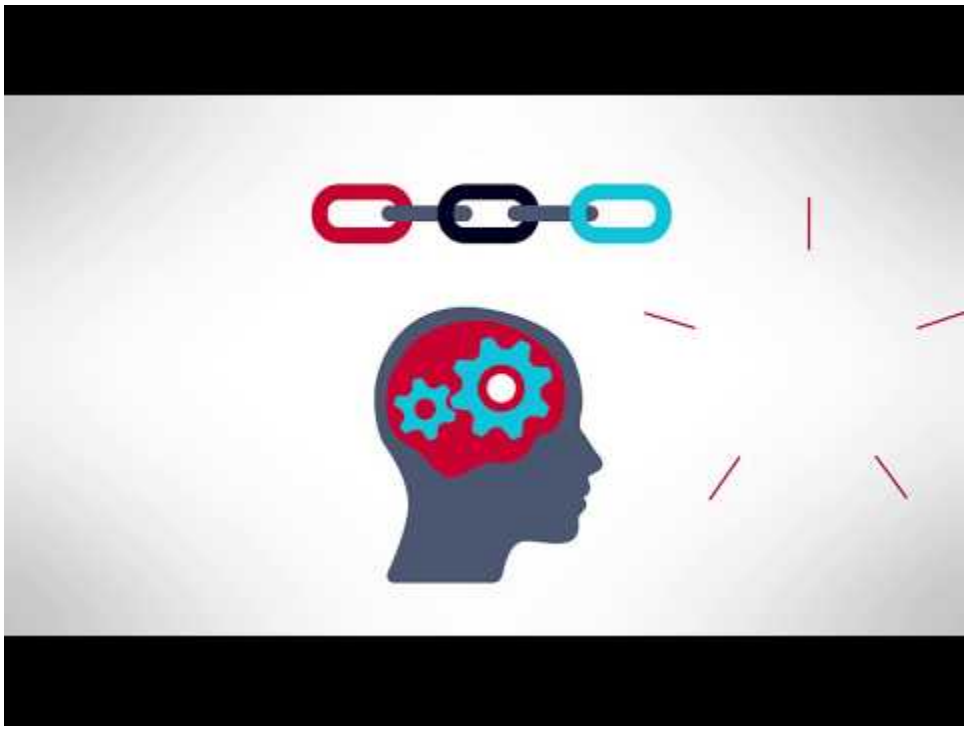
Vendor Managed Inventory (VMI) is an advanced supply chain relationship whereby a vendor (often a manufacturer) has access to their customer's inventory information and the vendor takes the responsibility for maintaining an agreed-upon level of product at the customers location. This arrangement can be used with manufacturers, distributors and retailers.

VMI has numerous benefits for both the supplier (vendor) and the customer. The vendor has strong motivation to ensure that shelves are fully stocked, any slow-moving stock is discontinued and that employees have full understanding of the product offerings. The customer benefits from these VMI relationships because less work is involved on the buyers' end. Due to EDI, there are few errors and goods flow quickly. Point-of-sale data updates the inventory and determines what items are needed. Salespeople from the vendor often provide assistance by training sales staff and assisting customers when possible.

Collaborative Planning, Forecasting and Replenishment (CPFR)

Collaborative Planning, Forecasting and Replenishment (CPFR) is an arrangement where two trading partners in a supply chain collaborate to agree on forecasts and orders between the manufacturer and distributor/retailer. The distributor/retailer will have collected POS data and added any additional information, such as promotion plans, inventory status or forecasts. That information gets shared with manufacturers who will then compare it with their own forecasts and capacity. Both teams can collaborate to solve any discrepancies, eliminate gaps and agree on a final set of numbers. Collaborating in this way will enable both firms to reduce inventory as well as reducing problems such as shortages and capacity problems.

Measuring Supply Chain Performance



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Inventory Turnover

Key Performance Indicators are measurements used to evaluate supply chain performance. One of the ways to evaluate the supply chain performance is to calculate **inventory turnover** (inventory turns):

$$\text{Inventory Turnover} = \frac{\text{Cost of goods sold}}{\text{Average Aggregate Inventory Value}}$$

Figure 4.5: Inventory turnover formula (cost of goods sold divided by average aggregate inventory value).

"Average aggregate inventory value" is a term used to describe all of the inventory held in stock, which includes raw materials, work in process and finished goods, all valued at cost.

Inventory turnover is an indicator of the policies and practices of an organization. It represents their ability to purchase materials, produce and sell their products in a timely manner. A higher value for the inventory turnover means that the organization has been capable of replenishing and selling its inventory more number of times in any particular amount of time, and as a result, have a better cash flow.

It is important to keep in mind that high or low value of inventory turnover for each company is relative to its

own industry. For example, dairy (milk) manufacturing has an annual inventory turnover of around 23, while this number is 14.7 for the grocery supermarkets, and 4.8 for the automotive industry.[9] Industries with higher volume, but lower margin, usually have the highest inventory turnovers.

Example

NED's Food Supply is a supplier to restaurants and institutions for frozen foods, meats, fish, canned and fresh fruits and vegetables. Here is an analysis from the past two years regarding their inventory management. In which year was their supply chain performance better?

	Last year	Two years ago
Cost of goods sold	17,550,000	16,255,000
Average aggregate inventory value	$1,650,000	$1,763,350

Solution

Inventory turns for last year = 17,550,000 / 1,650,000 = 10.64 turns

Inventory turns for two years ago = 16,255,000 / 1,763,350 = 9.22 turns

Last year, their inventory turnover was faster. If customer service was equivalent in both years, then their performance was better last year than it was two years ago. This may have resulted in customers receiving fresher foods as well.

Days of Supply

Another related performance measure is **days of supply**:

$$\text{Days of Supply} = \frac{\text{Average Aggregate Inventory Value}}{\text{Annual Cost of Goods Sold}} \times 365 \text{ days}$$

Figure 4.6: Days of supply formula (average aggregate inventory value divided by annual cost of goods sold, the sum of which is multiplied by 365 [days]).

Example

J's Custom Automotive Finishing has calculated that his annual cost of goods sold at 45,000,000. His average inventory value in 2019 is:

9. BDC. (2019). Inventory turnover ratio. Retrieved on November 4, 2019, from https://www.bdc.ca/en/articles-tools/entrepreneur-toolkit/business-assessments/pages/inventory-turnover-benchmarking-tool.aspx

Production components	2,350,000
Production supplies	450,000
Finished goods	225,600
Total aggregate inventory value:	**3,025,600**

Solution

Days of supply = (3,025,600 / 45,000,000) x 365 = 24.54

This measure can be thought of as how much inventory is sitting in the building at any one time. In terms of measuring the efficiency of the inventory, a lower number is better. It would imply that goods are purchased more frequently and spend less time in the facility before being converted into sales.

There are other ways to measure supply chain performance as well. In a warehouse or distribution setting, **fill rate** is an important measure. It is the percentage of customer orders that are filled from on-hand stock. In a manufacturing setting, a measure such as the **percentage of orders delivered on time** is an important indicator of customer service level.

Socially Responsible Supply Chain Management

Main areas of social responsibility in supply chains are:[10]

- Organizational practices
- Ethical practices
- Environmental practices
- Practices of human rights and working conditions
- Practices of occupational health and safety
- Practices to establish relationship with society

The following table[11] summarizes activities and practices considered good examples for the CSR areas listed above.

10. Carter, C.R., Jennings, M.M. (2002). Logistics Social Responsibility: An Integrative Framework. Journal of Business Logistics, 23(1), 145-180
11. Ciliberti, F., Pontrandolfo, P., Scozzi, B. (2008). Logistics Social Responsibility: Standard Adoption and Practices in Italian Companies. International Journal of Production Economics, 113, 88-106.

Relevant CSR Areas	Sample Practices
Organizational Practices	· Determining CSR goals for purchasing function · Determining and defining roles and responsibilities of human resources related to CSR in logistics · Providing relevant training in CSR to the suppliers · Sharing of CSR activities and practices with all relevant stakeholders · Implementing a mechanism to receive feedback from stakeholders regarding CSR practices
Ethical Practices	· Not accepting gifts, free services, etc. from suppliers (especially during supplier selection process) · Not creating illegitimate pressures on suppliers · Not sharing price and service information about suppliers with other irrelevant stakeholders · Not favoring any particular supplier just because of managers' preferences and assuring a fair selection process · Assuring all departments meet ethical standards in independent purchasing process · Not creating illegitimate advantage in competition by using contract items · Not giving out wrong information on purpose · Not using specific items pointing out specific suppliers in contracts
Environmental Practices	· Purchasing and using recycled materials for packaging · Supporting and encouraging suppliers on reducing waste (especially hazardous waste) · Putting special emphasis on producing recyclable and reversible materials in production and design · Meeting standards for protecting environment in the processes of lifecycle management, production, packaging and storing · Supporting suppliers to implement processes that are appropriate for sustainable environmental protection
Practices of human rights and working conditions	· Not keeping some suppliers out of cycle, just because they have managers from different backgrounds · Having procedures and also having mechanisms to monitor providing equal opportunity for each employee working in all supplier companies · Having appropriate procedures in place to assure that all employees can benefit from all their legal rights, are working in accordance with rules, regulations and national/ international standards · Assuring that physical and psychological working conditions comply with all rules and regulations in place
Practices of occupational health and safety	· Having appropriate procedures in place to assure that working conditions do not jeopardize human health and safety · Assuring that all safety, security and protection measures are in place for all activities · Having procedures in place to assure that sensitive and delicate products are stored under appropriate conditions
Practices to establish relationship with society	· Developing and carrying out programs for training and development of local suppliers · Actively participating into and organizing non-for-profit social activities, such as volunteer work, charities, public auctions, etc. · Supporting sport activities and public education

Among those aforementioned activities, ensuring that all activities and functions comply with national / international rules, regulations and standards and working with suppliers that fulfill same requirements constitute the most important factors for CSR in supply chains. This issue is also important to stay competitive in market and to have a sustainable growth in terms of strategic perspective.

Video: Business is about purpose

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5. Managing Quality

Learning Objectives

- Understand dimensions of design quality, process quality and service quality.
- Describe the quality gurus that contributed to the modern field of quality.
- Discuss the costs of quality.
- Understand and Differentiate between TQM, ISO9001 and Six Sigma.
- Describe the tools used in quality improvement projects.

Video: The importance of Quality Management

In today's business environment, quality can be broadly defined as the extent to which a product or service meets or exceeds a customer's expectations.

Prior to the 1980s, Quality was not a main priority for North American manufacturers. As high-quality goods began flowing into North American markets from Japan, it slowly became apparent that North American companies had fallen behind. Japanese products began to be preferred by consumers who recognized their superior level of quality. This was the case especially in the automotive market.

For any product the quality of that product is determined by two primary factors. These are DESIGN quality and PROCESS quality.

Design quality can be described as the quality that a product has in terms of the actual characteristics of the product. Think about the design of your favourite cell phone. The decisions made by Marketing as well as the Design team will determine the way your phone will operate, the quality of the sound, the features it has, not to mention the way it looks, feels and lasts. Below are some facets of quality in products.[1]

Design Quality	Description	Cellphone Example
Performance	Primary operating characteristics	Clarity of sound, speed of connection
Durability	Ability to withstand damage	A dropped phone withstands damage
Reliability	Long lasting; how long before a breakdown occurs	Several years of trouble-free performance
Features	Extra characteristics, bells, and whistles	Extra storage space, long lasting battery
Serviceability	How easy it is to fix and how willing the organization is to repair the product	Same day repairs, large network of locations
Reputation	Perceived image in the marketplace	High scores on global quality ratings
Aesthetics	The appearance of the product, feel, smell, taste	Sleek modern design, large screen

Figure 5.1: Table denoting design qualities (with cellphone example).

Process quality refers to the ability of the organization to produce the good or service having perfect quality at each stage of the process, or in other words, manufacturing defect-free products.

Element	Description
Raw Materials	Quality level of purchased inputs
Equipment	Capability, well maintained, flexibility
Employees	Experience, training, ability level
Technology	Matches the application

Figure 5.2: Table denoting process qualities.

1. Garvin, D. (1987). Competing on the Eight Dimensions of Quality. Retrieved on November 7, 2019, from https://hbr.org/1987/11/competing-on-the-eight-dimensions-of-quality%20accessed%20Dec%202019

Measurement of **service quality** is more challenging. Each customer has a certain performance level in mind from which to compare or evaluate a service. Below are some of the commonly accepted elements in which customers evaluate service performance.

Element	Description
Tangibles	Any physical products used during the service
Reliability	Dependable service, correctly done each time
Convenience	How accessible the service provider is
Responsiveness	The willingness to respond to customer requests
Time	How quickly the service is delivered
Courtesy	The politeness and friendliness of employees
Consistency	Repeated consistent performance without fail
Assurance	Employees have a high level of expertise and trust

Accessible format for Figures 5.1-5.3

Gurus of Quality

Much of the field of Quality originated from several individuals who spent their careers researching, teaching and developing the field of Quality. These individuals are Walter Shewhart, W. Edwards Deming, Joseph Juran, Philip Crosby and Armand Fiegenbaum.

Walter Shewhart (1891-1967)

Dr. Shewhart was an American physicist, engineer and statistician. He is known as the father of statistical quality control and spent much of his career researching variation and is credited with the creation of the first control chart. His work focused around the need to reduce variation in order to improve quality. He is responsible for the concepts of assignable and common variation.

The processes that produce goods and services will all have some variation. It is intuitive that the more variation in processes, the poorer the quality will be. **Assignable variation** is the type of variation where the cause can be clearly identified and corrected or managed. An example of an assignable variation might be an error by an employee, a software glitch, or a tool breakage. **Common variation**, also referred to as chance variation, is the type of variation that is inherent in the process. It is generally to be expected, and not a cause of an error. Intuitively, if we reduce or minimize either variation, we will improve product quality.

Edwards Deming (1900-1993)

Dr. Deming is likely the most well known of the Quality Gurus. He was an American engineer, statistician, professor and author. Dr. Deming was recruited to Japan after WWII to assist with their national census. Beginning in 1950 Deming trained thousands of Japanese engineers, managers, and scholars in basic statistical process control. He is credited with guiding the rise of Japanese superior quality. In appreciation for Deming's guidance the Japanese named their highest quality award after Dr. Deming (The Deming Prize). Dr. Deming

has an extensive list of published works but is likely most well known for **Deming's 14 points**[2] and the **Deming Cycle**.

Edwards Deming's "14 points:"

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive, to stay in business and to provide jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. Cease dependence on inspection to achieve quality. Eliminate the need for massive inspection by building quality into the product in the first place.
4. End the practice of awarding business on the basis of a price tag. Instead, minimize total cost. Move towards a single supplier for any one item, on a long-term relationship of loyalty and trust.
5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.
6. Institute training on the job.
7. Institute leadership The aim of supervision should be to help people and machines and gadgets do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.
8. Drive out fear, so that everyone may work effectively for the company.
9. Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and usage that may be encountered with the product or service.
10. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.

    1. Eliminate work standards (quotas) on the factory floor. Substitute with leadership.
    2. Eliminate management by objective. Eliminate management by numbers and numerical goals. Instead substitute with leadership.

11. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.
12. Remove barriers that rob people in management and in engineering of their right to pride of workmanship.
13. Institute a vigorous program of education and self-improvement.
14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

2. Wikipedia contributors. (2019). W. Edwards Deming. In *Wikipedia, The Free Encyclopedia*. Retrieved on November 9, 2019, from https://en.wikipedia.org/wiki/W._Edwards_Deming#Key_principles

The Deming Cycle or Deming Wheel is also known as **PDCA**, or "Plan, Do, Check, Act." It is a version of continuous improvement that emphasizes the continuous nature of process improvement.

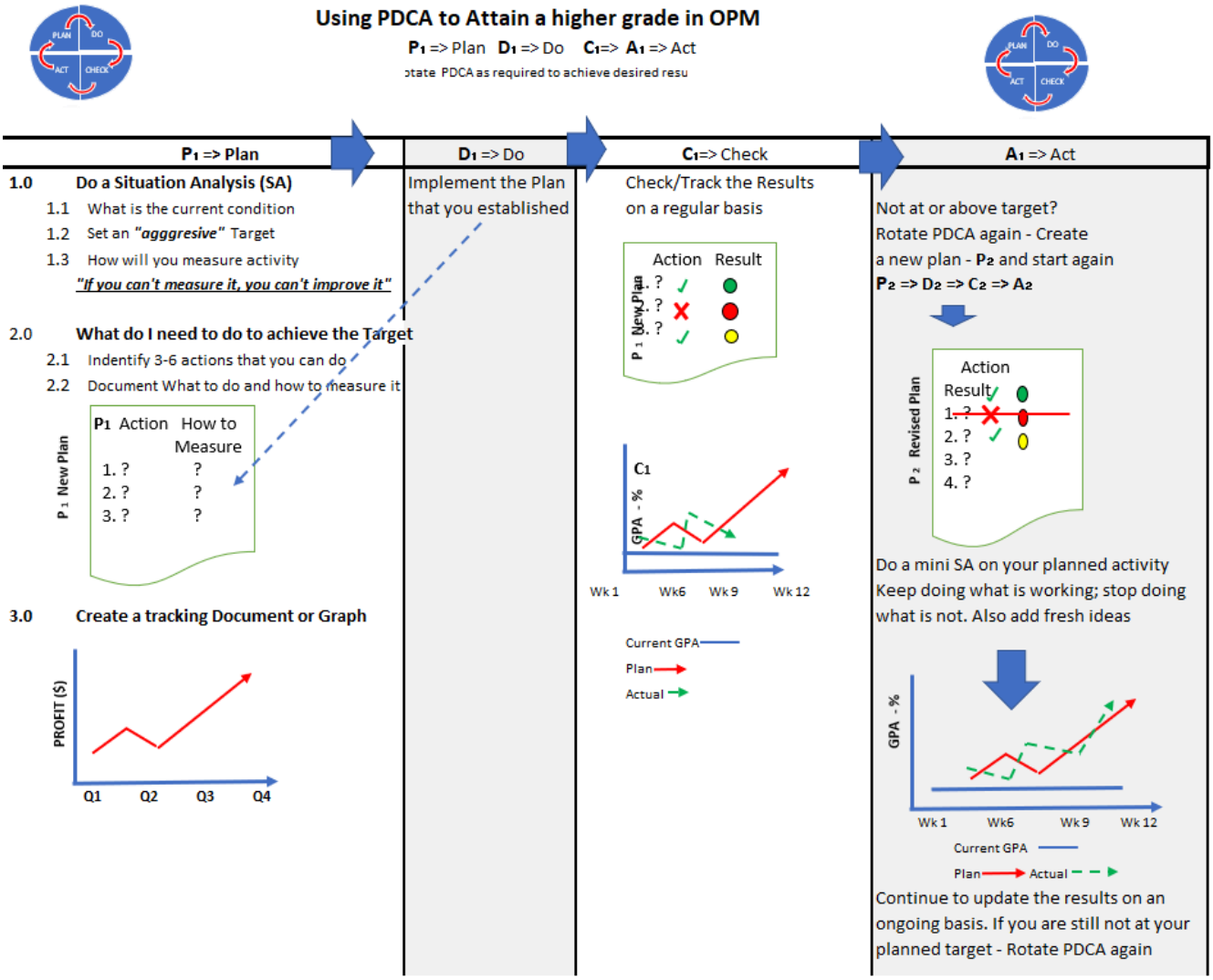

Figure 5.4: An example utilizing PDCA to attain a higher grade in OPM; Courtesy of Jim Philips.

Accessible format for Figure 5.4

Joseph Juran (1904-2008)

Juran was a Romanian-born American engineer. He is best known for the *Quality Control Handbook*, which was first published in 1951. He emphasized the importance of three specific factors which came to be known as the quality trilogy: quality planning, quality control and quality improvement. He authored hundreds of papers and 12 books. He is responsible for creating the concept known today the **cost of quality**. The Juran Institute in the U.S. is a leader in training and research in quality. Joseph Juran also came upon the work of Vilfredo Pareto (1848-1923) and made the Pareto Principle, also known as the 80/20 rule, well known today as a tool for problem solving and continuous improvement.

Pareto was an Italian economist and sociologist who noticed that 80% of the land in Italy was owned by about 20% of the population. This **Pareto principle** is alive and well today in the field of quality and continuous improvement. It is generally accepted that 80% of defects can be traced to a small number (20%) of the causes. Firms need to ensure that they are concentrating on fixing the correct or "root" causes.

Other examples of the 80/20 rule

- 80% of a company's profits are generated by 20% of the products or services sold
- 80% of the continuous improvement ideas are generated by 20% of the employees

Philip Crosby (1926-2001)

Crosby was an American businessman and author. He published *Quality is Free* in 1979. He believed that the costs of quality are often understated. He coined the phrase **zero defects** and felt that there was no reason for any errors. He taught that it is less expensive to do it right the first time rather than to pay for extra inspection, scrap, rework and repairs.

Armand Fiegenbaum (1920-2014)

Dr. Feigenbaum was an American quality engineer and businessman. He was the Director of Manufacturing Operations at General Electric from 1958-1968. He devised the concept of total quality control, which later became total quality management (TQM). He is also known for his concept of a "hidden plant." He felt that a large portion of a plant's capacity is wasted due to the large amount of failures and defects.

Cost of Quality

Companies who provide excellent quality goods and services are obviously able to excel and differentiate themselves from competitors. They also tend to be more profitable and their losses and extra costs due to poor productivity, rework, inspection, and scrap will be negligible.

The various costs of quality can be broken down into the following four categories: **prevention costs**, **appraisal costs,** and failure costs, which are further classified as **internal failure costs** and **external failure costs**.

Prevention costs

Prevention costs include all the funds spent to prevent the occurrence of defects. Examples include quality improvement initiatives, employee training, upgrading of equipment, implementing quality procedures and making proactive design changes.

Appraisal costs

All money spent in checking and testing of product during the production process would be considered Appraisal costs. Wages of inspectors when defined as part of the process, testing labs and equipment, gauging, and process control, would be included in this category.

Internal failure costs

Once a defect has been produced, with any luck the organization will detect the error before it leaves the building and is sent to the customer. Often, defective products can be repaired, but all of the extra time spent on the rework is considered internal failure costs. Product that is unable to be repaired is classified as scrap. This also is Internal Failure costs. This can cause many other problems because customers still expect on-time deliveries. Often other orders may have to be re-manufactured and expedited in order to compensate for products that are scrap. The customer is often not aware of these issues.

External failure costs

Once a defective product has been shipped to the customer, the costs then become external failure costs. Replacement product, expedited shipping, potential law suits, product recalls, and of course loss of future business are all external failure costs. It is impossible to predict the actual external failure costs since there is no way of gauging the impact of dissatisfied customers on future business.

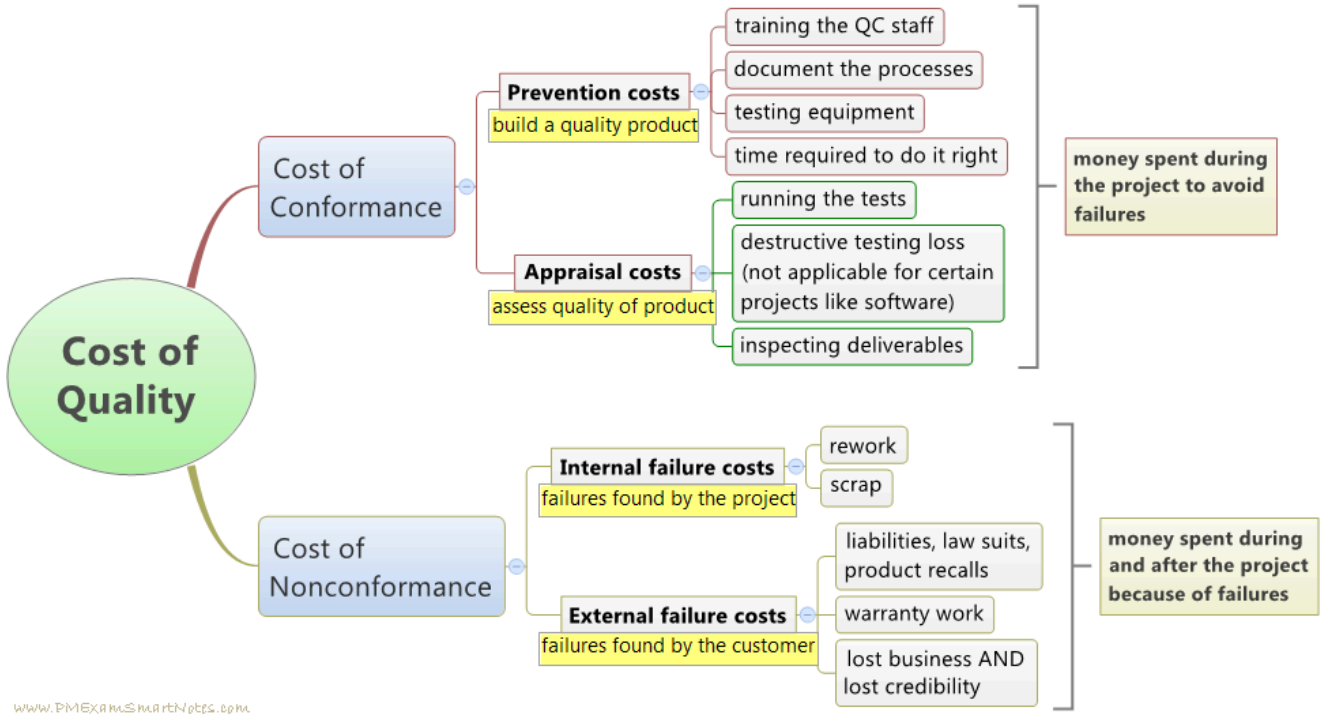

Figure 5.5: A diagram denoting the costs of conformance (prevention and appraisal costs) versus non-conformance (internal and external failure costs) in quality management; Credit: pmexamsmartnotes.com / Flickr / http://flic.kr/p/dYvQhj / CC BY-NC-ND

Quality Systems

Three common quality systems that many organizations use in order to manage their quality are total quality management (TQM), ISO9001, and Six Sigma.

Total Quality Management (TQM)

To compete today, companies must deliver quality goods and services that satisfy customers' needs. This is the objective of quality management. Total quality management (TQM), or quality assurance, includes all the steps that a company takes to ensure that its goods or services *meet or exceed the customers defined specifications* and are of sufficiently high quality to meet customers' needs. Generally speaking, a company adheres to TQM principles by focusing on three tasks:

1. Customer satisfaction
2. Employee involvement
3. Continuous improvement

Let's take a closer look at these three principles.[3]

Customer Satisfaction

Companies that are committed to TQM understand that the purpose of a business is to generate a profit by satisfying customer needs. Thus, they let their customers define quality by identifying and offering those product features that satisfy customer needs. They encourage customers to tell them how to make the right products, both goods and services, that work the right way.

Armed with this knowledge, they take steps to make sure that providing quality is a factor in every facet of their operations—from design, to product planning and control, to sales and service. To get feedback on how well they're doing, many companies routinely use surveys and other methods to monitor customer satisfaction. By tracking the results of feedback over time, they can see where they need to improve.

Employee Involvement

Successful TQM requires that everyone in the organization, not simply upper-level management, commits to satisfying the customer. When customers wait too long at a drive-through window, it's the responsibility of a number of employees, not the manager alone. A defective DVD isn't solely the responsibility of the manufacturer's quality control department; it's the responsibility of every employee involved in its design, production, and even shipping. To get everyone involved in the drive for quality assurance, managers must communicate the importance of quality to subordinates and motivate them to focus on customer satisfaction. Employees have to be properly trained not only to do their jobs but also to detect and correct quality problems.

In many companies, employees who perform similar jobs work as teams, sometimes called quality circles, to identify quality, efficiency, and other work-related problems, to propose solutions, and to work with management in implementing their recommendations.

Continuous Improvement

An integral part of TQM is continuous improvement: the commitment to making constant improvements in

3. Saylor Academy. (2012). Producing for Quality. Retrieved on November 9, 2019, from https://saylordotorg.github.io/text_exploring-business-v2.0/s15-07-producing-for-quality.html

the design, production, and delivery of goods and services. Improvements can almost always be made to increase efficiency, reduce costs, and improve customer service and satisfaction. Everyone in the organization is constantly on the lookout for ways to do things better.

ISO

The International Organization for Standardization (ISO) is an international standard-setting body composed of representatives from various standards organizations.

Founded on 23 February 1947, the organization promotes worldwide proprietary, industrial and commercial standards. It is headquartered in Geneva, Switzerland, and works in 164 countries.

ISO is an independent, non- governmental organization and is the largest developer of voluntary international standards. Use of these standards assists organization to create products and services that are safe, reliable and of good quality. The standards help businesses increase productivity while minimizing errors and waste. By enabling products from different markets to be directly compared, they facilitate companies in entering new markets and assist in the development of global trade on a fair basis. The standards also serve to safeguard consumers and the end-users of products and services, ensuring that certified products conform to the minimum standards set internationally.[4]

Video: What ISO Standards do for you

4. Wikipedia contributors. (2019). International Organization for Standardization. In Wikipedia, The Free Encyclopedia. Retrieved on January 2, 2020, from https://en.wikipedia.org/w/index.php?title=International_Organization_for_Standardization&oldid=930771418

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Steps in obtaining ISO certification

1. A firm must initially begin by documenting and implementing their systems for quality management. Add: These documents must include Policy, Procedures and work instructions. This is no small task. This documentation may take a great deal of time, effort and collaboration by all of their employees. In addition to this, the company will develop a Quality Manual that outlines how they will assure the quality of their goods and service.
2. Training of all employees involved with these processes must take place. The employees must gain full understanding and be comfortable with these new work procedures and documents
3. An audit must take place. The organization must arrange to have a certification body come to complete the audit. There are many different private companies that have been granted (by ISO) the authority to grant ISO9000 certification. These private companies are themselves accredited by ISO.

The cost for the above steps will clearly depend largely on the size and complexity of the organization. Many firms choose to use external consultants to guide and assist them in this process. Generally it is accepted that it will take somewhere from 12 to 18 months to complete this process. The usual certification process lasts for three years. Skeptics think that some organizations pursue their ISO Certification only because customers require it. In reality, a deep desire to improve internal performance should be the intrinsic motivation to implement any quality program.

Does ISO certification improve financial performance?

What benefits are there to obtaining ISO certification?

The benefits of ISO certification are many. Read the article below from Business Development Bank of Canada.

Seven ways ISO certification can help your business

There are other certifications besides ISO9001. ISO14001 is an International Standard for evaluating a firm's environmental performance.

Hazard Analysis Critical Control Point (HACCP)

HACCP is a quality management system for organizations in the food processing industry. By implementing a HACCP program, the following results will be obtained:[5]

- gain customer confidence
- sharpen your competitive edge and develop new export opportunities
- achieve more rigorous quality control
- reduce waste and spoilage
- control contamination risks and recall processes
- build awareness of hygiene and safety for employees
- eliminate potential allergen issues

What are the seven principles of HACCP?

Think of HACCP principles as the steps you need to take to manage and control food safety risks in your business.

Here is a link to view the seven steps to ensure food safety in the supply chain.

Any food business must have the safety of their customers as they key priority. By implementing a successful HACCP program, these risks can be controlled to protect from the chances of a foodborne illness outbreak. In 2005 it became mandatory for federally registered meat and poultry establishments to become HACCP Certified. The Canadian Food Inspection agency recommends HACCP compliance certification for all food businesses in the food supply Chain.

Video: Alberta Agriculture and Forestry on HACCP

5. https://www.bdc.ca/en/consulting/pages/haccp-certification.aspx

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Six Sigma

You may end up accepting a job in an organization that has a Six Sigma Program. Six Sigma is a set of techniques and tools for process improvement. It was introduced by engineer Bill Smith while working at Motorola in 1980. It is a comprehensive quality system for achieving business success by minimizing variation in business processes. Six Sigma quality is used to describe a process so well controlled that there are no more than 3.4 defects per million opportunities

Six Sigma comes from the term in statistics of sigma, meaning standard deviation. It is a measure of the amount of variation in a set of data. A usual company process might operate at a 3 sigma quality level. This indicates that 99.73% of all output will fall between plus and minus three standard deviations of the mean. The result then would be that 0.27% of all results are non-conforming, or defective. This is equivalent to 2700 defects per million opportunities. This is not so good if the business is operating in an industry where quality is critical to customer safety, such as manufacturing of aircraft, cars or medical devices. A process with a Six Sigma capability generates 99.99966% defect free outputs.

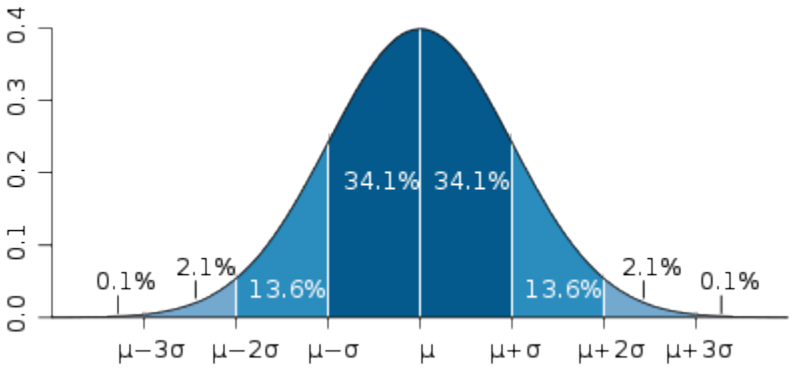


Figure 5.6: A diagram of a normal distribution utilizing Six Sigma; Credit: Ainali / Wikipedia / en.wikipedia.org/wiki/ File:Standard_deviation_diagram_micro.svg

Unique to Six Sigma is the DMAIC Improvement Model. In Six Sigma, improvements are made by the use of project teams. A team may be assembled in order to fix a quality issue, to streamline an old process or to develop a new process. The team will use the **DMAIC model**, which is an acronym that stands for Define, Measure, Analyze Improve and Control. Copyright © 1993 — American Society for Quality. All rights reserved. An explanation of the steps in the DMAIC process and some of the tools used are below.[6]

1. **Define** the problem, improvement activity, opportunity for improvement, the project goals, and customer (internal and external) requirements.
2. **Measure** process performance.
3. **Analyze** the process to determine root causes of variation and poor performance (defects).
4. **Improve** process performance by addressing and eliminating the root causes.
5. **Control** the improved process and future process performance.

6. American Society for Quality. (n.d.). THE DEFINE, MEASURE, ANALYZE, IMPROVE, CONTROL (DMAIC) PROCESS. Retrieved on January 22, 2020, from https://asq.org/quality-resources/dmaic

Figure 5.7: Cyclical diagram of the DMAIC model.

Also unique to Six Sigma is the use of the martial arts method of using coloured belts in order to symbolize the level of expertise in Six Sigma.

Green Belt is a designation indicating that an individual has had Six Sigma training. An individual with Green Belt status may have a full-time job in the organization but will be called upon to assist with projects part-time.

Black Belt is a full-time position in the Quality area where the individual works as a coach / leader in projects. These individuals will have extensive experience in Six Sigma.

Master Black Belt is a full-time position in the Six Sigma team with extensive experience in managing projects. They coach and mentor the Black Belt leaders.

Champion is usually a senior manager in the organization who oversees the other Six Sigma Quality employees.

The work on determining which projects should be prioritized, ensuring proper allocation of resources and removing any roadblocks that may prevent success.

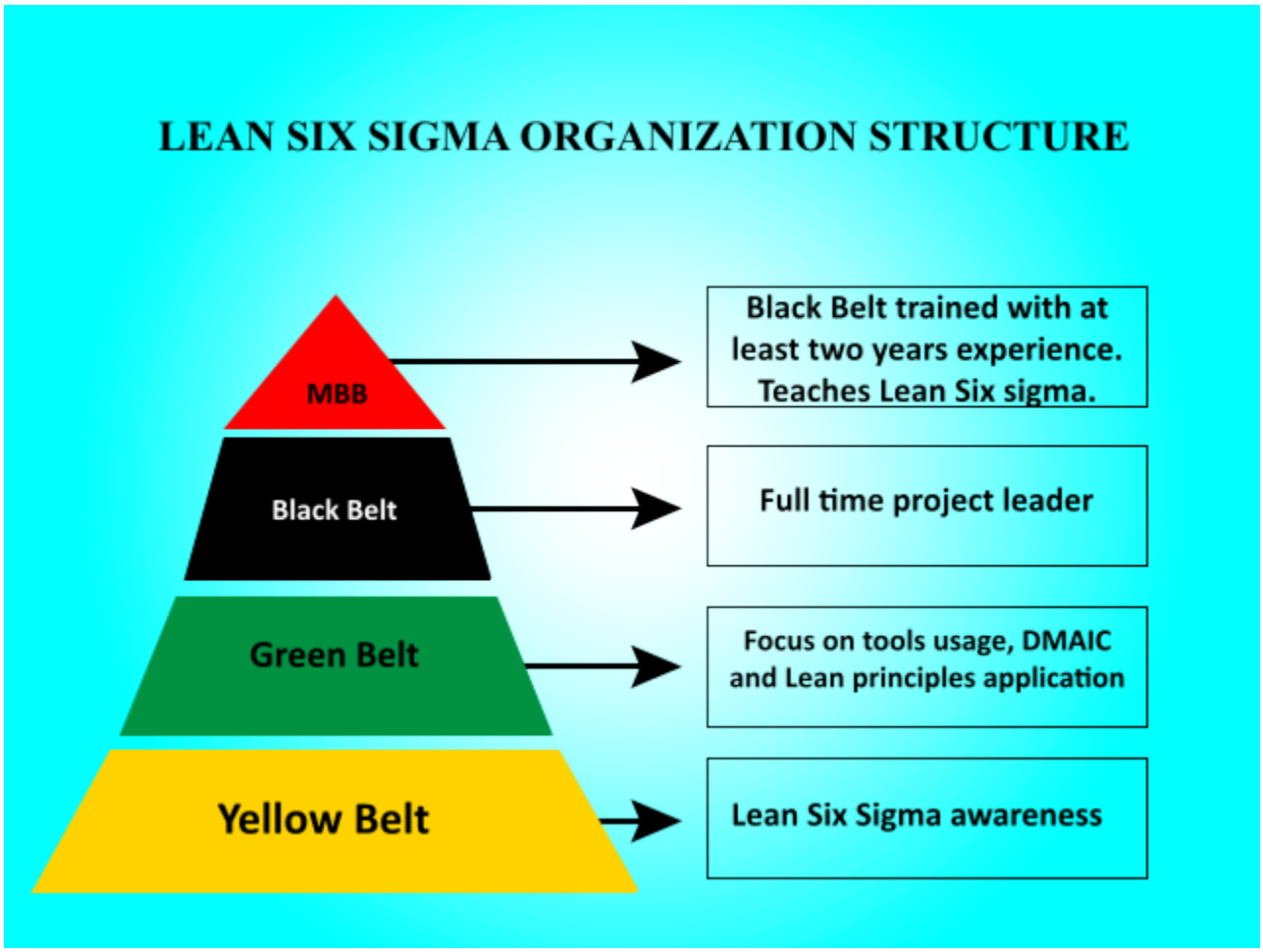


Figure 5.8: Variation of belt colours associated with Six Sigma ; Credit: Zirguezi / Wikimedia / commons.wikimedia.org/wiki/File:Lean_Six_Sigma_Structure_Pyramid.svg

Tools for Quality Improvement

In any Quality improvement initiative, the collection and evaluation of data is a critical step. There are a number of basic generic tools that are most commonly used. These tools include check sheets, histograms, control charts, Pareto charts, scatter diagrams, as well as cause and effect diagrams.

Check Sheets

This is a custom designed form used to record the number of occurrences of a particular outcome of interest. It may collect basic information such as how many incidents occurred, the timing, or the measurement that was non-conforming.

Motor Assembly Check Sheet

Name of Data Recorder: Lester B. Rapp

Location: Rochester, New York

Data Collection Dates: 1/17 - 1/23

Defect Types/ Event Occurrence	Dates							TOTAL
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	
Supplied parts rusted		𝍸	𝍸	𝍸	𝍸			20
Misaligned weld			𝍸			𝍸		5
Improper test procedure								0
Wrong part issued		𝍸		𝍸				3
Film on parts								0
Voids in casting				𝍸	𝍸			6
Incorrect dimensions						𝍸		2
Adhesive failure								0
Masking insufficient					𝍸			1
Spray failure			𝍸					5
TOTAL		10	13	10	5	4		

Histograms

Raw data from a check sheet may be put into a histogram. Data that is continuous in nature can be put into a Histogram that contains ranges of the data. It will show an accurate representation of the distribution of the data.

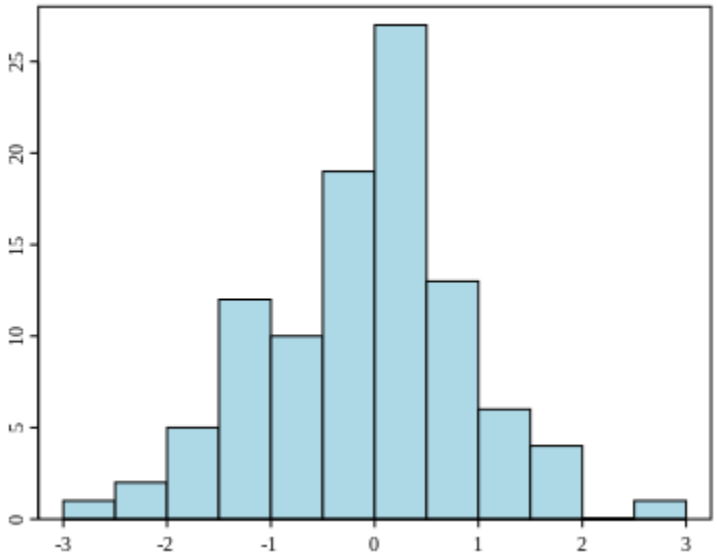


Figure 5.10: Example of a histogram.

Control Charts

In order to monitor the performance of a process over time, a control chart is the appropriate tool. A Control Chart includes an Upper Control limit and a lower Control limit, which are used to control the quality dimension that is measured. As long as points seem to appear randomly on both sides of the mean and they fall between the upper and lower control limits, the process is assumed to be in control.

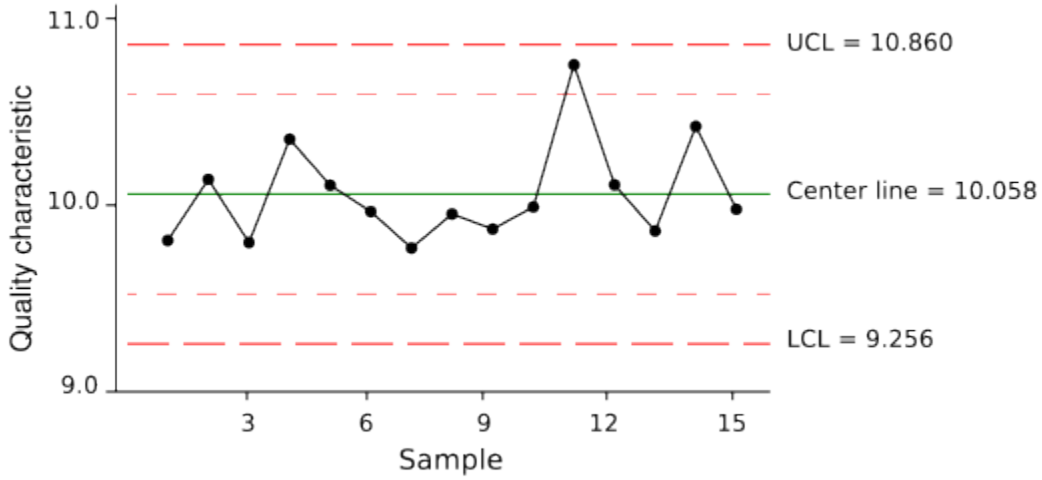


Figure 5.11: Example of a control chart.

Pareto Charts

A special type of bar chart that shows the number of occurrences of a particular characteristic, ordered from highest to lowest. The X axis represents each characteristic and the Y axis is the number of times this occurrence was recorded. In addition, a cumulative percent line shows the cumulative percentage that each category represents. The Y axis on the right hand side of the chart corresponds to the percentage on this line. In the management of quality, managers must allocate resources to rectify the most frequently occurring problems. A Pareto analysis helps us focus our attention on the defects that occur the most frequently and to allocate the resources accordingly.

Video: How to make a Pareto chart in Excel

Steps in a Pareto Analysis:

1. Collect your raw data and put it into a simple table in descending order. Sum the total number of results at the bottom of the column.

Complaints	**Number**
Long wait time	81
food not hot	48
Server unknowledgeable	20
bill inaccurate	16
floor not clean	9
Menu items sold out	7

2. Include a cumulative column and calculate the cumulative percentage of each.

Complaints	Number	Cumulative	Cumulative Percent
wait time long	81	81	44.8
food not hot	48	129	71.3
Server unknowledgeable	20	149	82.3
bill inaccurate	16	165	91.2
floor not clean	9	174	96.1
Menu items sold out	7	181	100.0

3. In EXCEL, your Pareto analysis will look like this.

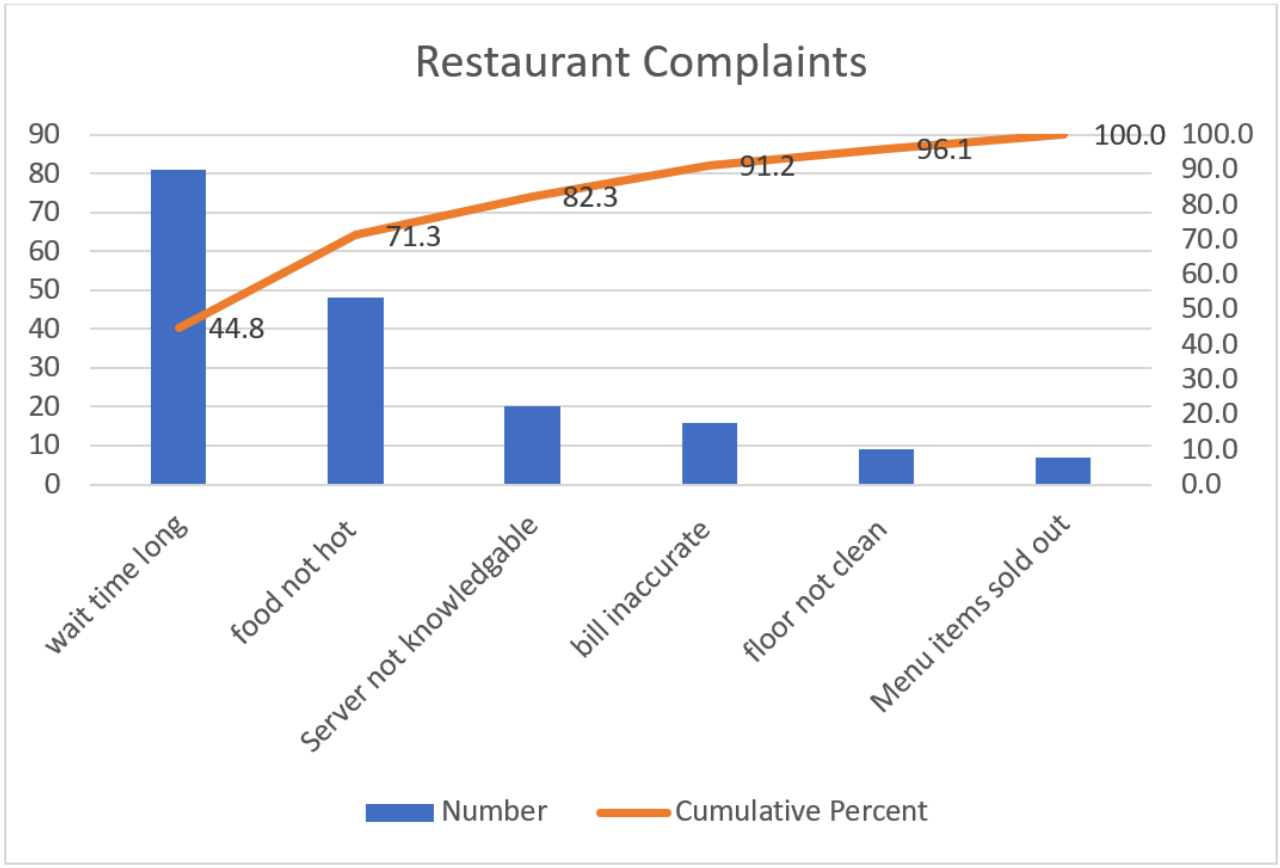


Figure 5.12: Example of a Pareto chart.

Scatter Diagrams

A simple diagram helps to figure out if there is a relationship between two variables.

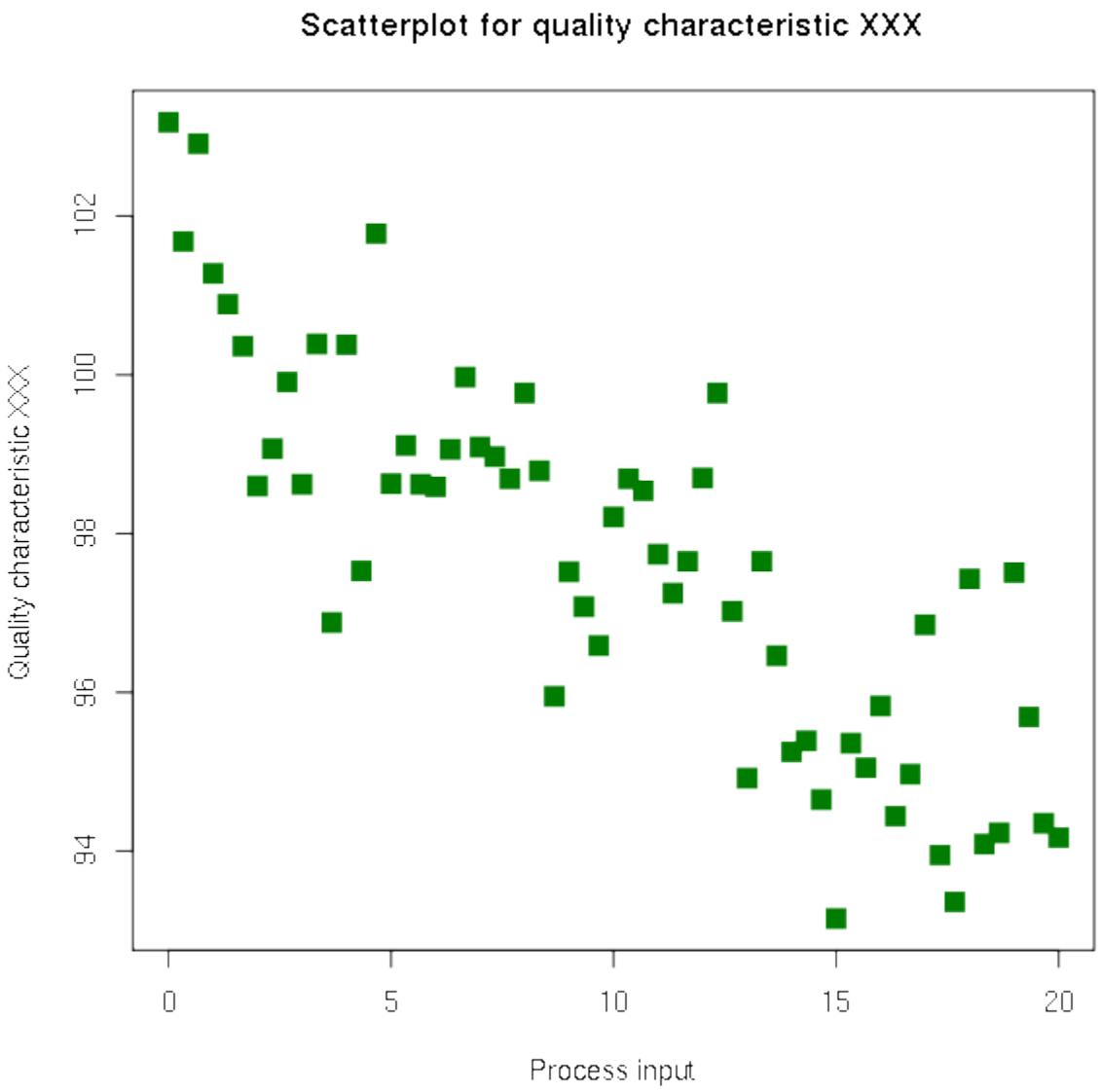


Figure 5.13: Example of a scatter diagram; Credit: DanielPenfield / Wikimedia / commons.wikimedia.org/wiki/File:Scatter_diagram_for_quality_characteristic_XXX.svg

Cause and Effect Diagrams

Also known as a Fishbone diagram, it was developed by Dr. Ishikawa[7] to help identify the causes of a problem. The overall shape is that of a fish. The pointy end points to the 'effect' or the problem. Each of the ribs represents a major cause, or category that is a potential contributor to the problem. Commonly, the rib bones tend to be categories such as the man, method, material, machine, and environment. The actual factors that fall under each category are written on their related rib.

7. https://en.wikiquote.org/wiki/Kaoru_Ishikawa

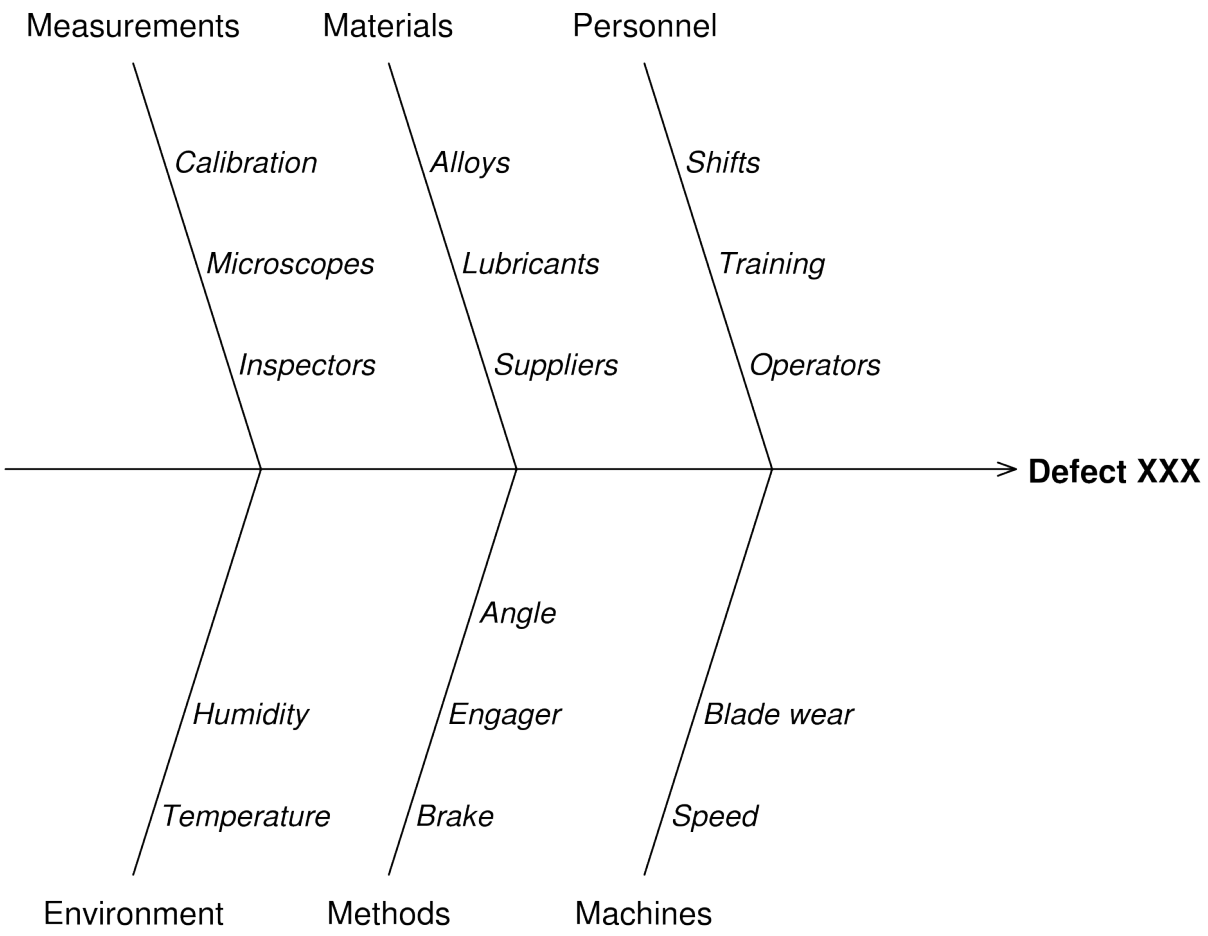
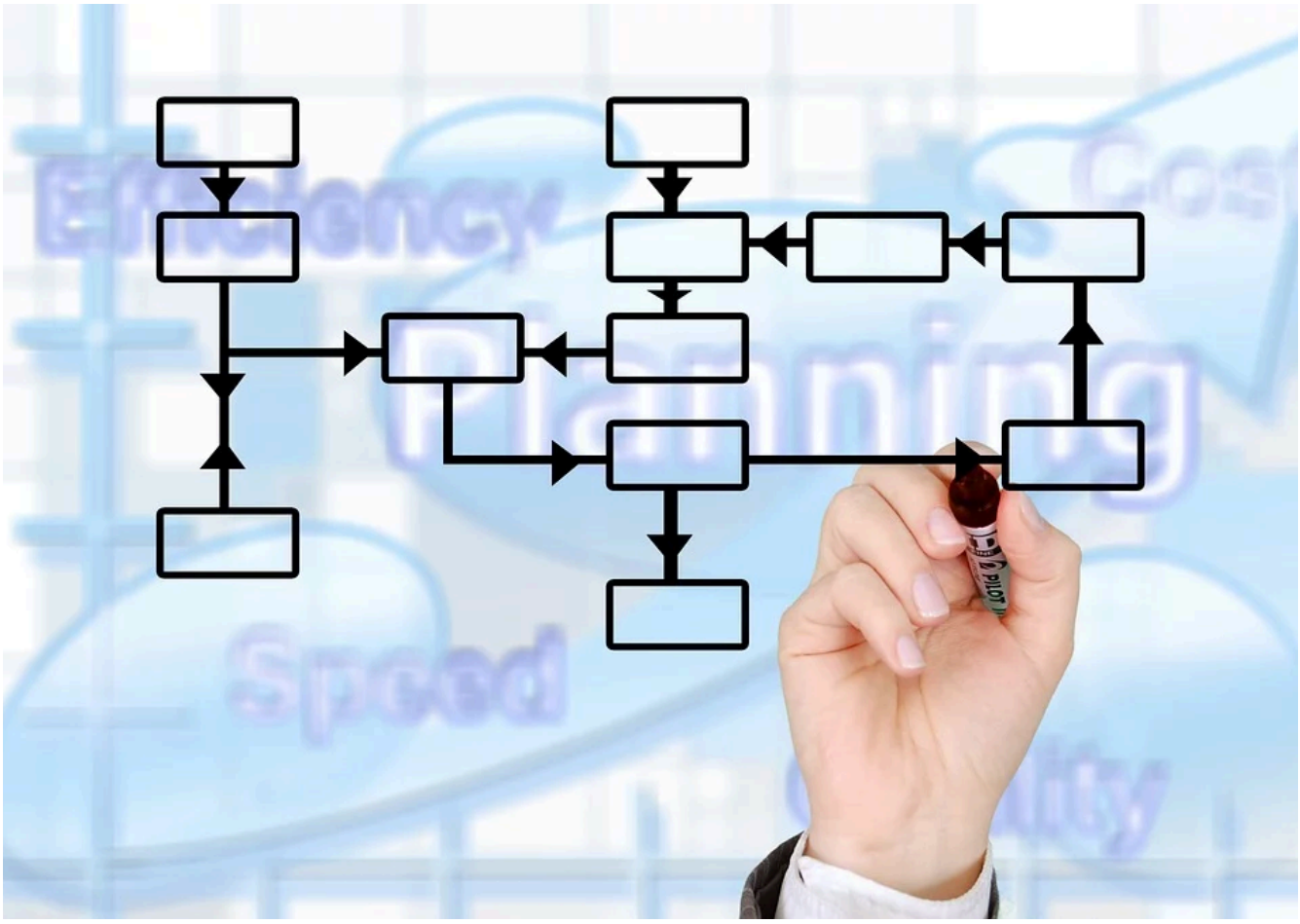


Figure 5.14: Example of a cause and effect diagram; Credit: DanielPenfield / Wikimedia / https://commons.wikimedia.org/wiki/File:Cause_and_effect_diagram_for_defect_XXX.svg

6. Process Design



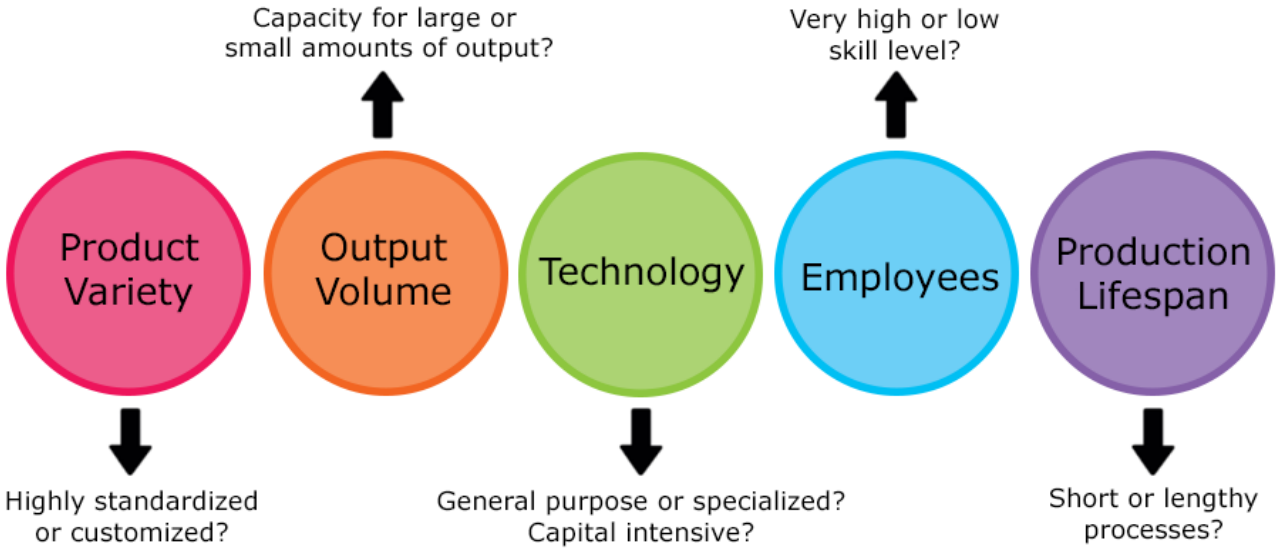
Learning Objectives

- Differentiate between the different types of processes.
- Understand common layouts and their challenges.
- Calculate takt time based on product demand.

Every firm that produces a good or a service will do so by the use of a process. This process will use the firm's resources in order to transform the primary inputs into some type of output. In designing the actual process, particularly the number and sequence of steps, several important factors need to be considered.

1. Product variety – Is the product highly standardized, or is the product highly customized?
2. Volume of output – Is the business created to produce large volumes or a small amount of output?

3. Is the technology to be used general purpose or specialized? Is it capital intensive?
4. The skill level of employees, it is very high or low?
5. What is the expected duration?



Make-to-order and Make-to-stock

It is useful to categorize processes as either make-to-order or make-to-stock.

In a **make-to-order** business, the customer's order is not manufactured until the order is received. This allows customization to the exact specifications that the customer requires. It may also be referred to as build-to-order. This type of production is considered a pull type system. The work is "pulled" through the process when customer demand is present.

The disadvantage of this type of system is that it takes time for the firm to acquire any materials and needed components, and then to schedule and produce the customers order. Goods are made in small amounts, and may be more expensive.

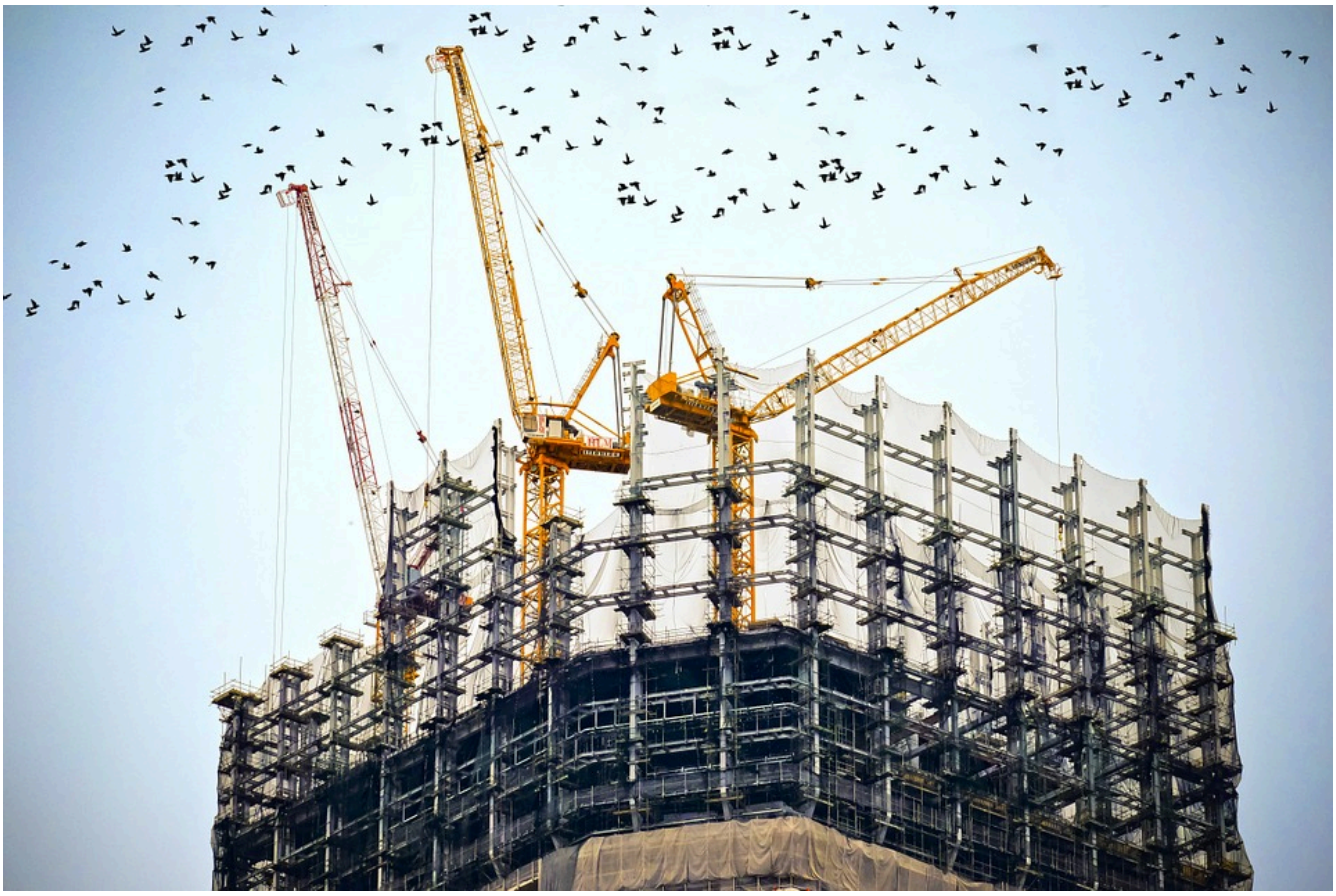
The advantage of this type of process is that inventory is lower than in a typical make-to-stock system. There is not any uncertainty about what the customer desires and there is no obsolete stock to be disposed of. Dell Computer has utilized this type of system to produce personal computers very successfully.

In a **make-to-stock** process, goods are produced in anticipation of customer demand, usually from a sales forecast. These products are generally made in larger amounts and put into storage to wait for customer orders. Although the unit cost may be lower due to large production volumes, there may be losses due to forecast error, excess inventory, obsolescence and theft. Lead times however are short because goods are available when the customer places the order. These goods are not customized, but standardized.

Process Types

Project

A one-time event, such as construction of an apartment building, implementation of a new ERP system, or writing a book, would all be considered a project type of process. Each of these projects have a high degree of customization, substantial use of resources, and a complex set of related activities. There is only a single output at the end of the project.



Job Shop

Many businesses have a job shop type of process. This is most commonly used when the product being produced is unique for each customer. It is a make-to-order type of business where production is intermittent (i.e. rather than one entire product being completed at a time, work will continue on multiple products as time permits). Often the product has unique characteristics for each customer. The workers in this type of business are very highly skilled in their craft or trade. Often they are referred to as craftsmen or makers. The volume of output is low in a job shop. The equipment used is quite general purpose. Examples include a small bakery that produces beautiful custom wedding cakes, or a business that makes custom guitars or bicycles based on the customers measurements and preferences of materials and components.

Batch

Some businesses are in the situation where they make groups of identical products on a regular basis. These groups are referred to as a batch. The batch will progress through a set of steps to be completed from the start to the end. An organization may have multiple batches at different stages coming through the process. This type of processing is also intermittent. (start, stop, start) There is less variety in this type of business (compared to a job shop) and the equipment used will be relatively general purpose and suited to the industry that they are in. Employees need to be skilled and experienced at operating that equipment and producing these products. Examples of products made using batch production are baked goods, aircraft parts, clothing, and vaccines. An important decision by these firms is how big the batch should be.

Repetitive

This type of business produces products that are more standardized in nature. Usually the output is high. Since the goods are quite standardized, the equipment used tends to be quite specialized and often highly customized for that process. The skill level of the employees is usually low because the steps are highly standardized. Although these types of jobs may not require a trade or extensive experience, they often do require skills such as multi-tasking, concentration, problem solving, and teamwork. Often, these processes use flexible automation that allows for customization such as the addition of upgraded features. Examples of a repetitive process include assembly lines such as assembling automobiles or electronics, a carwash, or a cafeteria line.

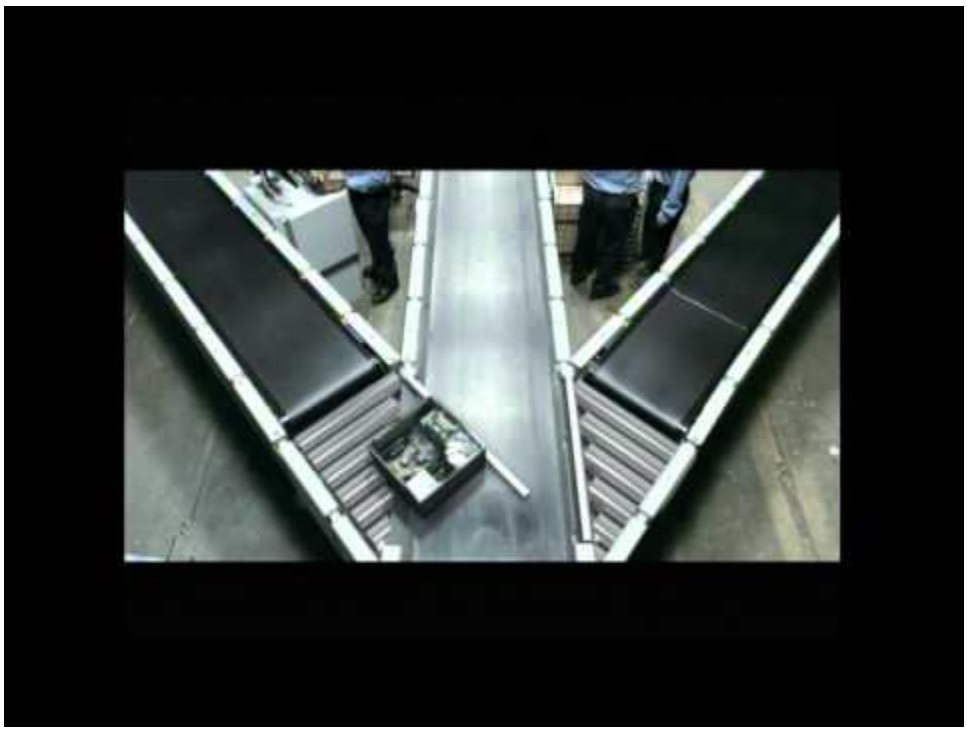
Attribution: Tansiis / Wikimedia Commons

Continuous

A continuous process is when a very high volume of standardized product is produced. The type of product being made is described as non-discrete. This means that these businesses do not produce individual products, rather a product that is often a liquid or a product such as sugar, gasoline, or steel. An example of this type of process is an oil refinery. There are not separate individual workstations, rather the product flows from one step to the next within the system. The equipment in this type of process is highly complex and designed solely for that product at that facility. There are very few workers except for those that are responsible for process monitoring, maintenance, and cleaning.

Hybrids

There are many firms using mixtures of process types. One such common exception is the **Mass Customization**model of production. In mass customization, a company combines low-cost high volume of output, but each and every customer order is customized to the customers specifications. Usually the use of computer-aided manufacturing systems is what permits this customization. Examples include furniture makers who wait to produce the exact model of sofa based on the customers dimensions and fabric choice, or the vehicle manufacturer that has dozens of customization packages and paint options such that each vehicle is custom for the purchaser. A key requirement for successful mass customization is a modular design to allow fast seamless change from each product to the next.



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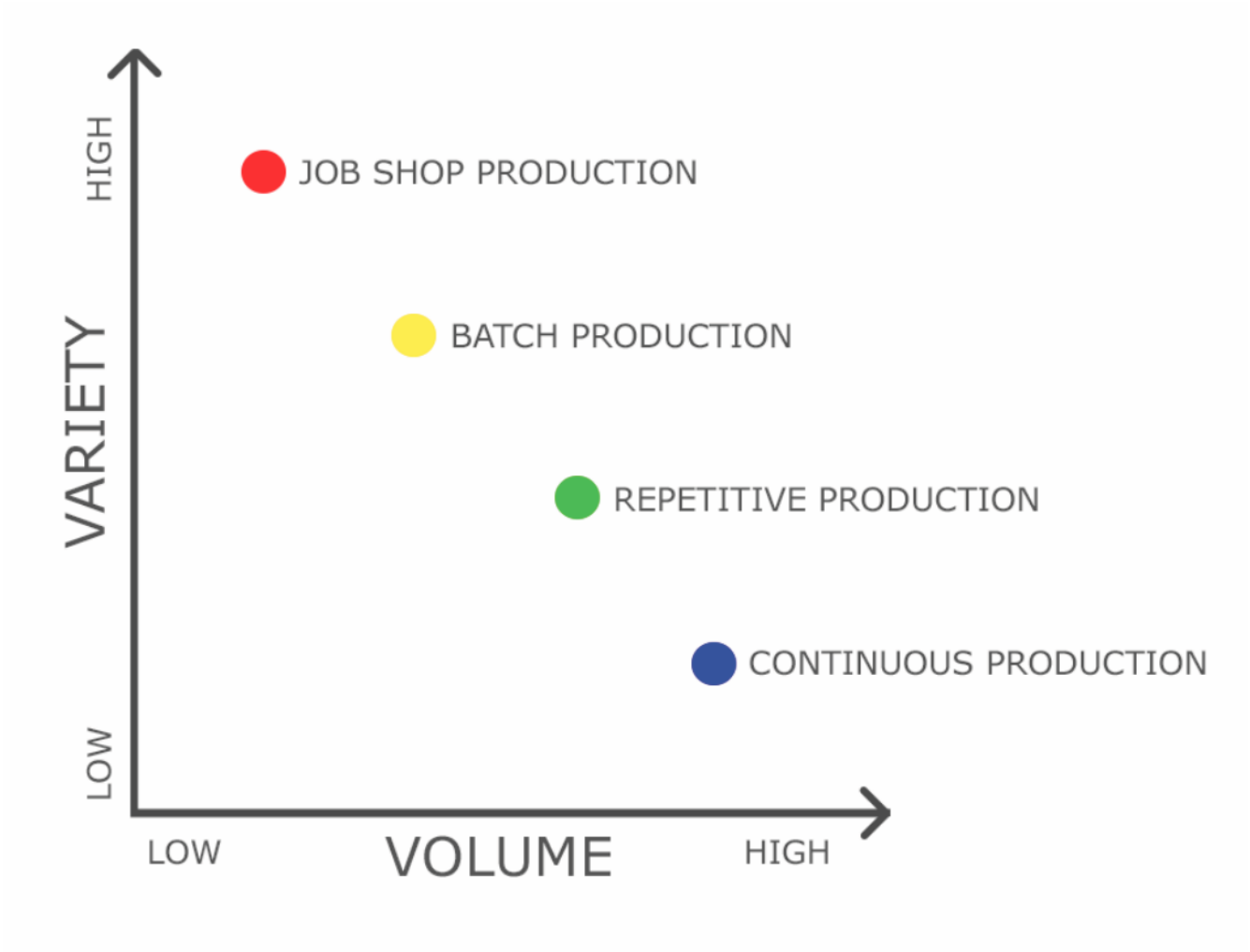


Facility Layout

Layout refers to the way in which organizations position their equipment, departments, or workcentres. Having an effective layout can streamline production activities, eliminate wasted or redundant movement and improve safety. The general types of layouts are: a fixed position layout, a process layout (functional), a product (line) layout, and a cellular layout, which is considered a hybrid. Other common layouts include office layouts, retail layouts, and warehouse layout.

Fixed Position Layout

When producing a product that is not easily able to be moved, it may require that the worker, their tools and equipment are brought to the site where the production is taking place. This is a common layout in manufacturing a building, a ship or performing repairs to major equipment.

Process Layout

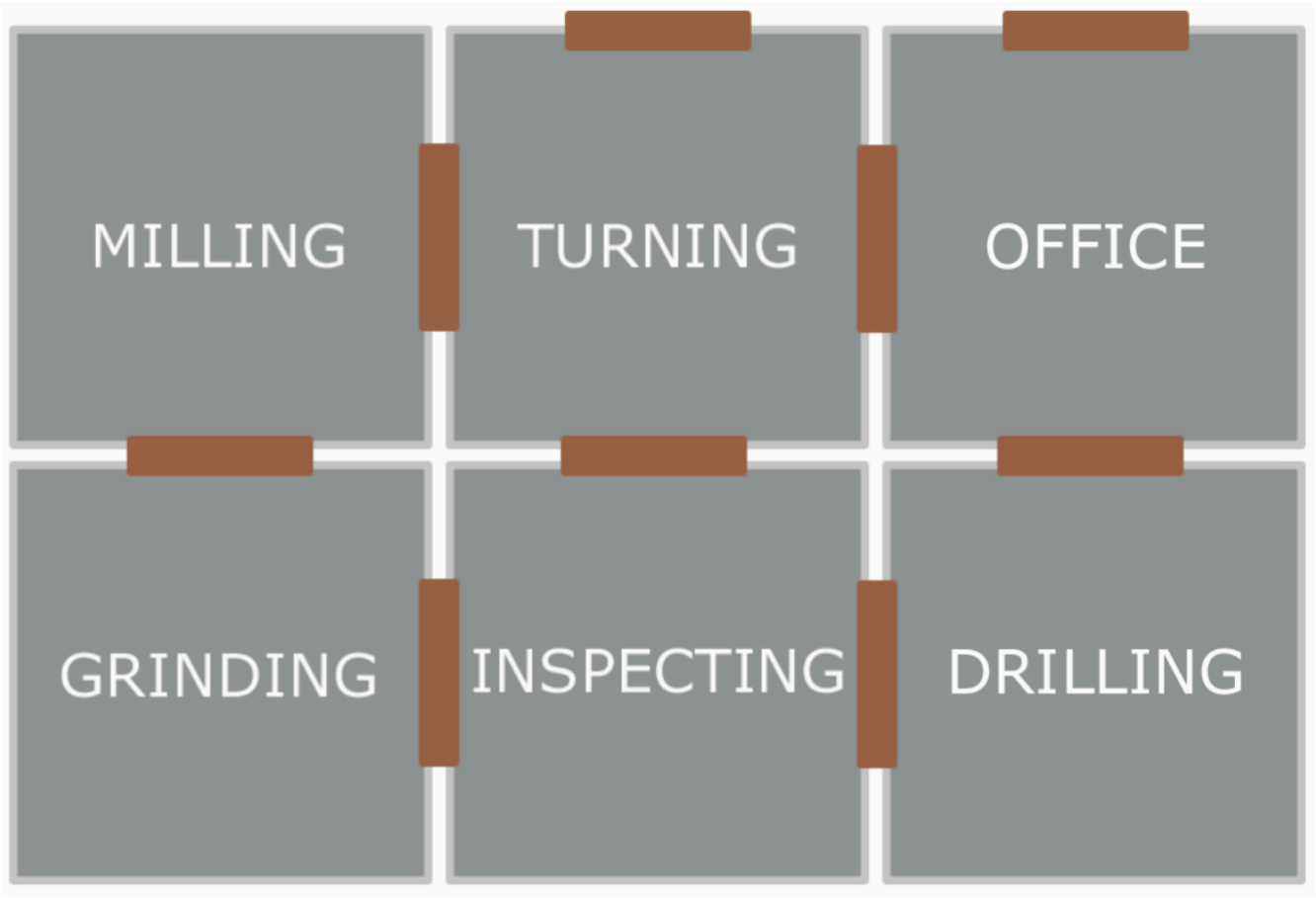
A process layout is a layout in which departments, equipment, or workcentres are arranged according to their

function. In a manufacturing environment, all of the milling machines may be in one area or "department," the lathes may be in another area, and the drilling machines all in another area. This layout is also common in services. In a department store, similar goods are arranged together such as footwear, jewelry, and housewares. At a hospital, cardiology is in one area, maternity in another location, and pediatrics elsewhere. The specific dedicated equipment and skilled practitioners work in each of these areas.

An advantage to a process layout is that equipment tends to be quite general-purpose. If one particular piece of equipment breaks down, it will not halt the entire process. This type of process gives flexibility to handle a variety of products or customers. It is ideal for job shops or small batch manufacturing.

A disadvantage of a process layout is that a particular product will likely have to travel from department to department to get the set of processes completed. This often leads to lots of material handling and movement of goods throughout the facility. A flexible material-handling system is needed such as forklifts. Inventory will sit in each area waiting for its turn to be processed. This waiting inventory is referred to as **queue.** When examining the total throughput time of jobs through the system, it is often discovered that each order spends much more time waiting in queue than it does actually being processed. For that reason, this type of layout is generally very inefficient. A major consideration in a process layout is to ensure that departments with a large amount of interaction are located nearby one another.

Below is an example of a machinery plant with a process layout:



Product (Line) Layout

These are used in businesses that use assembly lines or production lines. If the product has high volume an assembly line might be the best option. The equipment in these types of layouts are often very capital intensive and are laid out according to the progressive steps of the process. Each work station is located along the line and may consist of a worker with equipment, or robots. Often each work station is adding components (assembly line) or modifying a product (production line). It is important to note that it is not necessarily a straight line, often assembly lines zig zag or are in a shape to use the maximum amount of space available. Some services may use a line layout, such as preparing hospital meals, or a cafeteria line. Due to considerable cost involved with setting up an assembly line, a large volume of product needs to be produced. Demand that is steady and consistent is ideal.

The goods produced in a line layout are generally very standardized, and the work processes are also highly standardized. Each product follows the same set of steps so that a fixed path material handling system is used such as a conveyor belt. This conveyor belt may be manual or automatic. It may operate at a pre determined speed, or it may be worker paced. It may run continuously or pulsed. The speed of the conveyor will determine the amount of product that will be produced per shift.

In contrast to a process layout a product layout is very efficient**.** There are a number of reasons for this.

1. Because of the division of labour and the repetition, there is less variability in the work performed
2. There is no build up of inventory, and no waiting. When completed at one work station, the job automatically moves to the next workstation. Only the inventory that is in process is in the system. Goods

tend to be shipped when they are completed.
3. Due to the material handling system, goods move quickly and not very far.
4. Changeovers are not necessary so very little time is lost in changing between products.

It is important that assembly lines are balanced**.** The amount of time required at a preceding work station should be relatively similar to the amount of time required at the following work station.

Challenges in a product (line) layout include:

1. The fact that the line may be susceptible to shut downs if there are equipment malfunctions so preventative maintenance is critical. Preventative maintenance involves the inspection and replacement of any parts that have a high probability of failures, as well as holding ample spare parts in stock and having a detailed maintenance schedule for each piece of equipment.
2. Training and job rotation are critical activities to make sure employees are capable of completing the work tasks and that there are multiple people that can work at each individual job
3. With repetitive standardized jobs, it is critical that good ergonomic job design is performed. Organizations that ensure the health, safety and comfort of their employees reap rewards in terms of the quality of work they receive from employees.

Here is a fun video; see Rick Mercer on the Assembly line in GM Oshawa:

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Cellular Layout

Cellular layouts are considered a “hybrid” type of layout because it includes characteristics of both a Process layout and a product (line) layout. It is very common that a business may have multiple product lines, with far too much variety in order to take advantage of one assembly line. Often these businesses may have been using a process layout, with all of the associated product movement and waiting times. An alternative that became popular beginning in the late 1980s is the Cellular layout type. This type of production layout is still heavily utilized today.

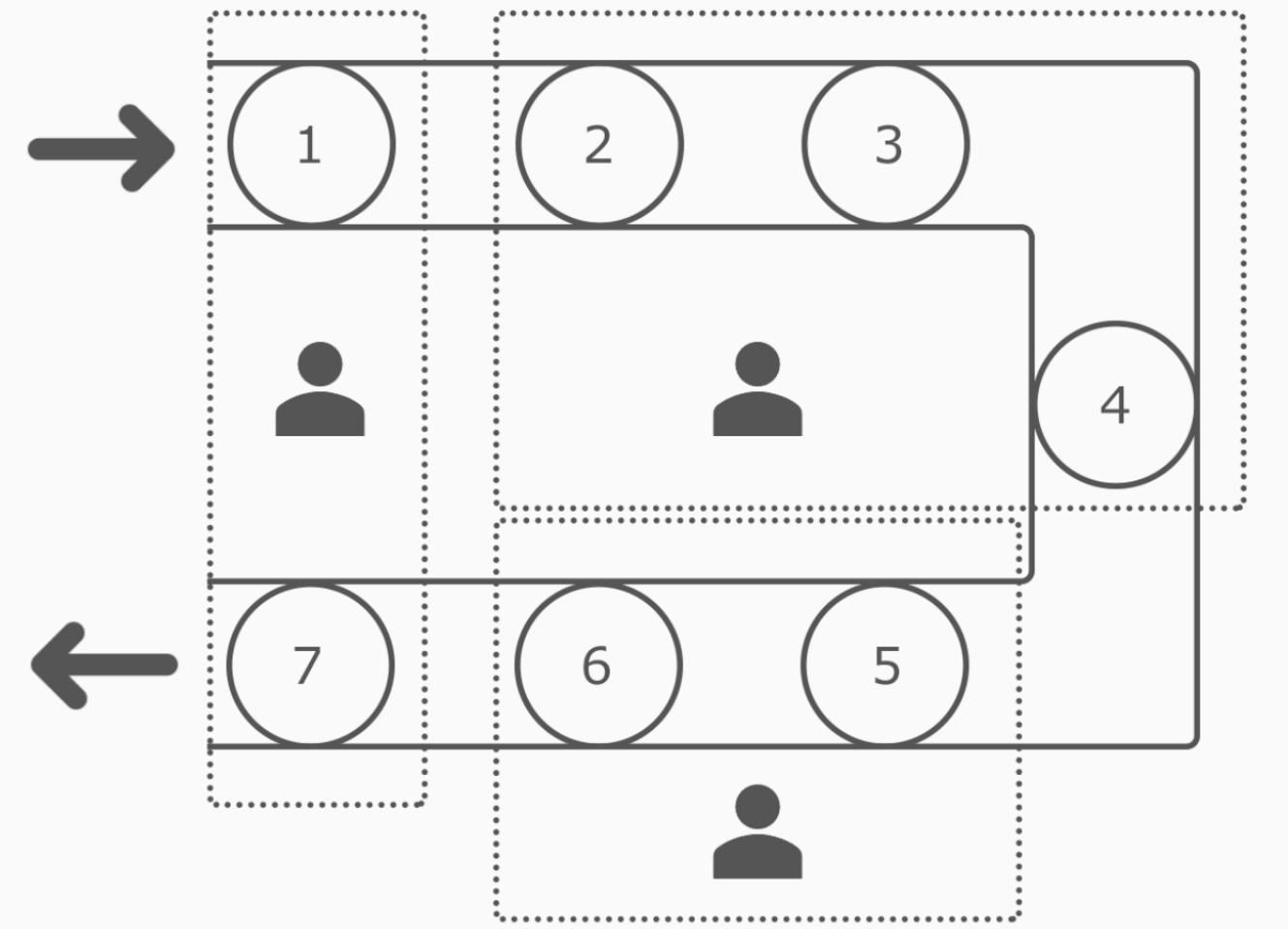
This type of layout begins with the company performing a thorough analysis of their products and deciding which products are similar to one another and often share common geometry and processing requirements in terms of equipment, machinery, technology and employee skills. These products are grouped together and manufactured in a work cell. This is referred to as group technology.

Each work cell will contain a unique set of equipment to manufacture this family of parts in an assembly line type of layout. The equipment is laid out in a U shape with equipment located close together so jobs do not have to move very far.

Advantages of a cellular layout include:

1. Reduced set up times for each piece of equipment because each machine is making products that are very similar, often set-ups are very fast or non-existent.
2. Speed is greatly enhanced because batches can now be small and goods that enter the system will continue until they are complete. Small batches means fast run times and short wait times.
3. Inventory investment is now reduced due to small batch sizes enabled because of the low set up times required.
4. Quality is enhanced because employees work only within that cell on a narrow range of products. Cross training of employees ensures good and thorough knowledge of the entire production process.
5. Employee morale is improved due to working as part of a team that has responsibility for the throughput and quality of the cell. The U-shaped design heightens collaboration among workers.
6. Less floor space is required due to machines being placed close together and less movement of product.

An example of a U-shaped layout can be found below:



Here is a video on cellular manufacturing:

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Other Layouts Include

Office Layout: In 2020 office spaces are a great deal different than in generations past. Floor space per employee has dropped significantly. There is far less worry about the flow of paperwork than in the past. Often employees are grouped according to the tasks they perform and the work teams they participate in. Workspaces now tend to be more flexible with less paper and less furniture to hold files and documents. Many organizations put more emphasis on having comfortable spaces for collaboration. Layouts are much more open concept with lower partitions to improve visibility of the workspace.[1]

1. Lashbrooke, B. (2019). This Is The Hottest Trend In Office Design Right Now, Retrieved on November 21, 2019, from https://www.forbes.com/sites/barnabylashbrooke/2019/08/27/this-is-the-hottest-trend-in-office-design-right-now/#5c26abb87787

Retail Layout: The overall goal when laying out a retail location is to try and maximize the amount of sales per square foot in the facility. This is done by careful study of traffic patterns in the store in order to try and maximize the amount of product to which each customer is exposed. That is why you will often find the milk at the far end of the store causing customers the need to walk past all other departments to reach it.

Warehouse Layout: Effective warehouse layout aims to make effective use of the total volume of space contained in the building. The relationship between the receipt of incoming goods, the storage space and the picking, packing and shipping of outbound goods is carefully analyzed. An important consideration is the placement of inventory items in order to minimize distance goods and employees are need to travel. Many warehouses have special holding requirements such as freezers, cold storage and high security areas.

Some important “Times” to be familiar with:

Throughput time is the time between the beginning – the very first operation in the process until the product is actually completed at the end of the process. Remember that this includes not only the process time, but also any waiting time, inspection time, time spent on rework and movement.

Lead time is the amount of time between when the customers order is received and when the product is completed and ready to ship.

Cycle time is the rate at which the operation is actually producing each unit. If you stood at the end of the process and measured the time between completion of each unit, that is the true cycle time.

Takt time is a calculated value which determines the rate at which a firm needs to process their product in order to meet customer demand. It can be calculated by:

$$\frac{\text{available production time}}{\text{demand}}$$

Example

A firm operates 8 hours per day (480 minutes). Their daily demand is 120 units. They can calculate their takt time required to meet this demand:

(8 hours x 60 min) / 120 = 4 min.

The firm must product **one product every 4 minutes.** This is also known as the drum beat of the operation. They must produce one product at least every 4 minutes to meet customer demand. If demand increases it may be required to use continuous Improvement tools to change the takt time or possibly add additional equipment.

The above calculation shows that an assembly line must have a takt time of 4 minutes in order to produce 120 units per day. What if customer demand rose sharply? What would need to happen to increase the output?

Solution

The takt time would need to decrease (actually run faster). A takt time of 3.0 minutes would produce an output of 480 min / 3 min = 160 units. A takt time of 2.0 minutes would produce 240 units per day.

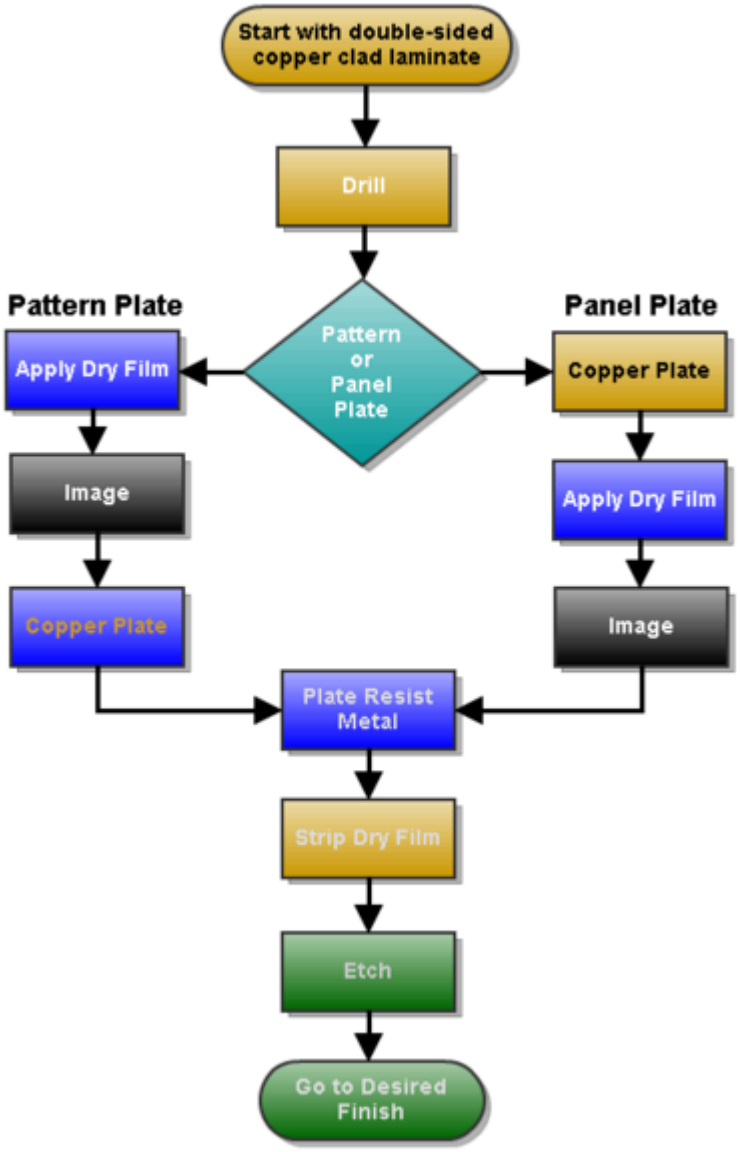
Process Flowcharting

Any process improvement initiative will always begin with mapping out a visual representation of the current process. This is necessary so that all members of the team have a clear understanding of how current process is working. All of the steps and flows need to be identified and laid out in the proper sequence. It is important that the correct stakeholders are involved in this activity!

There are many different types of flowcharts, and many different softwares that can assist with this activity. Most practitioners tend to prefer using a large roll of paper on the wall where the group can collaborate rather than using a computer projected onto a screen. It is important to go out into the workplace and walk the process before beginning this task. This is a very standard activity that takes place in organizations around the globe. As an Operations Manager, there is a high likelihood that you will become involved in this at some point in your career. To map a process, a standard set of symbols are used. There are many different symbols, it is best not to get too caught up in all of them. The standard symbols include:

Symbol	Meaning
	Start / Stop
	Operation
	Decision
	Storage
	Flow

For example:


Start with double-sided copper clad laminate
Drill
Pattern Plate
Pattern or Panel Plate
Panel Plate
Apply Dry Film
Copper Plate
Image
Apply Dry Film
Copper Plate
Image
Plate Resist Metal
Strip Dry Film
Etch
Go to Desired Finish

7. Strategic Capacity Planning

Learning Objectives

- What are common capacity strategies?
- Calculate efficiency and utilization measures.
- Describe factors that determine effective capacity.
- Understand the steps in the capacity planning process.
- Determine the capacity in a sequential process with a bottleneck.
- Use break even analysis to evaluate capacity alternatives.

This module examines how important strategic capacity planning is for products and services. The overall objective of strategic capacity planning is to reach an optimal level where production capabilities meet

demand. Capacity needs include equipment, space, and employee skills. If production capabilities are not meeting demand, it will result in higher costs, strains on resources, and possible customer loss. It is important to note that capacity planning has many long-term concerns given the long-term commitment of resources.

Managers should recognize the broader effects capacity decisions have on the entire organization. Common strategies include **leading capacity**, where capacity is increased to meet expected demand, and **following capacity**, where companies wait for demand increases before expanding capabilities. A third approach is **tracking capacity**, which adds incremental capacity over time to meet demand.

Finally, the two most useful functions of capacity planning are design capacity and effective capacity. **Design capacity** refers to the maximum designed capacity or output rate and the **effective capacity** is the design capacity minus personal and other allowances. These two functions of capacity can be used to find the efficiency and utilization. These are calculated by the formulas below:

Efficiency = (Actual Output / Effective Capacity) x 100%

Utilization = (Actual Output / Design Capacity) x 100%

Effective Capacity = Design Capacity – allowances

Example

Actual production last week = 25,000 units

Effective capacity = 28,000 units

Design capacity = 230 units per hour

Factory operates 7 days / week, three 8-hour shifts

1. What is the design capacity for one week?
2. Calculate the efficiency and utilization rates.

Solution

(Using the formulas above)

1. Design capacity = (7 x 3 x 8) x (230) = 38,640 units per week
2. Utilization = 25,000 / 38,640 = 64.7%
   Efficiency = 25,000 / 28,000 = 89.3%

Capacity Planning for Products and Services

Capacity refers to a system's potential for producing goods or delivering services over a specified time interval. Capacity planning involves long-term and short- term considerations. Long-term considerations relate to the overall level of capacity; short-term considerations relate to variations in capacity requirements due to seasonal, random, and irregular fluctuations in demand.

Excess capacity arises when actual production is less than what is achievable or optimal for a firm. This often means that the demand in the market for the product is below what the firm could potentially supply to the market. Excess capacity is inefficient and will cause manufacturers to incur extra costs. Capacity can be broken down in two categories: Design Capacity and Effective Capacity.

Three key inputs to capacity planning are:

1. The kind of capacity that will be needed
2. How much capacity will be needed?
3. When will it be needed?

Defining and Measuring Capacity

When selecting a measure of capacity, it is best to choose one that doesn't need updating. For example, dollar amounts are often a poor measure of capacity (e.g., a restaurant may have capacity of $1 million of sales a year) because price changes over time necessitate updating of that measure.

When dealing with more than one product, it is best to measure capacity in terms of each product. For example, the capacity of a firm is to either produce 100 microwaves or 75 refrigerators. This is less confusing than just saying the capacity is 100 or 75. Another method of measuring capacity is by referring to the availability of inputs. This is usually more helpful if we are dealing with several type of output. Note that one specific measure of capacity can't be used in all situations; it needs to be tailored to the specific situation at hand. The following table shows examples of both output and input used for capacity measures.

Type of Business	Input Measures of Capacity	Output Measures of Capacity
Car manufacturer	Labour hours	Cars per shift
Hospital	Available beds	Patients per month
Pizza parlour	Labour hours	Pizzas per day
Retail store	Floor space (sq. ft.)	Revenue per sq. ft.

Figure 4.1: Various businesses and their respective input and output measures of capacity.

Determinants of Effective Capacity

- **Facilities:** The size and provision for expansion are key in the design of facilities. Other facility factors include locational factors, such as transportation costs, distance to market, labor supply, and energy sources. The layout of the work area can determine how smoothly work can be performed.
- **Product and Service Factors:** The more uniform the output, the more opportunities there are for standardization of methods and materials . This leads to greater capacity.
- **Process Factors:** Quantity capability is an important determinant of capacity, but so is output quality. If the quality does not meet standards, then output rate decreases because of need of inspection and rework activities. Process improvements that increase quality and productivity can result in increased capacity. Another process factor to consider is the time it takes to change over equipment settings for different products or services.
- **Human Factors:** the tasks that are needed in certain jobs, the array of activities involved, and the training,

skill, and experience required to perform a job all affect the potential and actual output. Employee motivation, absenteeism, and labour turnover all affect the output rate as well.

- **Policy Factors:** Management policy can affect capacity by allowing or disallowing capacity options such as overtime or second or third shifts
- **Operational Factors:** Scheduling problems may occur when an organization has differences in equipment capabilities among different pieces of equipment or differences in job requirements. Other areas of impact on effective capacity include inventory stocking decisions, late deliveries, purchasing requirements, acceptability of purchased materials and parts, and quality inspection and control procedures.
- **Supply Chain Factors:** Questions include: What impact will the changes have on suppliers, warehousing, transportation, and distributors? If capacity will be increased, will these elements of the supply chain be able to handle the increase? If capacity is to be decreased, what impact will the loss of business have on these elements of the supply chain?
- **External Factors:** Minimum quality and performance standards can restrict management's options for increasing and using capacity.

Figure 4.2: Summary of examples of capacity factors.

Inadequate planning can be a major limitation in determining the effective capacity.

The most important parts of effective capacity are process and human factors. Process factors must be efficient and must operate smoothly. If not, the rate of output will dramatically decrease. They must be motivated and have a low absenteeism and labour turnover. In resolving constraint issues, all possible alternative solutions must be evaluated.

Steps in the Capacity Planning Process:

1. Estimate future capacity requirements
2. Evaluate existing capacity and facilities and identify gaps
3. Identify alternatives for meeting requirements
4. Conduct financial analyses of each alternative
5. Assess key qualitative issues for each alternative
6. Select the alternative to pursue that will be best in the long term
7. Implement the selected alternative
8. Monitor results

The above content is an adaptation of Saylor Academy's BUS300 course.[1]

The Sequential Processes and the Bottleneck

Any process that has several steps, one after another, is considered a **sequential process**. A good example of these processes is the manufacturing assembly line in which each workstation gets inputs from a previous workstation and give its outputs to the next workstation. It is safe to assume that each step has its own staff member, since this is exactly what happens in assembly lines. For this kind of process, it is crucial to have a balanced time across all steps. That is, there should not be any big difference between the amounts of time that different steps take to process one unit of product. For example, if step 1, 2 and 3 take 3, 10 and 5 minutes consecutively to process one unit of product, two main issues will happen during the production:

1) There will be a big pile of inventory sitting right before step 2, since step 1 is much faster than step 2, and the products that are already processed in step 1 will need to wait for step 2 to be done with its current unit at hand. As a result, this becomes an inventory holding issue, which is costly.

2) Step 3 will always need to wait for step 2 for an extra 5 minutes. This is due to the fact that step 3 finished its current product at hand in 5 minutes, but step 2 needs a total of 10 minutes to finish its work and feed it to step 3. This causes step 3 to be idle for a long time, which is also costly for the company. This is costly, because the company is already paying the staff who works in step 3 for the whole time, but they are not able to produce as many units as they should due to the very slow entry of the inputs coming from step 2.

1. Saylor Academy. (2019). Strategic Capacity Planning in Operations Management. Retrieved on November 4, 2019, from https://learn.saylor.org/mod/page/view.php?id=9282

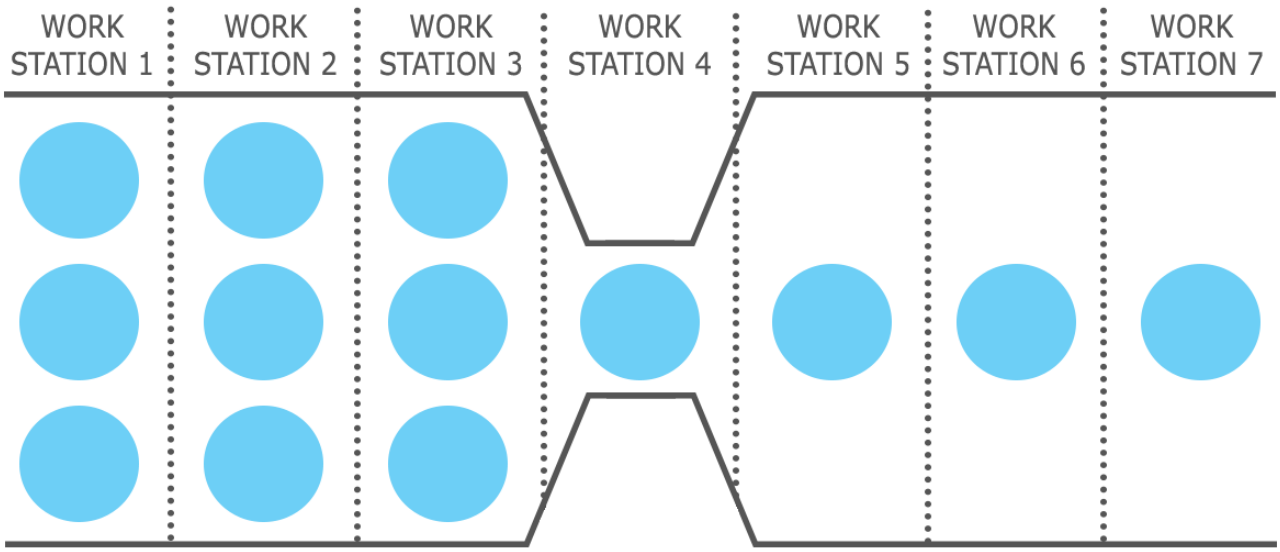


Figure 4.3: A diagram displaying the effects of a bottleneck.

The bottleneck is the slowest step in each process or the slowest process in a system. The capacity of the bottleneck defines the capacity of the whole process. In our example above, step 2 was the slowest, and as a result, the bottleneck. This means that the whole process (including all steps 1 to 3) will not be able to have an output any faster than one every 10 minutes. In the following, let's see why this is happening:

In an 8-hour shift per day, we have 8 x 60 = 480 minutes

Assuming that step 1 has enough input to process during the day, the total output from step 1 will be 480 / 3 = 160 units per day. This is the capacity for step 1. In a similar way, the capacity for step 2 is 480 / 10 = 48, and the capacity for step 3 is 480 / 5 = 96 units.

This means that the input to step 2 will be 160 units to be processed. But as we see, step 2 will only be able to process a maximum of 48 units per day. That means that only 48 units get to step 3 for processing. Since step 3 has a capacity of 96 units per day, it will easily process those 48 units of inputs, and the output from step 3 will be 48 units. Because the step 3 is the last step of our process, this output of 48 units will automatically be the total output of the whole process per day.

The key observation here is that the capacity of step 2, which is the bottleneck, determined the capacity of the whole process. This concept is very important in practice. Often times, the companies that do not pay attention to the concept of bottleneck and its implications invest in parts of the process that are not bottleneck. This will keep the bottleneck unchanged and as a result, they will not see any improvement in the capacity of the whole process.

Example

Caroline has a thriving business selling her tote bags through several popular websites. Her business volume has caused her to hire full-time employees. Her business has four main manufacturing operations: 1) cutting fabric (4 min), 2) stitching fabric (7 min), 3) adding zippers, toggles, and liner (10 min), and 4) inspecting, packing, and labeling (5 min).

4.3: Flow diagram depicting the time taken for each step of Caroline's manufacturing process.

Employees work 7 hours per day. Help Caroline to determine the following:

1. Based on her very high demand, is there a bottleneck and what stage is it? What is the capacity of the process per day?
2. Caroline's employee at step #2 has found a new machine that will enable him to do the stitching faster, at a rate of 5 min per bag instead of 7 min. The machine costs $3500. Would you suggest this is a good investment to help Caroline increase her output? Why or why not?
3. If there were another person to be added to the process, where should Caroline add him or her and what would be the new capacity?

Solution

Operation	Time	Daily Capacity
Step 1: Cutting fabric	4 min	420 / 4 = 105
Step 2: Stitching fabric	7 min	420 / 7 = 60
Step 3: Adding zippers, toggles, liners	10 min	420 / 10 = 42
Step 4: Inspecting, packing, labeling	5 min	420 / 5 = 84

Figure 4.4: Solution for Caroline's Totes example

(Based on 7×60 = 420 min per day)

Accessible format for Figure 4.4

1. The maximum output is 42 units, because that is what the bottleneck can do. The bottleneck is at stage #3, which is the slowest part of the process.
2. Caroline should NOT invest any funds into step #2. This may speed up the stitching, but the maximum output of the process will still be 42 units because step #3 has not changed.
3. If Caroline added another person, she should add it to step #3. (Install zippers/ toggles/ liner). Because that is where the bottleneck is. The capacity at stage three would now double to 84 units per day. The new capacity for the whole process would now be 60 units per day, as determined by Step 2 (Basic stitching) which is the new bottleneck of the process.

Evaluating Capacity Alternatives

There are two major ways to evaluate the capacity alternatives to select the best one: economic and non-economic.

Economic considerations take into account the cost, useful life, compatibility and revenue for each alternative. Techniques used for evaluation are:

- Break Even Analysis (this is the only one discussed in this chapter)
- Payback Period
- Net Present Value

Non-economic considerations include public opinion, reactions from employees and community pressure.

Break Even Analysis

Basically, since there is usually a fixed cost (FC) associated with the usage of a capacity, we look for the right quantity of output that gives us enough total revenue (TR) to cover for the total cost (TC) that we have to incur. This quantity is called Break-Even Point (BEP), Break-Even Quantity (Q_{BEP}).

Total cost is the summation of the fixed cost and the total variable cost (VC, which depends on the quantity of output). In other words, at Q_{BEP}, we have: TC = FC + VC

A list of relevant notation can be found below:

TC = total cost
FC = total fixed cost
VC = total variable cost
TR = total revenue
v = variable cost per unit
R = revenue per unit
Q = volume of output
Q_{BEP} = break even volume
P = profit

Fixed cost is regardless of the quantity of output. Some examples of fixed costs are rental costs, property taxes, equipment costs, heating and cooling expenses, and certain administrative costs

With the above notation and some simplification in the calculation, we have:

$TC = FC + VC$
$VC = Q \times v$
$TR = Q \times r$
$P = TR - TC = Q \times r - (FC + Q \times v)$
$Q_{BEP} = FC / (r - v)$

Example

The management of a pizza place would like to add a new line of small pizza, which will require leasing a new equipment for a monthly payment of $4,000. Variable costs would be $4 per pizza, and pizzas would retail for $9 each.

1. How many pizzas must be sold per month in order to break even?
2. What would the profit (loss) be if 1200 pizzas are made and sold in a month?
3. How many pizzas must be sold to realize a profit of $10,000 per month?
4. If demand is expected to be 700 pizzas per month, will this be a profitable investment?

Solution

1. $Q_{BEP} = FC / (r - v) = 4000 / (9 - 4) = 800$ pizzas per month
2. total revenue – total cost = 1200 x 9 – 1200 x 4 = $6000 (i.e. a profit)
3. $P = \$10000 = Q(r - v) - FC$;
   Solving for Q will give us: $Q = (10000 + 4000) / (9 - 4) = 2800$
4. Producing less than 800 (i.e. Q_{BEP}) pizzas will bring in a loss. Since 700 < 800 (Q_{BEP}), it is not a profitable investment.

Finding a break-even point between "make" or "buy" decisions:

Question: For what quantities would buying the product be preferred to making it in-house? For quantities larger than the break-even quantity or for smaller ones?

v_m = per unit variable cost of "make"
v_b = per unit variable cost of "buy"

total cost of "make" = total cost of "buy"
$= Q \times v_m + FC = Q \times v_b$
$= FC = Q \times v_b - Q \times v_m$
$= Q = FC / (v_b - v_m)$

Example

The ABX Company has developed a new product and is wondering if they should make this product in-house or have a capable supplier make the product for them. The costs associated with each option are provided in the following table:

	Fixed Cost (annual)	**Variable Cost**
Make in-house	$160,000	$100
Buy		$150

1. What is the break-even quantity at which the company will be indifferent between the two options?
2. If the annual demand for the new product is estimated at 1000 units, should the company make or buy the product?

3. For what range of demand volume it will be better to make the product in-house?

Solution

1. $Q_{BEP} = FC / (v_b - v_m) = 160{,}000 / (150 - 100) = 3200$
2. Total cost of "make" = 1000 x 100 + 160,000 = $260,000; Total cost of "buy" = 1000 x 150 = $150,000
   Thus, it will be better to buy since it will be less costly in total.
3. It will always be better to use the option with the lower variable cost for quantities greater than the break-even quantity.
   This can also be proven as follows:

We want "make" to be better than "buy" in this part of the question. Thus, for any quantity Q, we need to have:

Total cost of "make" < Total cost of "buy"
$= 160{,}000 + 100Q < 150Q$
$= 160{,}000 < 50Q$
$= 3200 < Q$

Finding a break-even point between two make decisions

Question: For what quantities would machine A be preferred to machine B? For quantities larger that the break-even quantity or for smaller ones?

If we assume the two options for making a product are machine A, with a fixed cost of FC_A and a variable cost of v_A, and machine B, with a fixed cost of FC_B and a variable cost of v_B, we have:

total cost of A = total cost of B
$= Q \times v_A + FC_A = Q \times V_B + FC_B$
$= FC_A - FC_B = Q \times V_B - Q \times V_A$
$= Q = (FC_A - FC_B) / (V_B - V_A)$

In any problem, it is suggested that you write down the total cost of each option and simplify from there to make sure that you do not miss any possible additional cost factors (if any).

Example

The ABX Company has developed a new product and is going to make this product in-house. To be able to do this, they need to get a new equipment to be able to do the special type of processing required by the new product design. They have found two suppliers that sell such equipment. They are wondering which supplier they go ahead with. The costs associated with each option are provide in the following table:

	Fixed Cost (annual)	**Variable Cost**
Supplier A	$160,000	$150
Supplier B	$200,000	$100

1. What is the break-even quantity at which the company will be indifferent between the two options?
2. If the annual demand for the new product is estimated at 1000 units, which supplier should the company use?

3. For what range of demand volume each supplier will be better?

Solution

1. $Q_{BEP} = (FC_B - FC_A) / (v_A - v_B) = (200{,}000 - 160{,}000) / (150 - 100) = 40{,}000/50 = 800$
2. Total cost of Supplier A = 1000 x 150 + 160,000 = $310,000; Total cost of Supplier B = 1000 x 100 + 200,000 = $300,000
   Thus, it will be better to go with Supplier B, since it will be less costly in total.
3. It will always be better to use the option with the lower variable cost for quantities greater than the break-even quantity.
   This can also be proven as follows:

Let's see for what quantities Supplier B will be better than Supplier A. In that case, for the quantity Q, we need to have:

Total cost of Supplier B < Total cost of Supplier A
$= 200{,}000 + 100Q < 160{,}000 + 150Q$
$= 40{,}000 < 50Q$
$= 800 < Q$

This means that for quantities above 800 units, Supplier B will be cheaper in total. Thus, for quantities less than 800, Supplier A will be cheaper in total.

8. Facility Location

There are many factors that can determine where an organization will locate its facilities. For any given situation, some factors become more important than others in how facility location affects an organization's performance. For example, when a company needs to open a new manufacturing facility, there are several factors that determine which location reduces the company's operating costs while providing a great level of responsiveness to the market.

Key Factors in Facility Location Decision-Making

- Proximity to sources of supply:
  - Firms that process bulk raw materials usually locate close to the source of supply to reduce transportation costs. Paper mills locate close to forests, canneries are built close to farming areas, and fish processing plants are located close to the harbors where the fishing vessels dock.
- Proximity to customers:
  - There are several reasons why an organization would locate close to end customers. Service firms need to be close to customers to be convenient, as is the case for grocery stores, gas stations, fast food restaurants, and hospitals. Transportation costs can also require proximity to customers, as in the case of concrete manufacturing. Perishable products often require that they be produced close to the final market, as is the case for bakeries and fresh flowers.
- Community factors:
  - Communities may offer a number of incentives to entice companies, including waiving or reducing taxes, and providing access roads, water and sewer connections, and utilities. Community attitudes

can also play a role in an organization's location decision. Some communities may actively discourage companies that might bring more pollution, noise, and traffic to the area. Some communities may not want a prison to be located in their community. Other communities may welcome such firms because of the jobs, tax revenues, and economic diversity they promise.

- Labor factors:
  - Research shows that the majority of location decisions are largely based on labor factors, since labor is a critical variable for many firms. Labor factors include the prevailing wage rate in a community for similar jobs, the supply of qualified workers, and the average education level of the local population (percentage of high school graduates, etc.). Other labor factors can include the degree of union organizing and the general work ethic of a community, as well as other measures of absenteeism, and worker longevity in a job can play a strong role when a firm makes a location decision.

- Other factors:
  - Many other factors can play a role in the location decision, including quality of life (crime rates, good schools, climate, and recreation options), access to major transportation arteries, construction costs, proximity of the competition, and opportunities for future expansion.[1]

Methods for Finding the Best Facility Location

Location Factor Rating

One method to assist in choosing the best location is the Location Factor Rating (also known as Weighted Scoring Model). The various factors important in this decision are decided upon and each is given a weight between zero and 1.0 to reflect each factor's importance. Every site is then evaluated in comparison with each other and given a score. Weighted scores are calculated by multiplying each score by its corresponding weight. When weighted scores are summed up, the highest weighted score reflects the location which is the most attractive based on all factors.

Example

1. Saylor Academy. (2019). Location Choice and Site Planning in BUS300: Operations Management. Retrieved on December 23, from https://learn.saylor.org/mod/page/view.php?id=21970

Location Factor	Weight	Site #1	Site #2	Site #3
Proximity to Suppliers	0.3	80	85	80
Business Environment	0.25	65	90	55
Wage Rates	0.15	72	55	65
Community	0.1	65	60	40
Proximity to Customers	0.1	55	90	70
Labour Pool	0.05	40	45	65
Proximity to Airport	0.05	60	55	80

Weighted Scores

Location Factor	Site #1	Site #2	Site #3
Proximity to Suppliers	24.0	25.5	24.0
Business Environment	16.3	22.5	13.8
Wage Rates	10.8	8.3	9.8
Community	6.5	6.0	4.0
Proximity to Customers	5.5	9.0	7.0
Labour Pool	2.0	2.3	3.3
Proximity to Airport	3.0	2.8	4.0
Total Score	**68.1**	**76.3**	**65.8**

In this example, site #2 shows the highest score when evaluated against site #1 and #3. So, we choose site #2.

Centre of Gravity Method

In order to minimize transportation costs, the centre of gravity method may be used to locate a facility that serves several area (or other facilities) such as a warehouse or distribution centre. This method uses an (X-Y) coordinate system to cover the geographical map of the areas under study, and identifies the x and y coordinates for the location of the new facility based on the coordinates of the other facilities and the volume (quantity) of demand for each area (facility). For example, in the following figure, each blue star represents a market area that needs to be served, and the size of area also shows the demand quantity for that market. We are looking for the whereabouts (i.e., $\bar{x}$ and $\bar{y}$) of the location for our facility to be set up to serve all these markets while minimizing our total transportation costs.

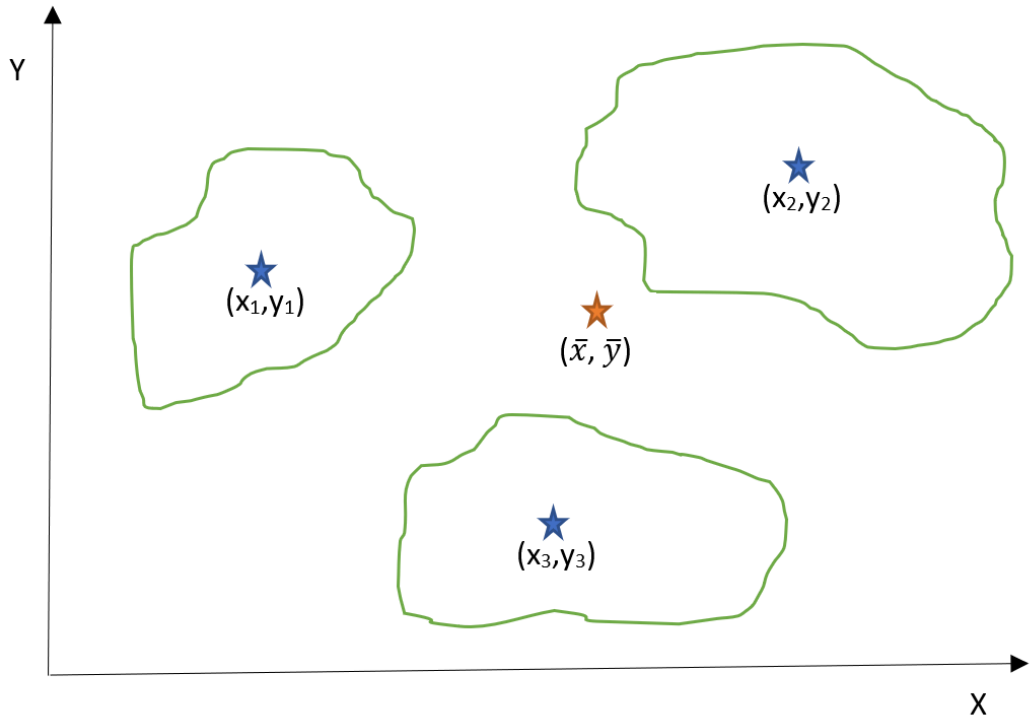


Figure 8.1: Three market areas on an X-Y coordinate axis.

In the following, we show the formulas and use them in an example:

$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i}$$

$$\bar{y} = \frac{\sum y_i Q_i}{\sum Q_i}$$

Figure 8.2: Centre of Gravity formula.

$\bar{x}$ = the x coordinate for the new facility

$\bar{y}$ = the y coordinate for the new facility

x_i = x coordinate of destination (market) i

y_i = y coordinate of destination (market) i

Q_i = quantity to be transported to destination i

Example

Using the center of gravity method and the information on the location of the potential markets, determine where the new facility should be located to minimize the total transportation cost. Note that a selected point in the middle of each region is representing the regional market.

$$\bar{x} = \frac{1(600) + 3(400) + 6(550) + 2(800)}{600 + 400 + 550 + 800} = 2.9$$

$$\bar{y} = \frac{2(600) + 4(400) + 4(550) + 6(800)}{600 + 400 + 550 + 800} = 4.2$$

Figure 8.3: Equation for example.

Accessible format for Figure 8.1-8.3

This is where you can add appendices or other back matter.