Fundamentals of Operations Management

FUNDAMENTALS OF OPERATIONS MANAGEMENT

AZIM ABBAS AND SEYED GOOSHEH

Fanshawe College Pressbooks
London Ontario

CONTENTS

Chapter 3: Forecasting

Chapter 4: Strategic Capacity Planning

Chapter 5: Facility Location

Chapter 6: Managing Quality

Chapter 7: Supply Chain Management

ACKNOWLEDGEMENTS

This open textbook has been compiled and adapted by Azim Abbas & Seyed Goosheh in partnership with the OER Design Studio and the Library Learning Commons at Fanshawe College in London, Ontario.

This work is part of the FanshaweOpen learning initiative and is made available through a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License unless otherwise noted.

Attribution

This book is an adaptation of the following resources:

- Introduction to Operations Management by Mary Drane and Hamid Faramarzi is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, except where otherwise noted.
- Introduction to Operations Management by Hamid Faramarzi and Mary Drane is licensed under a Creative Commons Attribution-NonCommercial ShareAlike 4.0 International License, except where otherwise noted.
- Operations Management: Engineering and Technology by Vikas Singla is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, except where otherwise noted.

Specific section attributions can be found at the bottom of each section, with a note about modifications as applicable.

Collaborators

- Stephany Ceron Salas, *Instructional Design*
- Catherine Steeves, *Instructional Design & Quality Assurance*
- Shauna Roch, *Project Lead*
- Sanaz Habibi, *Graphic Design Student*
- Wilson Poulter, *Copyright Officer*
- Elisha Girard, *Ancillary Resource Developer*
- Jason Benoit, *Ancillary Resource Developer*

ABOUT THIS BOOK

The Fundamentals of Operations Management introduces students to the essential concepts and practices in operations management. It covers various topics such as strategic capacity planning, facility location, supply chain management, just-in-time and lean systems, and risk monitoring. This book provides a solid foundation for understanding the complexities of managing operations in various industries.

This book includes:

- examples
- key terms
- chapter summaries
- end of chapter review questions
- slide decks
- test banks

Author Biographies

Azim Abbas, MSc (Engineering), MBA, BSc (Hons) Grad Cert SCM

Azim Abbas is a seasoned Supply Chain and Operations Management professional with extensive experience in academia and industry. He currently serves as a full-time faculty member at Fanshawe College as a Coordinator of the Operations Management program. Azim has held significant roles in various organizations, and his extensive professional experience spans significant roles in the aviation and maritime industries, where he managed global logistics and operations. His academic credentials include an MSc in Advanced Manufacturing Systems and Technology from the University of Liverpool and an MBA. Azim's diverse background and expertise make him a valuable contributor to the field of supply chain and operations management.

Seyed A. Goosheh, PhD., P.Mgr., C.Mgr

Schooled in Industrial Engineering, Business and Industrial Management, and worked with Fanshawe and St. Clair College, Universities of Guelph, Western and Nipissing. As Industrial Liaison for St. Clair, he was involved in corporate training/consultation in auto manufacturing and led global development teams at Volvo Motor Graders, International Truck and Engine, and Navistar Canada. Later managed the operations and projects of the Center of Agricultural Renewable Energy and Sustainability at University of Guelph. Prior to migrating to Canada, had held senior positions in combined international transportation operations directing port, land and marine operations while providing logistic support for international trade between Iran, Europe, Persian Gulf, Southeast Asia and Far East while teaching at numerous management and engineering schools.

Accessibility Statement

We are actively committed to increasing the accessibility and usability of the textbooks we produce. Every attempt has been made to make this OER accessible to all learners and is compatible with assistive and adaptive technologies. We have attempted to provide closed captions, alternative text, or multiple formats for on-screen and off-line access.

The web version of this resource has been designed to meet Web Content Accessibility Guidelines 2.0, level AA. In addition, it follows all guidelines in Appendix A: Checklist for Accessibility of the *Accessibility Toolkit – 2nd Edition.*

In addition to the web version, additional files are available in a number of file formats, including PDF, EPUB (for eReaders), and MOBI (for Kindles).

If you are having problems accessing this resource, please contact us at oer@fanshawec.ca.

Please include the following information:

- The location of the problem by providing a web address or page description

- A description of the problem
- The computer, software, browser, and any assistive technology you are using that can help us diagnose and solve your issue (e.g., Windows 10, Google Chrome (Version 65.0.3325.181), NVDA screen reader)

Feedback

Please share your adoption and any feedback you have about the book with us at oer@fanshawec.ca

CHAPTER 1: INTRODUCTION TO OPERATIONS MANAGEMENT

Chapter Overview

1.0 LEARNING OUTCOMES

Learning Objectives

At the end of this chapter, students will be able to:

- Explore the key current trends in Operations Management.
- Define operations management and its core functions within a business.
- Explain the role of operations management in transforming inputs (materials, labour) into outputs (goods, services) for a business.
- Explain why a business student should study Operations Management.
- Identify some of the Professional Organizations involved in Operations Management.
- Describe the phases of Operations Management history.
- Discuss how producing goods is different from performing services.

1.1 OPERATIONS MANAGEMENT

Operations Management and Everyday Life

Although Operations Management is often taught in business schools, one can skip business school to relate to this topic. Perhaps we can learn it by looking at the everyday life of a family living in London, Ontario.

Figure 1.1.1: "Operations Management in Everyday Life, London, Ontario" by Sanaz Habib, CC BY-SA 4.0

To conduct what we refer to as everyday life, they would need to do weekly grocery shopping to buy milk, meat, bread, fruit and vegetables and a few other necessities. Now, let us focus on the bread they are buying. It turns out that that bread was brought to that store in a truck from a bakery that relies on a mill to supply it with flour, which comes from a farm. The kids would have to go to school on a school bus that needs to pick them up and bring them home every day. Mom and Pop would go to work in their cars, which they had bought from a dealership and supplied by auto manufacturers. These cars needed to be maintained by a mechanic in a garage who would rely on parts and supplies delivered to his garage. The family needs to handle their finances using a bank, their garbage has to be handled by the city, and when they are ill, they need the service of a medical facility. Are these the only things this family needs to manage their daily life? Certainly not! Now, let us return to the bread they buy from their grocery store. Like you and I, they do not care "how" that loaf of bread was made available, but they certainly know "what" they need, in this case, a loaf of bread. If we want to connect the "what" to "how," we are stepping into the field of operations management.

Operations management is a discipline that involves the processes of converting inputs into goods and services, creating value for customers. It is the foundation for any organization, ensuring efficient resource utilization in producing the products we rely on daily.

What is Operations Management

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

Every day, you use a multitude of physical objects and a variety of services. Most physical objects have been manufactured, and most of the services are 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 you buy and consume daily 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.

Video: "Operations Management" by Skillsoft YouTube [3:12] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

Producing Goods and Services

In the production of goods, the result is the creation of tangible products such as vehicles, articles of clothing, cell phones, or shovels. On the other hand, a service is intangible, such as a car repair, haircut, or medical treatment.

In operations management, both the production of goods and the delivery of services play crucial roles. However, there are significant differences between the two.

1. Nature of Output:
    - **Goods**: Tangible products like vehicles, clothing, cell phones, and shovels.
    - **Services**: Intangible offerings such as car repairs, haircuts, and medical treatments.
2. Customer Interaction:
    - Services involve more direct customer contact. Customers either visit the service provider or vice versa.

  - In manufacturing, customers rarely visit the production facility; purchases occur elsewhere.

3. Labour Content:
   - Services typically require more labour than manufacturing organizations.
4. Input Variability:
   - Services face greater input variability due to unique customer circumstances.
   - Manufacturing companies deal with more standardized inputs.
5. Quality Measurement:
   - Manufacturing quality assessment is technical and straightforward.
   - The perception of service quality depends on various factors.
6. Productivity Measurement:
   - Manufacturing productivity is easier to measure due to standardization.
   - Services pose challenges in productivity measurement.
7. Inventory Handling:
   - Manufacturing can store unsold goods for later sale.
   - Services lack this option; once the time passes, capacity is lost.

Figure 1.1.1 Image Sources

Top row L-R: "RBC Royal Bank of Canada 2", Peter Glyn, CCO; "Downtown London, Ontario", Ken Lund, CC BY-SA 2.0; "Victoria Park – London Ontario", WabbitWanderer, CC BY-SA 2.0; "Middlesex County

Court House, London Ontario“, Ken Lund, CC BY-SA 2.0; “Downtown London, Ontario” by Ken Lund, CC BY-SA-2.0; “Eldon House, London Ontario” by Ken Lund, CC BY-SA 2.0.

Bottom row L-R: “Canadian School Bus in Toronto“, Navjot Singh, CC BY-SA 2.0; “Covent Market, London“, Boris Kasimov, CC BY 2.0; “Door mating – Lansing Grand River automobile assembly plant production line“, Joe Ross, CC BY-SA 2.0; “University Hospital London ON“, Nephron, CC BY-SA 3.0.

1.2 TRANSFORMATION PROCESSES

Video: "What is Operations Management?" by Frankfurt School of Finance & Management [1:35] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

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).

Organizations often need to transform three types of input: materials, information, and customers. For instance, withdrawing money from a bank account involves handling information related to the customer's account, physical materials like cheques and currency, and the customer. Similarly, providing medical treatment to a patient in a hospital requires considering the patient's health status (the 'customer'), the materials used in treatment, and relevant patient information.

These transformation processes can be grouped into four categories (Figure 1.2.1):

- **Manufacture**: This involves physically creating products, such as automobiles.
- **Service**: Service-oriented processes focus on treating customers or storing products, as seen in hospitals or warehouses.
- **Supply**: This category encompasses changes in ownership of goods, often observed in retail settings.
- **Transport**: Processes related to the movement of materials or customers, such as taxi services.

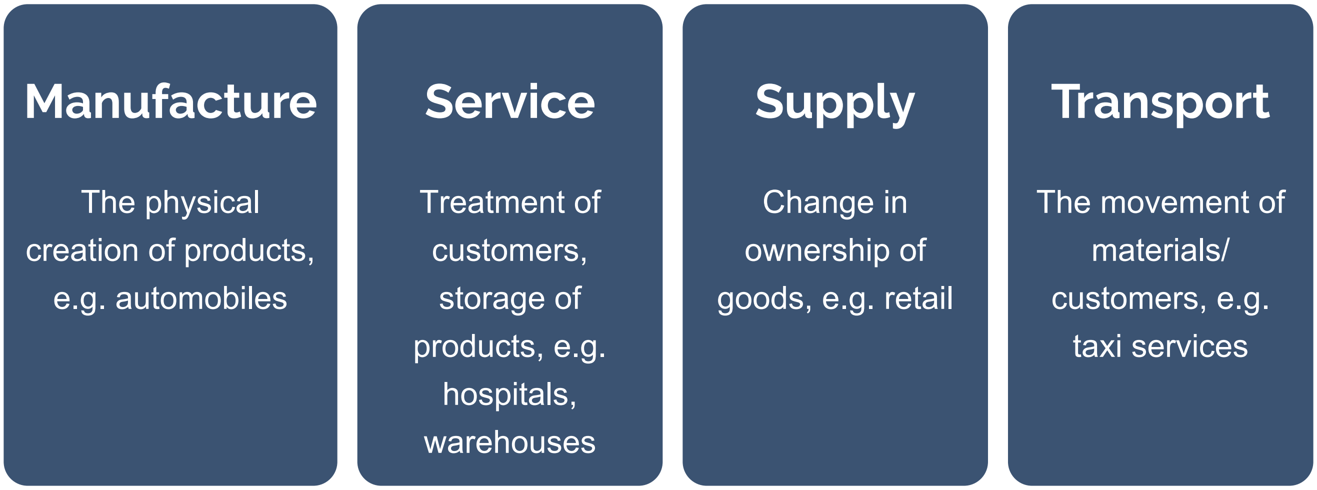


Figure 1.2.1: Categories of transformation processes.

Several different transformations are usually required to produce a good or service. The overall transformation can be described as the **macro-operation**; the more detailed transformations within this macro-operation are **micro-operations**. For example, the macro-operation in a brewery is making beer, and the micro-operations involved in beer production are (Figure 1.2.2):

- Milling: Grind malted barley into grist.
- Mashing: Mix the grist with hot water to create wort.
- Fermentation: Add yeast to wort and ferment it into beer.
- Cooling and Transfer: Cool the wort and transfer it to the fermentation vessel.
- Filtering: Remove spent yeast from the beer.
- Packaging: Decant the beer into casks or bottles.

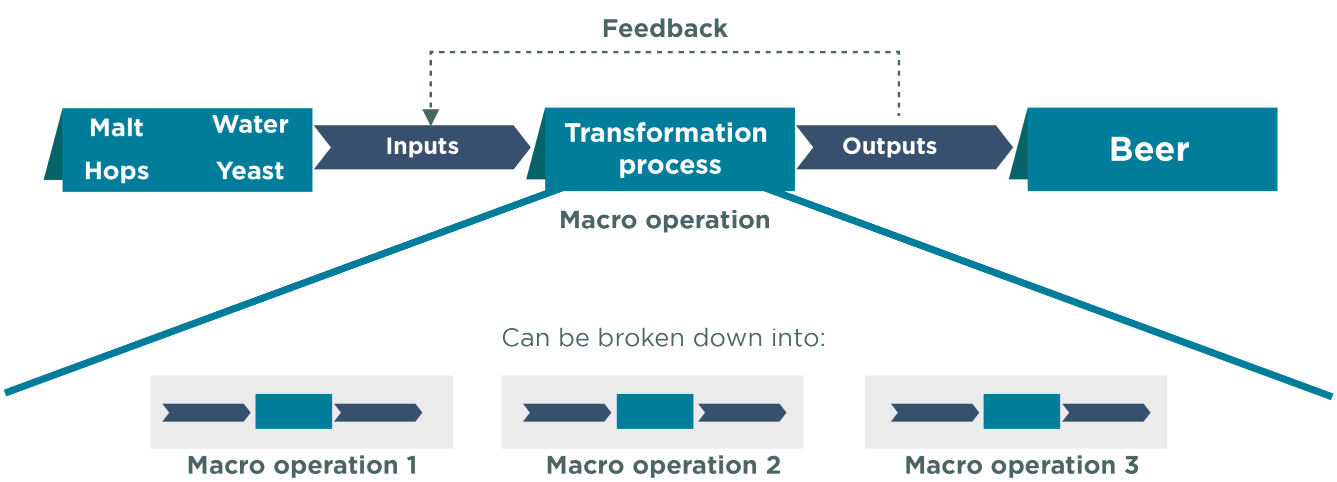


Figure 1.2.2: "Macro and Micro Operations (transformation processes)" by The Open University, CC BY-NC-SA 4.0. Mods: re-coloured by Fanshawe College

1.3 THE OPERATIONS FUNCTION

Regardless of whether it explicitly labels it as 'operations,' every organization has a fundamental function related to producing goods and services. This involves resource procurement, conversion into outputs, and distribution to users. **Operations** encompasses all activities necessary for delivering an organization's goods or services to customers and clients.

In large and complex organizations, operations is a critical functional area. Designated individuals manage various aspects of the organization's operational processes. The effectiveness of operations significantly impacts customer satisfaction. For private-sector companies, the operations function aligns with profit, growth, and competitiveness, while public and voluntary organizations focus on delivering value for money.

Some examples to illustrate the concept of operations within organizations:

- Manufacturing Company: A manufacturing company produces automobiles. Its operations involve sourcing raw materials (such as steel, plastic, and electronics), assembling components, and delivering finished cars to dealerships.
- Retail Chain: A retail chain operates multiple stores. Its operations include inventory management, restocking shelves, handling customer transactions, and ensuring a smooth checkout process.
- Healthcare Facility: A hospital's operations encompass various functions, such as patient admissions, medical treatments, laboratory testing, and maintaining medical records.
- Online Marketplace: An e-commerce platform manages operations related to product listings, order processing, payment gateways, and logistics for shipping products to customers.
- Service-Based Organization: A consulting firm's operations involve client engagement, project management, resource allocation, and delivering high-quality consulting services.

Operations managementis concerned with designing, managing, and improving 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 fundamental functional areas: operations, marketing and sales, finance, and human resources. Operations directly produce the product or service that customers pay for, while the other three departments provide support to ensure smooth business operations.

Marketing: The Voice of the Customer

Marketing acts as the bridge between customers and operations. They ensure the company creates products or services that fulfill customer needs and desires. They identify the most valued features and benefits, keeping operations on the right track.

Finance: The Engine that Keeps Things Running

Finance is the lifeblood of the company. They manage the money flow, ensuring there's enough to cover everything from materials and payroll to equipment upgrades. This allows operations to run smoothly without disruptions.

Human Resources: Building the Dream Team

HR is the foundation of any successful organization. They recruit, hire, and train the talented individuals who make up the operations team. They handle everything from compensation and benefits to ensuring a smooth succession plan and guaranteeing a skilled workforce for the future.

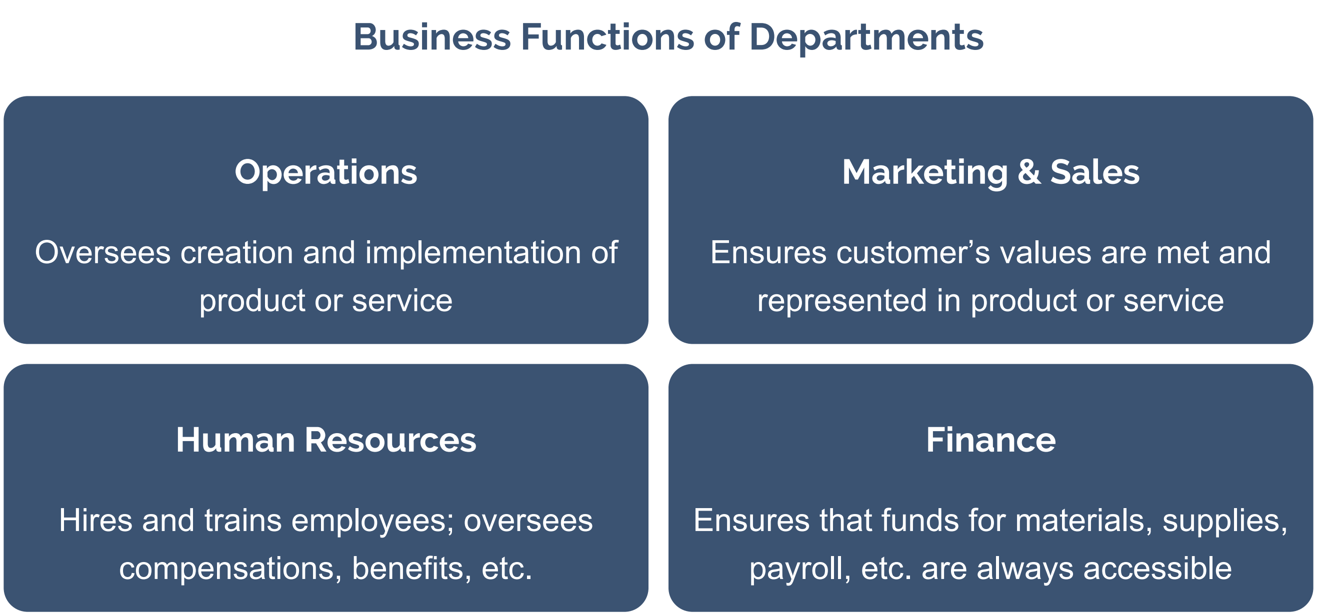


Figure 1.3.1: Business functions of departments.

1.4 WHY STUDY OPERATIONS MANAGEMENT?

In most organizations, operations tend to be the largest department in terms of the number of employees. If you're a recent graduate, consider starting your career in a company's operations department. A career in operations can provide more job openings than smaller departments. Larger companies can provide more growth opportunities as well. You can focus on finding a great company culture and worry less about the specific job title. With a good work ethic (punctuality, energy, and proactiveness), you can likely get promoted to your desired role later.

Photo, olia danilevich, Pexels License

Operations: The Engine of the Business

Operations play a critical role in any organization:

- Cost Center: This department spends a significant portion of the company's budget, making it a central focus for leadership.
- Interconnectedness: All departments (finance, marketing, HR) interact with operations regularly. Understanding the core processes, regardless of your department, is valuable.
- Innovation Hub: Major breakthroughs often happen in operations. Companies like Toyota, Amazon, and Dell achieved success through innovative operational practices.

What is Operational Innovation?

It's about finding new ways to run the business – fulfilling orders, developing products, providing customer service, and more.

As a new graduate in an organization, you will find that every business is looking for new ideas, tools, and suggestions for improvement in order to improve its effectiveness and efficiency.

- **Effectiveness**: It's about doing the right things. This means making choices and taking actions that benefit the business and, most importantly, add value for the customer. Think of it as picking the winning strategy.
- **Efficiency**: It's about doing things well but without wasting resources. This means finding ways to streamline tasks and avoid unnecessary steps that cost time or money. Think of it as getting the job done smartly.

In short, businesses want to do the right things (effectiveness) in the best way possible (efficiency).

Many decisions involve a trade-off between effectiveness and efficiency. For instance, consider hiring an additional full-time server in a restaurant. While this may lead to faster service and a more attentive customer experience, it also comes with higher costs, reducing overall efficiency.

Value, in this context, relates to the balance between quality and price. We create value if we can offer customers a higher-quality product at the same price. Similarly, providing the same product at a lower price benefits the customer.

Resources for Operations Management Learners and Professionals

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

1.5 DEVELOPMENT OF OPERATIONS MANAGEMENT

Operations in some form have been around as long as human endeavour 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.

Craft Manufacturing: The Hands-On Era

Imagine skilled artisans meticulously building furniture or clocks. That's craft manufacturing in a nutshell. This system, where craftspeople made unique products for individual customers, thrived for centuries. Skills were passed down through apprenticeships and workshops buzzed with activity. While ideal for small-scale production, it struggled with competition in a growing world.

Mass Production: The Age of Efficiency (1910 – 1980)

The 19th century ushered in a revolution: mass production. Here, the focus shifted to churning out large quantities of standardized goods at lower costs. Think assembly lines and interchangeable parts. This innovation came with a trade-off – less variety for consumers who got what was offered.

Key innovations of mass production:

- Standardized parts: Imagine car parts fitting seamlessly across models. This American system streamlined production and reduced costs.
- Scientific Management: Frederick Taylor aimed to find the "one best way" to complete tasks, breaking them down for maximum efficiency. This approach, while efficient, raised concerns about worker well-being.
- The Assembly Line: Henry Ford perfected this concept, bringing the product (cars) to the workers, further boosting production speed and lowering costs.

The Modern Period: Adapting to Change (1995 – 2015)

By the 1970s, mass production began to show its limitations. Consumer preferences were diversifying, and markets were changing rapidly. Enterprising Japanese manufacturers challenged the status quo with innovative approaches like Total Quality Management (TQM) and Just-in-Time (JIT) production, emphasizing quality and efficiency.

Modern Manufacturing Paradigms

Several popular models have emerged in this era:

- Flexible Specialization: Small firms collaborate in networks to focus on specific stages of production, creating a whole product. This requires strong communication and long-term partnerships.
- Lean Production: Inspired by Toyota's success, this approach eliminates waste and minimizes inventory, leading to faster production and lower costs.
- Mass Customization: Imagine getting a customized product at mass-produced prices. This concept is becoming a reality with advancements in technology and automation.
- Agile Manufacturing: Rapidly adapting to shifting market demands is key here. Technology plays a crucial role in achieving this agility.

Industry 4.0 – Fourth Industrial Revolution (4IR)

According to McKinsey & Company (2024), the Fourth Industrial Revolution (4IR) builds upon the innovations of the Third Industrial Revolution, also known as the digital revolution. The digital revolution spanned from the 1950s to the early 2000s and introduced technologies like computers, the Internet, and various electronics. Industry 4.0 takes these advancements further by leveraging four key disruptive technology categories across the entire value chain:

- Connectivity, Data, and Computational Power: Examples include cloud technology, the Internet, blockchain, and sensor networks.
- Analytics and Intelligence: This category encompasses advanced analytics, machine learning, and artificial intelligence.
- Human–Machine Interaction: Technologies such as virtual reality (VR), augmented reality (AR), robotics, and autonomous guided vehicles enhance interaction between humans and machines.
- Advanced Engineering: Additive manufacturing (such as 3-D printing), renewable energy solutions and nanoparticles contribute to cutting-edge engineering practices.

These technologies collectively drive Industry 4.0, revolutionizing how we approach manufacturing, production, and overall business processes.

In various ways, these approaches combine the high volume and low cost associated with mass production with product customization and high levels of innovation and quality associated with craft production. As technology continues to evolve, we can expect even more exciting advancements in how we make things in the future.

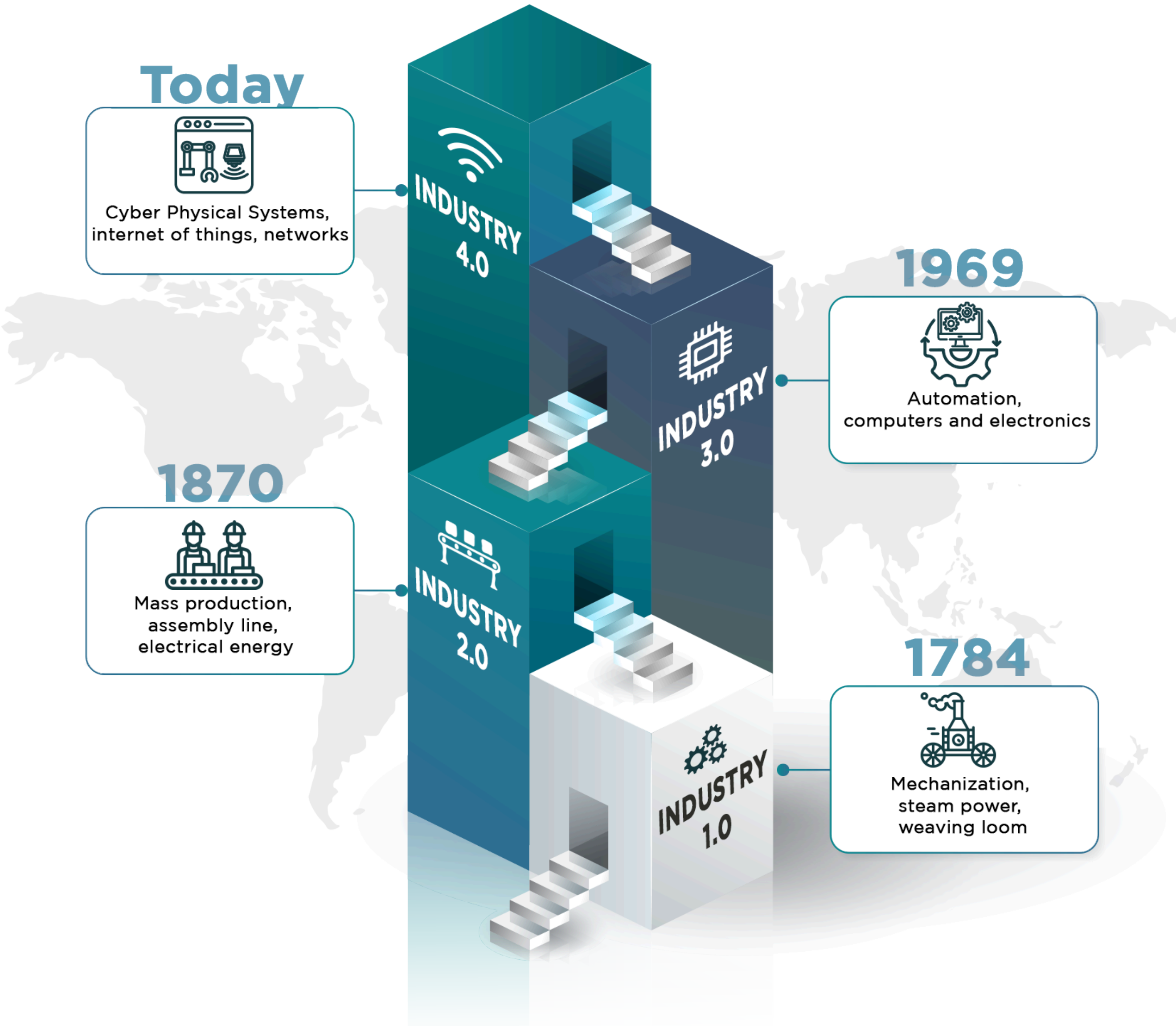


Figure 1.5.1: "Industrial Revolution" by Sanaz Habib, CC BY-NC-SA 4.0

1.6 KEY TRENDS IN OPERATIONS MANAGEMENT

In the previous section, we looked at the evolution of operations management. Those changes largely took place in response to the business and economic changes that aimed at improving productivity through innovation in pursuit of greater economic gains. In doing so, however, the business world realized the need to balance economic and non-economic bottom lines. Such realization created some key trends that impacted operations management.

Globalization

The economic principle of "competitive advantage" led both the public and private sectors in many countries to part from "self-sufficiency" and "protectionism" and open doors to trade. This change allowed companies to obtain their material or establish manufacturing facilities in a country at a lower cost.

Supply Chain Expansion

With larger trade volume, supply chains also expanded, making it easier for businesses to find more supply sources and/or new markets for their products. The expanded chains also made it possible to find more distributors, wholesalers, manufacturers, and other partners in the chain, such as logistics companies and warehouses. The longer supply chain allowed more companies to get involved, from providers of raw materials to the sellers of final products.

E-Commerce

Allowed businesses to sell to other businesses or customers online. As e-commerce relies on internet use, however, businesses and consumers may not use it with equal success. For example, many small businesses, which contribute significantly to almost any economy's gross domestic product (GDP), do not use e-commerce. This is true for many consumers as well.

Technology

Information technology (IT) has played a vital role in facilitating commerce between businesses (B2B) or between businesses and consumers. An example of such impact can be found in the order-to-delivery process in Amazon, whereby a Canadian places an order for pieces of custom-made clothing that are made in China and Brazil and have it delivered to their front door in days.

Sustainability

Aside from profit (economic gain), in the past few decades, businesses have also paid attention to social and environmental gains. Metaphorically, these three can be perceived as a tripod; if the economic leg is heavier, the tripod will become imbalanced. Therefore, such initiatives that pay closer attention to the social well-being of underpaid workers that work in sweatshops have gained a place in business practices. In addition, closer attention to "closed-loop supply chain" and "life cycle analysis" have been encouraged in product design.

Recent (Post-Covid) Trends

The COVID-19 pandemic changed business practices in many ways and created new trends in their operations. While some of the previously mentioned trends helped business companies during the Pandemic, the human/social aftermath of COVID-19 seems to have created new challenges in business operations. For example, while enhanced information technology (IT) and advances in artificial intelligence (AI) led to better digital communication and increased productivity, they also took away personal connections and led people to scrutinize business corporations' social/environmental footprint. The following video explains these trends in more detail.

Video: "7 Key Business Trends for 2023" by Shifft [21:52] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

1.7 CHAPTER SUMMARY & REVIEW

Summary

The first chapter of the Operations Management text outlines the fundamental concepts and significance of operations management in a business context. It defines operations management as the process of transforming inputs into valuable outputs (goods and services) and highlights its critical role in ensuring efficient resource utilization. The chapter emphasizes the importance of operations management for business students, explaining that understanding these processes is vital for managing and improving the systems that create an organization's products or services. Additionally, it covers the historical phases of operations management, from craft manufacturing to mass production and the modern period, showing how the field has evolved in response to changing market demands and technological advancements.

The chapter also differentiates between producing goods and providing services, noting that while goods are tangible and standardized, services are intangible and often require direct customer interaction. It discusses the transformation processes involved in operations management, categorizing them into manufacturing, service, supply, and transport. Furthermore, the chapter highlights the interconnectedness of operations with other business functions like marketing, finance, and human resources, stressing the importance of operations in achieving organizational success. Lastly, it touches upon recent trends in operations management, such as globalization, supply chain expansion, e-commerce, technology, and sustainability, and examines the impact of the COVID-19 pandemic on business practices, pointing out the challenges and opportunities it has created.

OpenAI. (2024, May 7). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than two paragraphs. Reviewed by authors.*

Review Questions

1. Define operations management and describe its core functions within a business. How does operations management contribute to the overall success of an organization?
2. Explain the role of operations management in transforming inputs into outputs. Provide an example of this transformation process in a manufacturing setting and in a service setting.
3. Discuss why it is important for business students to study operations management. What benefits can this knowledge provide in a professional career?
4. Identify and discuss some of the professional organizations involved in operations management. How can these organizations benefit students and professionals in the field?
5. Describe the three phases of operations management history: craft manufacturing, mass production, and the modern period. What are the key characteristics and innovations of each phase?
6. Compare and contrast the production of goods and services. What are the main differences in terms of output, customer interaction, labour content, input variability, quality measurement, productivity measurement, and inventory handling?
7. What is a transformation process in operations management? Give examples of different types of transformation processes and explain how they add value to inputs.
8. Explain the concept of operations functions within an organization. How do operations interact with other functional areas, such as marketing, finance, and human resources?
9. Discuss the importance of efficiency and effectiveness in operations management. How can businesses balance these two aspects to create value for customers? Provide examples.
10. Examine the key trends in operations management, including globalization, supply chain expansion, e-commerce, technology, sustainability, and post-COVID trends. How have these trends impacted the field of operations management?

OpenAI. (2024, May 28). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

Explore the Resources for Operations Management Learners and Professionals list in section 1.4. Select one 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 networking opportunities to meet professionals?
4. Do they offer job search assistance?
5. Would you consider joining either of these organizations? Why or why not?

1.8 KEY TERMS

Key Terms

- **Effectiveness**: It's about doing the right things. This means making choices and taking actions that benefit the business and, most importantly, add value for the customer.
- **Efficiency**: It's about doing things well but without wasting resources. This means finding ways to streamline tasks and avoid unnecessary steps that cost time or money.
- **Finance** is the lifeblood of the company. They manage the money flow, ensuring there's enough to cover everything from materials and payroll to equipment upgrades.
- **Goods:** Tangible products like vehicles, clothing, cell phones, and shovels.
- **HR** is the foundation of any successful organization. They recruit, hire, and train the talented individuals who make up the operations team.
- **Macro-operation** is an overall transformation that is usually required to produce a good or service
- **Manufacture**: This involves physically creating products, such as automobiles.
- **Marketing** acts as the bridge between customers and operations. They ensure the company creates products or services that fulfill customer needs and desires.
- **Micro-operations** are the more detailed transformations within the macro-operation.
- **Operations** encompasses all activities necessary for delivering an organization's goods or services to customers and clients.
- **Operations management** is the management of the processes that transform inputs into goods and services that add value for the customer.
- **Service**: Service-oriented processes focus on treating customers or storing products, as seen in hospitals or warehouses.
- **Services:** Intangible offerings such as car repairs, haircuts, and medical treatments.
- **Supply**: This encompasses changes in ownership of goods, often observed in retail settings.
- **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.

- **Transport**: Processes related to the movement of materials or customers, such as taxi services.

CHAPTER 2: BUSINESS COMPETITIVENESS & OPERATIONS STRATEGY

Chapter Overview

2.0 LEARNING OUTCOMES

Learning Objectives

By the end of this chapter, students will be able to:

- Explore the modern environment of business and the key players that can influence business decisions.
- Explain the factors that influence purchasing decisions.
- Differentiate between essential criteria for being considered as a supplier (order qualifiers) and criteria that give a competitive edge (order winners).
- Identify the four main priorities (cost, quality, speed, and flexibility) and the strategies firms use to achieve them.
- Describe the concept of core competency, which refers to a company's unique strengths and capabilities.
- Explain the three levels of strategy—corporate, business, and functional.
- Describe the six categories of operations strategy, such as cost, quality, and innovation.

2.1 MODERN ENVIRONMENT OF BUSINESS

"Entrance of Dr. Oetker Canada plant in London, Ontario", Global Affairs Canada, Crown NC (CAN). The Government of Canada is not affiliated with nor endorses the reproduction of its official documents here.

To better appreciate competitiveness, let's take a look at the dynamic environment of business today and the key players that can impact business decision-making. Consider a business unit like Dr. Oetker's pizza factory in London, Ontario. That plant is embedded in multiple layers of the environment (local, provincial, national, and international), and its products are prepared there. Within these layers of environment, there are countless players that directly or indirectly can impact what happens inside this factory, as shown in Figure 2.1.1.

These players include ISO, financial institutions, environmental activists, food research institutions, farming, engineering, logistic and IT firms. In addition, four prominent players (suppliers, competitors, customers and regulatory bodies) are present. All these players can interact with each other and collectively influence the decisions made by this company and the activities that take place inside this factory.

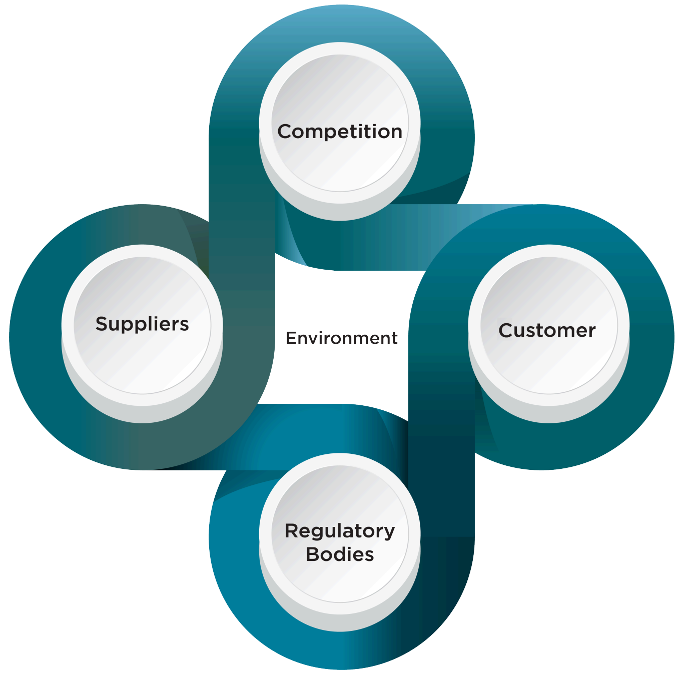


Figure 2.1.1. "Environment Layers" by Sanaz Habibi, CC BY-NC-SA 4.0

For Dr. Oetker, customers are most important because they can determine the sales volume and, hence, the firm's profit. The challenge is what Dr. Oetker should do to win more customers while the competition pursues the same objective. Both are competing for a bigger share of the market, for which they would need suppliers, and both must follow the regulatory standards as they are operating in the food industry. Therefore, their internal decisions and activities (operations) are influenced by external forces, namely, suppliers, customers, and competition. All business firms seek and plan for more profit by expanding their market share. However, the success of such a plan (Strategy) depends on their awareness of the influences in the business environment and their competitiveness.

2.2 COMPETITIVENESS

Competitiveness refers to a firm's ability and performance in selling and supplying goods and services within a given market ("Competition (companies)", 2019). It's about how a company can win over customers to become their preferred choice. Competitive Advantage is achieved by offering better value than competitors through lower prices or higher quality. Key purchasing criteria include price, quality, variety, and timeliness. Customer decisions are influenced by these criteria when choosing a service or product.

Competitive Advantage and Key Purchasing Criteria

Competitive Advantage and Key Purchasing Criteria are two sides of the same coin in business. They both deal with why a customer chooses one company over another.

Competitive advantage is what makes a business stand out from its competitors. It's the reason a customer would choose their product or service over another company's offering. This advantage can come in many forms, like:

- *Lower prices:* Some companies can offer a similar product at a cheaper cost due to efficiencies or economies of scale.
- *Higher quality:* Some companies focus on building superior products that last longer or perform better.
- *Better customer service:* Companies that prioritize customer experience can build loyalty through strong support.
- *Unique features:* A groundbreaking product or service can create a competitive advantage if it fills a specific customer need.

Understanding what motivates buyers is crucial for any organization, regardless of who those buyers are. These motivators, known as Key Purchasing Criteria, are the factors that influence buying decisions.

The Customer isn't always a single person. Sometimes, it can be another company. For example, imagine the City of Toronto buying heavy-duty trucks for park maintenance or Toyota searching for a new supplier of car windshields. In both cases, key purchasing criteria will guide their choices.

Key Purchasing Criteria are the factors that influence a customer's buying decision. When customers consider different options, they will weigh these criteria to determine the best fit for their needs. Here are some common factors:

- *Price* – Firms must understand how much the Customer will pay for an item. If products are seen to be very similar, the Customer will choose based on price.
- *Quality* – Many customers are willing to spend more 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* – A part of the market values 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 to gain new customers. This can also be related to the capability of the company to deliver at the time that they had promised.

By understanding their competitive advantage, a business can tailor their marketing and sales to resonate with a customer's key purchasing criteria. This increases the chance of the Customer choosing them over the competition.

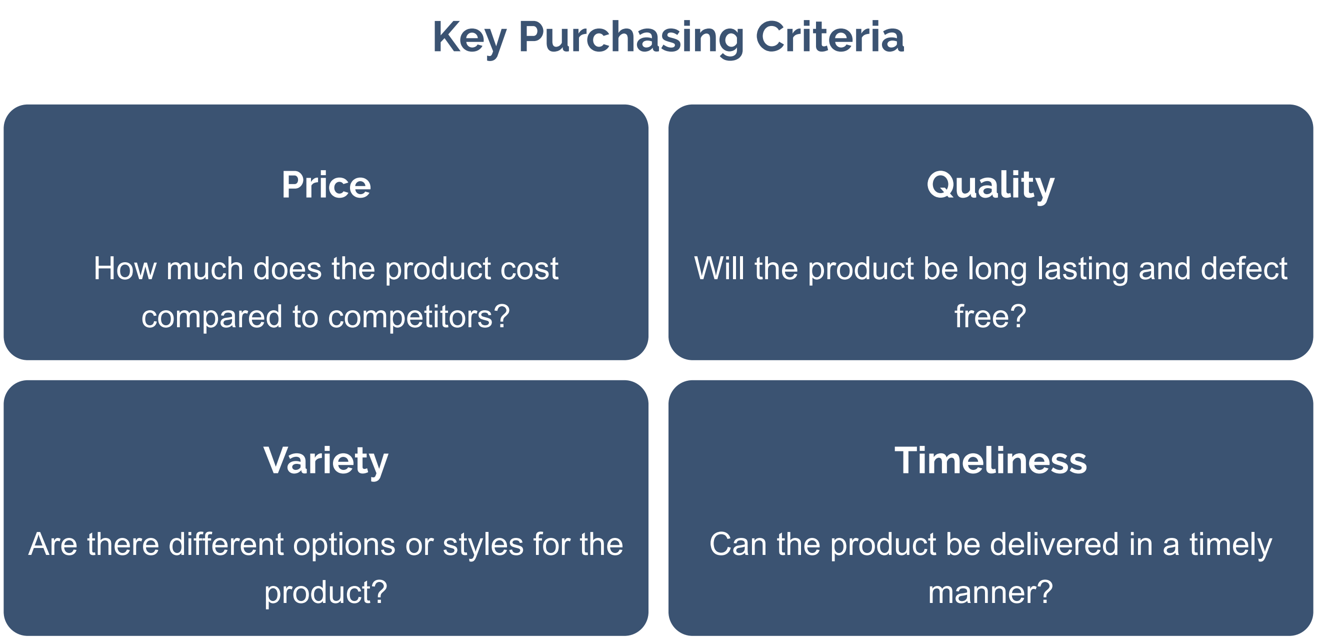


Figure 2.2.1: Categories of key purchasing criteria.

Order Qualifiers vs. Order Winners

Two essential concepts related to purchasing criteria are order qualifiers and order winners, which were initially introduced by Terry Hill (Hill, 2000). When making significant purchases, customers evaluate which characteristics are non-negotiable requirements and which can influence their decision.

Order Qualifiers

These are the non-negotiable features or requirements that customers expect. If a product or service lacks these characteristics, customers will seek alternatives.

For example, minimum safety features and air conditioning might be order qualifiers for a car. In Smartphones, customers expect a minimum level of battery performance, a certain level of display quality is essential, and the phone must function reliably.

Order Winners

These characteristics differentiate a product or service and lead to winning the Customer's order.

Order winners can include new technical features, attractive warranties, service agreements, or competitive pricing.

Over time, what was once an order winner may become an order qualifier and vice versa. For instance, air conditioning in cars was a novelty (order winner) in 1989 but has now become an expected feature (order qualifier). Regarding the example of Smartphones, a superior camera with advanced features can be a decisive factor; a visually appealing and distinctive design can attract customers, and innovative software functionalities set a product apart.

Marketing teams must understand their customers' order qualifiers and order winners. Operations should promptly address these requirements to meet customer expectations.

These concepts evolve, so businesses must stay attuned to changing customer preferences.

Competitive Priorities

In the world of business, every company wants to be the champion. But how do they win? Operations Management plays a critical role by focusing on four key areas that customers care about cost, quality, flexibility, and speed.

Cost: Keeping it Affordable

Imagine customers who only want the best deals. For these price-conscious shoppers, companies need to be cost champions. This means finding ways to cut waste and get the most out of everything they have. They become ninjas at identifying and eliminating unnecessary steps in their operations. Reducing mistakes (defects) also saves money, so these companies keep a close eye on quality to keep costs down. Think of it like this: the less you waste, the less you spend!

Quality: Products Worth Bragging About

Some customers value quality above all else. For them, companies strive to be quality kings and queens. This means creating top-notch products and figuring out the best way to make them. Imagine the marketing and engineering teams working together to design amazing products that meet Customer needs precisely. Then, the manufacturing team ensures these products are built perfectly every single time. It's like a two-part recipe for success: a great design and a perfect production process, both working together to satisfy happy customers.

Flexibility: Adapting on the Fly

What if customers want lots of choices and new products all the time? In that case, companies need to be flexibility fighters. They achieve this by using equipment that can handle many different tasks, like a Swiss Army knife of the business world! They also keep some extra space and resources on hand to ramp things up quickly. Imagine having employees who can wear many hats and switch between tasks or machines easily. This allows these companies to get new products to market fast and switch between making different products in a flash. They also want to be able to adjust their production levels quickly if demand changes. Think of it like this: the more adaptable you are, the easier it is to keep up with customer needs.

Delivery: Getting There Fast

Sometimes, speed is king (or queen!). Companies whose customers value fast delivery need to be in the delivery dash. Imagine companies like McDonald's or Amazon – they're all about getting things to you quickly and efficiently. This means having streamlined processes and being super fast at providing their products and services.

By understanding these competitive priorities, operations managers can make strategic decisions to give their company the edge and become the ultimate champion in the eyes of their customers!

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

Trade-offs in Operations: The Balancing Act

Have you ever tried juggling? It takes practice to keep all the balls in the air! In operations management, it's similar. There are many important things to focus on, but you can't necessarily be the best at everything all the time. This is because of trade-offs. Imagine a company that wants to be the absolute cheapest (cost champion). To make fewer mistakes (defects), they might switch to a higher-quality part. But guess what? That usually costs more! This is a classic trade-off between cost and quality.

Just like juggling different coloured balls, there are trade-offs between flexibility and speed. If a company wants to offer many choices (flexibility), it can get complicated to make everything quickly (speed). Think about a pizza place that makes everything from hand-tossed dough to gourmet toppings. It might take longer to get your pie compared to a place with just a few basic options.

Every decision in operations management involves a balancing act. By understanding these trade-offs, companies can determine what matters most to their customers and focus on excelling in those areas.

Core Competencies

Imagine a bakery famous for its mouthwatering pies. What makes their pies so good? Maybe it's a secret family recipe, perhaps it's their generation of baking experience, or maybe it's their special touch for creating flaky crusts. This special something is like a company's core competency.

Core competency is a business term that means a company's unique strengths and talents. It's what makes them stand out from the crowd, just like the secret ingredient that makes those pies so delicious.

This idea of core competencies came from a Harvard Business Review article, 'The Core Competence of the Corporation,' written in the 1990s.

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 to succeed against the competition.

Many things can contribute to a company's core competency. It could be their amazing employees, equipment, a secret formula they hold (like a patent), or even their awesome brand reputation.

The key thing is that a successful company knows what it does better than anyone else and why. Their core competency is the "why" behind their success. By identifying and using their core competency, a company can become the bakery everyone raves about or whatever industry they're in!

The Core Competency Checklist: Three Must-Haves

In an article, C.K. Prahalad and Gary Hamel came up with a special checklist to identify core competencies.

1. A core competency should deliver a superior value or benefit to the Customer. Think about McDonald's fries. They might not be the most gourmet, but they're tasty, consistent, and affordable – a win for customers who want a quick and reliable fry fix.
2. It should be difficult for competitors to imitate. Imagine Apple's stylish designs. Sure, other companies

can make phones, but Apple's unique design and user experience blend is tough to replicate.

3. A core competency should be rare. Only some companies can have the same strength. Take Walmart's buying power. Their massive size allows them to negotiate incredible deals with suppliers, giving them a big advantage over smaller competitors. (Twin, 2023).

These three conditions are like a secret code for identifying a company's strengths. If a strength checks all these boxes, then it's a core competency. By focusing on these core competencies, businesses can become the McDonald's of fries, the Apple of style, or the Walmart of low prices, dominating their competition!

2.3 STRATEGY

The term "strategy" originates from the Greek word "strategos," which translates to "general." This etymology reflects the concept's roots in military tactics, where a strategist guided the overall course of warfare. In the business domain, this notion of leading military campaigns has been adapted to the leadership of business activities. Business strategy entails establishing long-term goals and outlining a course of action for a firm, differentiating it from the day-to-day operational activities.

Operations Strategy and Operations

As previously mentioned, winning a greater market share requires a plan (strategy). Once this plan is set, it should be executed by internal activities (operations) and resources that deliver the plan for the external market. The effectiveness of a plan lies in a realistic grasp of what the customers want, which often tends to be dynamically changing, ambiguous or heterogeneous. On the other hand, internal activities and resources could be complex enough not to change dynamically. Despite this disagreement, the two sides should complement each other. The following video explains this in more detail:

Video: "The Difference Between Operations and Strategy" by cmoeinc [5:18] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Organizations and Internal View of Operations Strategy

While the operations strategy is formulated in response to external market demands, the decision-making process and execution occur entirely within the organization. Two prominent approaches to operations strategy exist: top-down and bottom-up. These approaches differ in the organizational levels involved in strategic decision-making. This section will first delve into these two perspectives and then examine the role of organizational hierarchy in formulating strategic choices.

Video: "Operations Strategy Part 1" by Dr Ogunseyin [6:20] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

The Strategic Hierarchy: A Framework for Decision-Making

Organizations operate at various levels, each requiring its own strategic focus. Understanding this strategic hierarchy is crucial for effective decision-making.

At the highest level sits the **corporate strategy**. This broader scope vision defines the company's core values, mission, and desired competitive advantage. It essentially answers the question: "In which industries should we compete, and how will this create synergy and value for the entire corporation?"

Next comes the **business-level strategy**. Here, the focus narrows to individual business units (SBUs) within a diversified corporation. This strategy determines how each SBU will achieve a sustainable competitive advantage. Michael Porter's framework proposes three main approaches: cost leadership (offering the lowest price), differentiation (standing out through unique features), or focus (targeting a specific market niche).

Delving deeper, we encounter **functional strategies**. These are department-specific plans that support the overall business-level strategy. The marketing department might craft a strategy for brand awareness, while finance might prioritize cost-reduction measures. These functional strategies may have departmental focus, alignment with the business strategy, and focus on short-to-midterm goals.

Traditional functional structures are sometimes deemed inefficient. In such cases, companies may adopt a structure based on processes or SBUs. An **SBU** is a semi-autonomous unit responsible for its own budgeting, product development, hiring, and pricing decisions. It operates as an internal profit center within the corporation.

Finally, we reach the **operational strategy**. This highly focused level deals with day-to-day operational activities, such as scheduling production runs or setting quality control parameters. Operational strategies are naturally informed by the business-level strategies, which themselves align with the broader corporate vision.

> The strategic hierarchy acts as a framework for decision-making at all organizational levels. Corporate Strategy sets the overall direction, informing business-level strategies which in turn guide functional and operational activities. This coordinated approach ensures efficient resource allocation and propels the organization toward long-term goals.

Critical Decisions in Operations Strategy: Executing the Game Plan

Operations strategy translates the high-level business strategy into actionable steps. The decisions made at this level determine the success or failure of the overall plan. Here are 10 critical areas that demand careful consideration in operations management (Kettering Global, 2016):

1. *Product and Service Design:* The fundamental design of your offering significantly impacts production costs and achievable quality. Every aspect, from materials to functionality, plays a role.
2. *Quality Management:* Ensuring your product or service consistently meets specifications is paramount. This may involve implementing methodologies like Statistical Process Control (SPC), Total Quality Management (TQM), or Six Sigma.
3. *Process and Capacity Design:* The type of product, its volume, and variety all influence the optimal production process. For instance, high-volume, standardized products might benefit from assembly lines, while low-volume, customized products might require a more flexible job-shop approach.
4. *Location Strategy:* Decisions regarding the number and placement of facilities are crucial. Factors like proximity to raw materials, transportation networks, and customer base all need to be considered. Location directly impacts the speed of production and customer deliveries.
5. *Layout Design:* This involves strategically positioning workstations, materials handling systems, and information flow within the production facility. Optimizing layout minimizes waste and maximizes efficiency.
6. *Human Resources and Job Design:* Training, motivation, and skill development of your workforce are critical for operational excellence. Job design should balance employee satisfaction with task efficiency.
7. *Supply Chain Management:* Decisions regarding supplier locations and the level of collaboration directly impact cost and delivery speed. Building strong relationships with reliable suppliers is key.
8. *Inventory Management:* Developing strategies for efficient inventory control throughout the supply chain is essential. This involves balancing the need to have enough materials on hand with the cost of holding excess inventory.
9. *Scheduling:* Effective scheduling of production processes, resources, and employees ensures timely deliveries and customer satisfaction. This requires balancing workload with available resources and capacity.
10. *Maintenance:* Regularly maintaining equipment and machinery minimizes downtime, maintains quality, and ensures smooth and stable production processes.

By carefully considering these 10 critical decisions, organizations can translate their business strategy into a successful operational reality.

Common Operations Strategies: Competing on Quality and Speed

Within the realm of operations strategy, two dominant approaches emerge quality-based strategies and time-based strategies. Let's explore how these strategies can empower organizations to achieve a competitive edge.

Quality-Based Strategies: Building a Reputation for Excellence

Quality-based strategies are a powerful tool for companies seeking to elevate their market standing. These strategies prioritize continuous improvement in product design and a relentless pursuit of error reduction. By implementing such initiatives, firms establish a reputation for superior quality, fostering customer loyalty and potentially commanding premium pricing.

Several frameworks and methodologies underpin quality-based strategies. Some of the most prominent include:

- **ISO 9001**: This internationally recognized standard provides a framework for establishing a quality management system, ensuring consistent product quality and adherence to customer specifications.
- **Six Sigma**: This data-driven methodology focuses on identifying and eliminating defects in manufacturing and business processes, leading to significant improvements in quality and efficiency.
- **Total Quality Management (TQM)**: A holistic approach to quality management, TQM emphasizes continuous improvement across all organizational levels, fostering a culture of quality that permeates every aspect of the business.

By embracing these quality-focused approaches, companies can enhance customer satisfaction and reduce production costs through minimized rework and improved process efficiency.

Time-Based Strategies: The Race Against the Clock

In today's fast-paced markets, speed can be a significant competitive differentiator. **Time-based strategies** focus on reducing lead time, the time elapsed between a customer's order and product delivery. Companies that can deliver faster often enjoy several advantages:

- *Increased Customer Satisfaction:* Faster deliveries enhance customer experience and satisfaction, potentially leading to repeat business and positive word-of-mouth marketing.
- *Reduced Inventory Costs:* By streamlining processes and minimizing lead times, companies can hold less inventory, reducing associated storage and financing costs.
- *Enhanced Responsiveness to Market Shifts:* Shorter lead times allow organizations to rapidly adapt to

changing market demands, potentially introducing new products or modifying existing ones with greater agility.

Lean Production is a prominent methodology frequently employed in time-based strategies. Lean principles focus on eliminating waste in all its forms, from unnecessary production steps to excessive inventory levels. By streamlining processes and optimizing resource allocation, lean production helps companies achieve faster lead times and greater operational efficiency.

The choice between a quality-based or time-based strategy is not always clear-cut. Many organizations incorporate elements of both approaches to achieve a balance between delivering high-quality products and services while maintaining responsiveness to customer needs.

2.4 THE POWER OF PRODUCTIVITY MEASUREMENT: GAUGING OPERATIONAL PERFORMANCE

In the realm of operations, measurement reigns supreme. A key metric for judging operational effectiveness is productivity. But what exactly is productivity, and how can it be measured?

Understanding Productivity:

- **Relative Measure**: Productivity is a relative measure, meaning it holds little meaning in isolation. Its true value is revealed when compared to a previous period, a similar department, or a competitor. The focus lies on whether productivity has improved, declined, or stagnated.

Types of Productivity Measures

The measure of a firm's **output** depends on the nature of its products. For homogenous goods, output can be expressed as the number of units produced. However, when dealing with diverse products that vary in labour and material costs, the output is often described in terms of the dollar value of all goods produced within a specific time frame.

Inputs, on the other hand, are typically measured in dollars spent, although exceptions exist (such as labour hours, water usage, or electricity consumption). Productivity is usually assessed for significant expenditures, with farmers, for instance, measuring meat output and feed consumption.

To gain a comprehensive understanding of operational efficiency, we can explore various types of productivity measures:

- **Labour Productivity**: This metric measures the output (goods or services produced) per unit of labour input (typically labour hours).

- **Machine Productivity**: This metric focuses on the output produced per unit of machine time (e.g., number of widgets produced per hour of machine operation).
- **Material Productivity**: This metric measures the output per unit of material input (e.g., number of finished products per unit of raw material).
- **Multifactor Productivity**: This broader measure takes into account all inputs (labour, materials, machinery, etc.) to determine the overall efficiency of the production process.

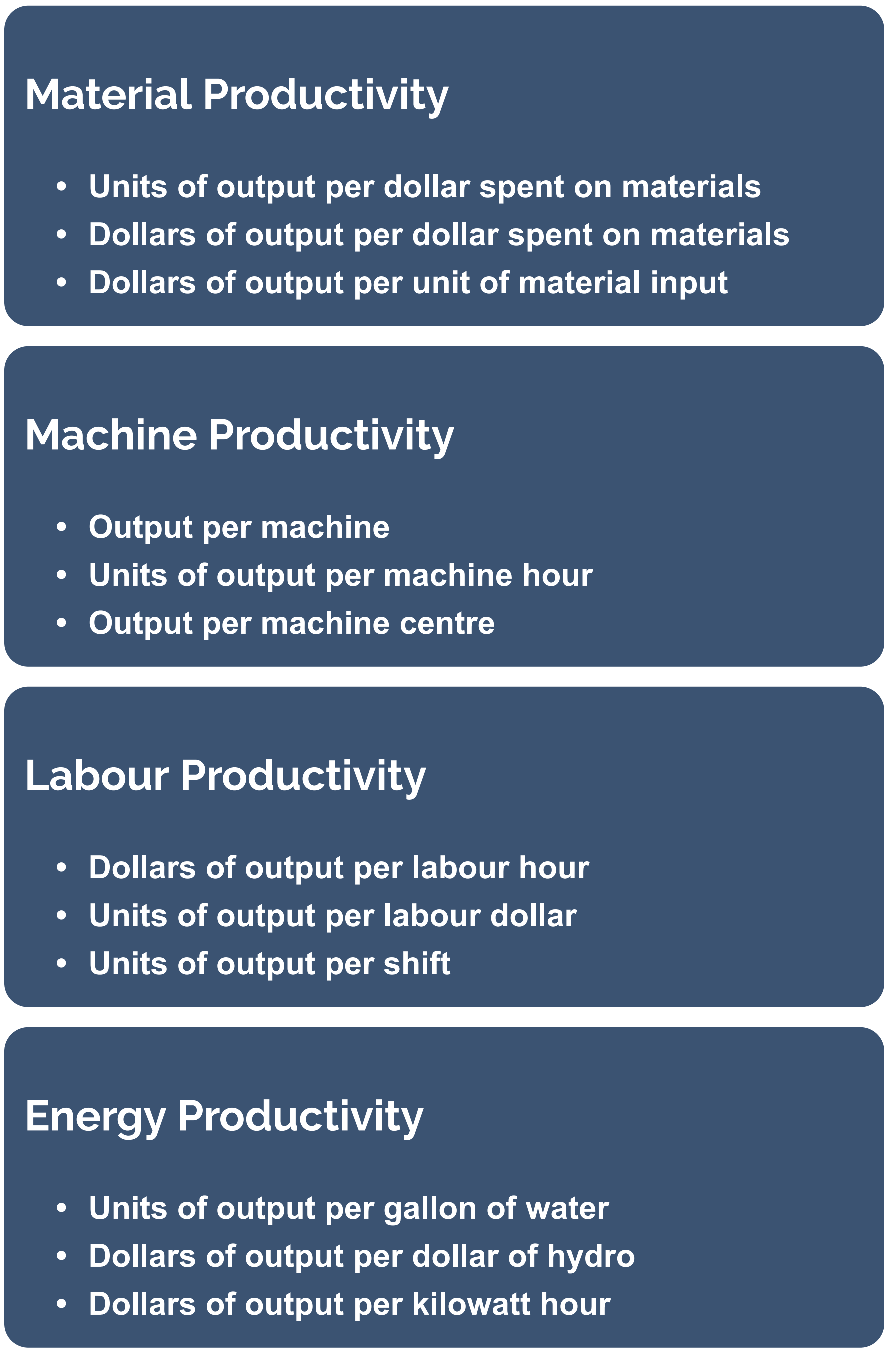


Figure 2.3.1: Examples of productivity measures.

Calculating Percent Change

Once you've chosen the appropriate productivity measure, you can calculate the percent change over a specific period. Here's the formula:

Percent Change in Productivity = ((New Period Productivity – Old Period Productivity) ÷ Old Period Productivity) × 100

Percent Change

$$Percent\ Change = \frac{New\ Value - Old\ Value}{Old\ Value} \times 100\%$$

If the result is positive, it is an increase.

If the result is negative, it is a decrease.

Examples of Productivity Measures

Partial Productivity

$$PP = \frac{Output}{Labour}$$

$$PP = \frac{Output}{Energy}$$

$$PP = \frac{Output}{Materials}$$

Multi-factor Productivity

$$MFP = \frac{Output}{Labour + Materials}$$

$$MFP = \frac{Output}{Energy + Labour + Materials}$$

Total Productivity

$$TP = \frac{Output}{All\ inputs}$$

Example

Let's say a company's labour productivity in the previous quarter was 10 units per labour hour. In the current quarter, the productivity has increased to 12 units per labour hour.

Using the formula, the percent change in productivity is:

Percent Change = ((12 units/hour – 10 units/hour) ÷ 10 units/hour) × 100 = 20%

This indicates a 20% improvement in labour productivity over the quarter.

By employing various productivity measures and tracking their changes over time, organizations can gain valuable insights into their operational effectiveness. This allows them to identify areas for improvement, optimize resource allocation, and ultimately achieve a competitive advantage.

2.5 CHAPTER SUMMARY & REVIEW

Summary

This chapter explores the modern business environment and its impact on competitiveness. A discussion on how businesses like Dr. Oetker's pizza factory must navigate multiple layers of local to international influences, including regulatory bodies, suppliers, customers, and competitors, is included. Competitiveness is defined by a firm's ability to offer better value than competitors, often achieved through lower prices or higher quality. Key purchasing criteria such as price, quality, variety, and timeliness are crucial in customer decision-making. Order qualifiers (non-negotiable features) and order winners (differentiating features) are essential for businesses to understand and leverage to attract customers.

The chapter also delves into competitive priorities—cost, quality, flexibility, and speed—each representing a strategic focus area for operations management. Businesses must navigate trade-offs between these priorities, as excelling in one area often means compromising in another. Core competencies, unique strengths and capabilities are critical for sustaining competitive advantage and must meet specific criteria, including delivering superior value, being difficult to imitate, and being rare. The chapter further outlines the strategic hierarchy from corporate to operational levels, emphasizing the importance of aligning strategies across these levels to achieve overall business goals. Lastly, the chapter addresses critical decisions in operations strategy, such as product design, quality management, and supply chain management, highlighting the necessity of careful planning and execution to maintain competitiveness.

OpenAI. (2024, May 24). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than two paragraphs. Reviewed by authors.*

Exercises

1. How do external factors such as regulatory bodies, suppliers, and customers influence a business's internal operations and strategic decisions? Can you provide examples from the chapter?
2. Discuss the difference between order qualifiers and order winners. How can a company effectively identify and leverage these concepts to gain a competitive advantage in the market?
3. Explain the four competitive priorities—cost, quality, flexibility, and speed. How do businesses balance these priorities, and what are the potential trade-offs involved?
4. What are core competencies, and why are they important for a company's long-term success? Discuss the criteria that a core competency must meet according to the chapter.
5. Describe the strategic hierarchy from corporate strategy to operational strategy. How does alignment across these levels contribute to a company's overall competitiveness and operational efficiency?
6. What are the ten critical decisions in operations strategy mentioned in the chapter? How do these decisions impact a company's ability to execute its business strategy effectively?

OpenAI. (2024, May 28). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create six discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

2.6 CHAPTER PROBLEMS

Problem #1

Billco Windows and Doors is preparing its monthly productivity report. Their monthly costs are shown below. Calculate the:

a) Labour productivity (output ÷ labour hours)

b) Machine productivity (output ÷ machine hours)

c) The multifactor productivity (output ÷ (labour cost + material cost + energy cost)) of dollars spent on labour, materials, and energy. The 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
= 0.91 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 × $18) + $81000 + $21600)
= 0.013 units per dollar spent

Problem #2

A company makes seasonal jams and jellies. Yesterday they produced 520 jars of jam with five workers who each worked an 8-hour day. What was the labour productivity?

Solution
= 520 ÷ 5 workers × 8 hours
= 13 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

c) Total productivity

Also, calculate the percent change for each measure.

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

Solution

Question	June	July	% Change
a) Food cost productivity	52500 ÷ 15750 = **$3.33**	59650 ÷ 16702 = **$3.57**	(3.57 – 3.33) ÷ 3.33 × 100 = **+7.02%**
b) Labour productivity	52500 ÷ 11550 = **$4.55**	59650 ÷ 14512 = **$4.11**	(4.11 – 4.55) ÷ 4.55 × 100 = **−9.7%**
c) Total productivity	52500 ÷ (15750 + 11550 + 3500) = **$1.70**	59650 ÷ (16702 + 14512 + 3500) = **$1.72**	(1.72 – 1.70) ÷ 1.70 × 100 = **+1.2%**

2.7 KEY TERMS

Key Terms

- **Business Strategy** entails establishing long-term goals and outlining a course of action for a firm, differentiating it from the day-to-day operational activities.
- **Business-level Strategy** Here, the focus narrows to individual business units (SBUs) within a diversified corporation.
- **Competitive Advantage** is what makes a business stand out from its competitors.
- **Competitiveness** refers to a firm's ability and performance in selling and supplying goods and services within a given market ("Competition (companies)", 2019).
- **Core Competencies** are the resources and capabilities that comprise the strategic advantages of a business.
- **Corporate Strategy** is a broader scope vision that defines the company's core values, mission, and desired competitive advantage.
- **Functional Strategies** are department-specific plans that support the overall business-level strategy.
- **Inputs** are typically measured in dollars spent, although exceptions exist (such as labour hours, water usage, or electricity consumption).
- **ISO 9001**: This internationally recognized standard provides a framework for establishing a quality management system, ensuring consistent product quality and adherence to customer specifications.
- **Key Purchasing Criteria** are the factors that influence a customer's buying decision. These include price, quality, variety, and timeliness.
- **Labour Productivity**: This metric measures the output (goods or services produced) per unit of labour input (typically labour hours).
- **Lean Production** is a prominent methodology frequently employed in time-based strategies. Lean principles focus on eliminating waste in all its forms, from unnecessary

production steps to excessive inventory levels.

- **Machine Productivity**: This metric focuses on the output produced per unit of machine time (e.g., number of widgets produced per hour of machine operation).
- **Material Productivity**: This metric measures the output per unit of material input (e.g., number of finished products per unit of raw material).
- **Multifactor Productivity**: This broader measure takes into account all inputs (labour, materials, machinery, etc.) to determine the overall efficiency of the production process.
- **Operational Strategy: T**his highly focused level deals with day-to-day operational activities, such as scheduling production runs or setting quality control parameters.
- **Output:** For homogenous goods, output can be expressed as the number of units produced. However, when dealing with diverse products that vary in labour and material costs, the output is often described in terms of the dollar value of all goods produced within a specific time frame.
- **Quality-based Strategies** prioritize continuous improvement in product design and a relentless pursuit of error reduction.
- **Six Sigma**: This data-driven methodology focuses on identifying and eliminating defects in manufacturing and business processes, leading to significant improvements in quality and efficiency.
- **Strategic Business Unit (SBU)** is a semi-autonomous unit responsible for its own budgeting, product development, hiring, and pricing decisions. It operates as an internal profit center within the corporation.
- **Time-based Strategies** focus on reducing lead time, the time elapsed between a customer's order and product delivery.
- **Total Quality Management (TQM)**: A holistic approach to quality management, TQM emphasizes continuous improvement across all organizational levels, fostering a culture of quality that permeates every aspect of the business.

CHAPTER 3: FORECASTING

Chapter Overview

3.0 LEARNING OUTCOMES

Learning Objectives

By the end of this chapter, students will be able to:

- Define forecasting and differentiate it from related concepts such as prediction.
- Describe the role of forecasting in marketing strategy implementation.
- Outline the differences between qualitative and quantitative forecasting methods.
- Perform forecast calculations such as simple moving averages, weighted moving averages, and exponential smoothing.
- Use associative/causal methods of forecasting for operational decision-making.
- Calculate forecasts using time series analysis and seasonal index.
- Calculate Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) to assess forecast accuracy.

3.1 GOING WITH THE FLOW FOR BUSINESS SUCCESS

In the previous chapter, we learned about the players in multiple layers of the modern business environment and identified customers, competitors, suppliers, and government as the four key players. These and many other players can be influenced by the economic, technological, and social forces, which can change the climate in the marketplace.

For a profit-seeking firm, the most prominent player is the customer. However, with climate change, the marketplace's requirements dynamically change, and customers become heterogeneous in what they want and ambiguous in the sense that sometimes they need to learn what they want and why. The inevitable result is a market that might be different in the future than it is now. To remain competitive, a business firm should adapt to these changes, go with the flow, and foresee how things might change. To do so, business firms use forecasting. The following video explains what forecasting is in simple terms.

Video: "What is Forecasting?" by Marketing Business Network [2:13] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

The following video explains forecasting and why and how it is done.

Video: "What is Forecasting? | Process & Benefits of Forecasting" by Educationleaves [5:04] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

3.2 THE ROLE OF FORECASTING IN MARKETING STRATEGY

This chapter delves into forecasting, a crucial component of marketing strategy implementation. **Forecasting** is the process of predicting future events or trends by analyzing historical and contemporary data. It is most commonly achieved through trend analysis, aiming to estimate a variable of interest at a specified future time. While similar, prediction is a broader term encompassing various methodologies.

Within marketing, forecasting practices encompass formal statistical methods employing time series, cross-sectional, or longitudinal data. Additionally, less formal judgmental methods may be used. It's noteworthy that the terminology can differ across disciplines. For instance, "forecast" is reserved for specific future time point estimations in hydrology. At the same time, "prediction" refers to more general conjectures, such as the number of times floods will occur over a long period.

Uncertainty and Risk in Forecasting

Uncertainty and risk are inherent aspects of forecasting and prediction. Best practices dictate that the extent of uncertainty associated with a specific forecast should be explicitly communicated. Data accuracy is paramount for generating reliable forecasts. In some instances, the data employed for predicting the variable of interest is itself a forecast ("Forecasting", 2020).

Sales Forecasting and Strategic Alignment

Marketing strategies must be aligned with the overarching corporate strategy. Sales forecasting, which entails estimating a company's future sales volume, plays a vital role in this strategic synchronization. When implementing a marketing strategy, the entire organization must be prepared to address its ramifications. A critical aspect of this execution is the sales forecast. This Forecast is a benchmark for production, inventory management, and resource allocation across the organization.

The Consequences of Inaccurate Forecasts

Accuracy is paramount in sales forecasting. Overestimation of product demand can lead to excessive expenditures on manufacturing, distribution, and customer service activities that ultimately go unused.

Conversely, underestimating demand can be equally detrimental. When a new product is launched, marketing and sales initiatives are implemented to generate demand. However, if the company is unable to fulfill the market's requirements, competitors can capitalize by capturing those sales.

A company needs to conduct accurate demand forecasting to maintain its competitive position in the market. The following video explains demand forecasting and how it should be done.

Video: "What is Sales forecasting?" by Educationleaves [8:34] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Elements of a Sales Forecast

A sales forecast encompasses more than just the company's anticipated sales figures. The process is multifaceted, as the company's sales potential depends on various factors such as pricing strategy and competitor actions. Each of these variables needs to be factored into the sales forecast to determine a realistic sales projection. As these elements change, the Forecast must be revised to maintain accuracy. Consequently, a sales forecast is a dynamic composite of numerous constantly evolving estimates.

Market Potential and Sales Potential

A typical initial step involves determining market potential, which refers to the total projected industry-wide sales for a particular product category within a given timeframe. Market research firms like Nielsen and Gartner estimate market potential for various products and offer this data to companies within those industries.

Once market potential is established, the company's sales potential can be estimated. This represents the maximum anticipated revenue or unit sales achievable for the product. Sales potential is typically expressed as a percentage of the market potential, reflecting the company's projected maximum market share for the designated timeframe. By incorporating sales forecasts into budgets, companies can effectively compare projected revenue against market potential and product costs.

3.3 FORECASTING HORIZONS AND THEIR APPLICATIONS

The selection of an appropriate forecasting horizon is crucial for effective decision-making within an organization. Forecasting horizons can be broadly categorized into three distinct temporal scopes: long-term, medium-term, and short-term.

Long-Term Forecasting (LT)

Long-term forecasting, typically encompassing a timeframe exceeding two years, is often undertaken at the strategic level of an organization. Due to the inherent high degree of uncertainty associated with such extended timeframes, this approach necessitates a deep understanding of the target products and markets. Long-term forecasts are particularly relevant for strategic decisions concerning new product launches, implementing emerging technologies, and establishing new facilities. Notably, the absence of historical data often presents a significant challenge in long-term forecasting, requiring a greater reliance on expert judgment and scenario planning techniques.

Medium-Term Forecasting (MT)

Medium-term forecasting, also referred to as intermediate-term forecasting, typically spans from several months to two years into the future. This timeframe allows for the utilization of both quantitative and qualitative forecasting methodologies. Medium-term forecasts are instrumental in tactical decision-making, informing strategic initiatives and operational planning.

Short-Term Forecasting (ST)

Short-term forecasting focuses on a timeframe ranging from daily to a few months. These forecasts are primarily employed for operational decision-making processes, such as inventory management, production scheduling, and workforce allocation. Quantitative methods, particularly time series analysis, are prominently used in short-term forecasting due to their effectiveness in analyzing and extrapolating from historical data.

3.4 TYPES OF FORECASTS

Organizations typically use three major types of forecasts for planning their future operations:

1. **Economic forecasts**. Economic forecasts address the overall business cycle and predict economic indicators such as housing starts, inflation rates, money supply, and others. These forecasts help organizations anticipate and plan for broader economic conditions impacting their operations.
2. **Technological forecasts**. Technological forecasts monitor the rates of technological progress and trends. These forecasts enable organizations to stay abreast of emerging technologies that could lead to new products, processes, or services. Anticipating technological advancements allows companies to plan for potential new facilities, equipment, or infrastructure needed to capitalize on those technologies.
3. **Demand forecasts** (or sales forecasts). Demand forecasts, also known as sales forecasts, estimate consumers' future demand for a company's products or services. These forecasts drive critical operational planning decisions such as production scheduling, capacity planning, inventory management, financial planning, workforce planning, and marketing strategies (The Art and Science of Forecasting in Operations Management, n.d.).

The sources emphasize that demand/sales forecasts are particularly crucial for operations managers, as they inform decisions related to resource allocation, capacity utilization, supply chain management, and overall operational efficiency to meet the anticipated demand effectively.

While the time horizons may vary (short-term, medium-term, or long-term), these three types of forecasts provide organizations with insights into economic conditions, technological landscapes, and customer demand, enabling them to plan and align their operations accordingly and proactively.

3.5 CATEGORIES OF FORECASTING METHODS

Qualitative Forecasting

Qualitative forecasting techniques, unlike their quantitative counterparts, rely on subjective judgments and opinions rather than historical data. These methods are particularly valuable when historical data is scarce or inapplicable, such as in situations involving new products, emerging markets, or disruptive technologies. They are typically employed for intermediate-term or long-term forecasts that inform strategic decision-making.

Several established qualitative forecasting techniques exist, each offering unique advantages.

Qualitative Forecasting Methods:

1. Executive Judgement (Top Down)
2. Sales Force Opinions (Bottom-up)
3. Delphi Method
4. Market Surveys

Executive Judgement (Top Down)

This approach leverages the expertise of high-level executives within an organization. These executives collaboratively analyze market data, identify future trends, and potentially utilize statistical models and market research to arrive at a consensus forecast.

Sales Force Opinions (Bottom-up)

The sales force, by virtue of their direct customer interaction, possesses valuable insights into customer behaviour and market trends. This approach solicits individual sales forecasts from sales personnel within their designated territories. These individual forecasts are then aggregated to form a comprehensive forecast for a district or region.

Delphi Method

Developed by the Rand Corporation, the Delphi Method provides a structured approach to gathering expert opinions. A panel of experts anonymously participates in a series of surveys, iteratively refining their forecasts based on the anonymized collective insights provided. This anonymity fosters open and unbiased consideration of all perspectives, ultimately leading to a consensus forecast.

Market Surveys

Market research firms can be employed to conduct surveys that gauge consumer sentiment toward products and future purchasing intentions. The resulting data provides valuable qualitative insights to inform forecasting models.

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 categorized 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).

Quantitative Forecasting Methods:

1. Associative Models

1. Linear Regression
2. Multiple Linear Regression

0. Time Series Models

1. Naïve
2. Simple Moving Average
3. Exponential Smoothing
4. Trend Projection Model

The quantitative forecasting methods will be explained in detail in the following section.

3.6 ASSOCIATIVE MODELS/ CAUSAL (ECONOMETRIC) FORECASTING

Associative model forecasting methods, also known as causal or econometric forecasting methods, are quantitative techniques used in operations management to predict future values of a variable by analyzing its relationship with other related variables. These methods are particularly useful when historical data is available for both the variable of interest and the potential causal factors influencing it.

Associative forecasting models, unlike time-series methods, consider multiple independent variables (causal factors) that are related to or influence the forecasted dependent variable. These models aim to establish and quantify the cause-and-effect relationships between the independent and dependent variables, enabling more accurate predictions by accounting for the impact of various factors. These factors, termed explanatory variables, can significantly improve the accuracy of forecasts. For instance, incorporating climate data into a sales forecast model for umbrellas can enhance its predictive power.

Some forecasting methods try to identify the underlying factors that might influence the variable being forecasted. 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.

Regression Analysis

Regression analysis is one of the most widely used associative forecasting methods, which involves constructing a mathematical equation that relates the dependent variable to one or more independent variables. This statistical technique estimates the relationships between variables. It encompasses a diverse set of methods for modelling and analyzing the interplay between a dependent variable (the variable being forecast) and one or more independent variables (factors believed to influence the dependent variable). Regression analysis is particularly valuable for understanding how changes in independent variables impact the average value of the dependent variable while holding all other independent variables constant.

The coefficients of the independent variables in the regression equation represent the magnitude and direction of their impact on the dependent variable.

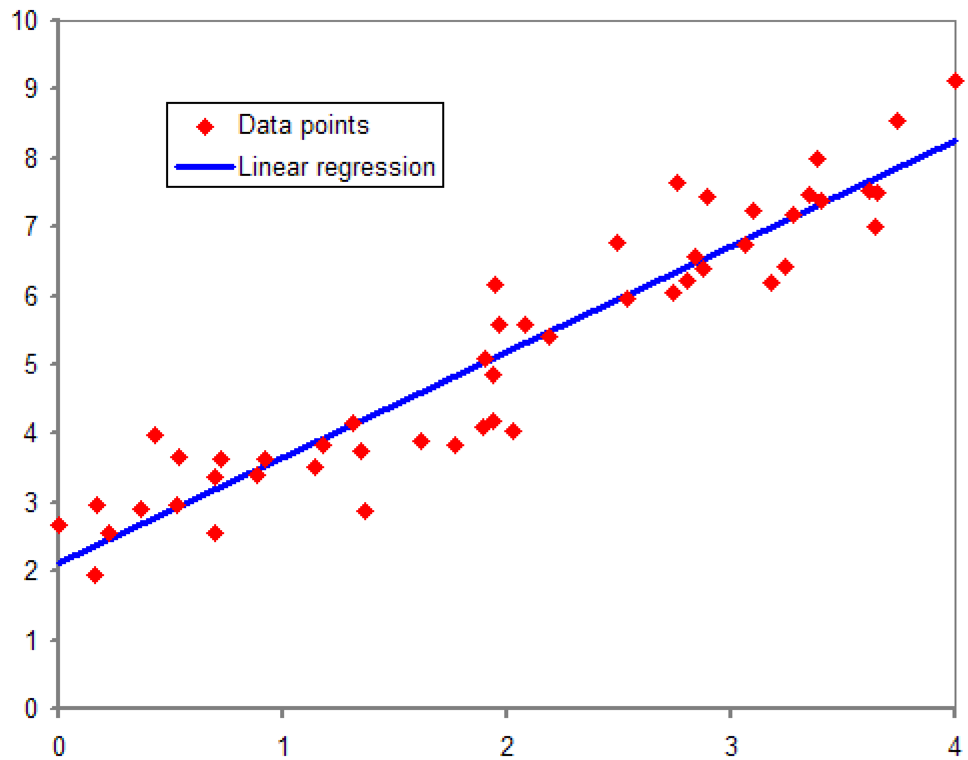


Figure 3.6.1: Example of regression analysis.

Image Description

The image is a scatter plot depicting data points and a linear regression line. The x-axis ranges from 0 to 4. The y-axis ranges from 0 to 10. The red diamonds represent the data points. The blue line represents the linear regression line, showing the best-fit line through the data points.

The data points follow an upward trend, indicating a positive correlation between the variables. The linear regression line slopes upward from left to right, suggesting a strong linear relationship. The legend in the plot identifies the red diamonds as "Data points" and the blue line as "Linear regression."

Simple Linear Regression

In its simplest form, a linear regression model with a single independent variable can be expressed as:

Y = bX + a

Where:

'Y' is the dependent variable (the variable being forecasted)

'X' is the independent variable (the causal factor)

'b' is a slope of the regression line (a measure of its steepness, i.e. the ratio of the rise to the run, or rise divided by the run)

'a' is Y-intercept (the point on the Y-axis by which the slope of the line sweeps)

Multiple Linear Regression

When there are multiple independent variables influencing the dependent variable, a multiple linear regression model can be employed:

$Y = a + b_1X_1 + b_2X_2 + \ldots + b_nX_n$

Where:

- $X_1, X_2, \ldots, X_n$ are the independent variables (causal factors)
- $b_1, b_2, \ldots, b_n$ are the regression coefficients associated with each independent variable

Correlation Analysis

Correlation analysis is often used with regression analysis to measure the strength and direction of the linear relationship between the dependent and independent variables. The correlation coefficient, denoted by *r*, ranges from -1 to 1, with values closer to 1 or -1 indicating a stronger linear relationship and values closer to 0 indicating a weaker or no linear relationship.

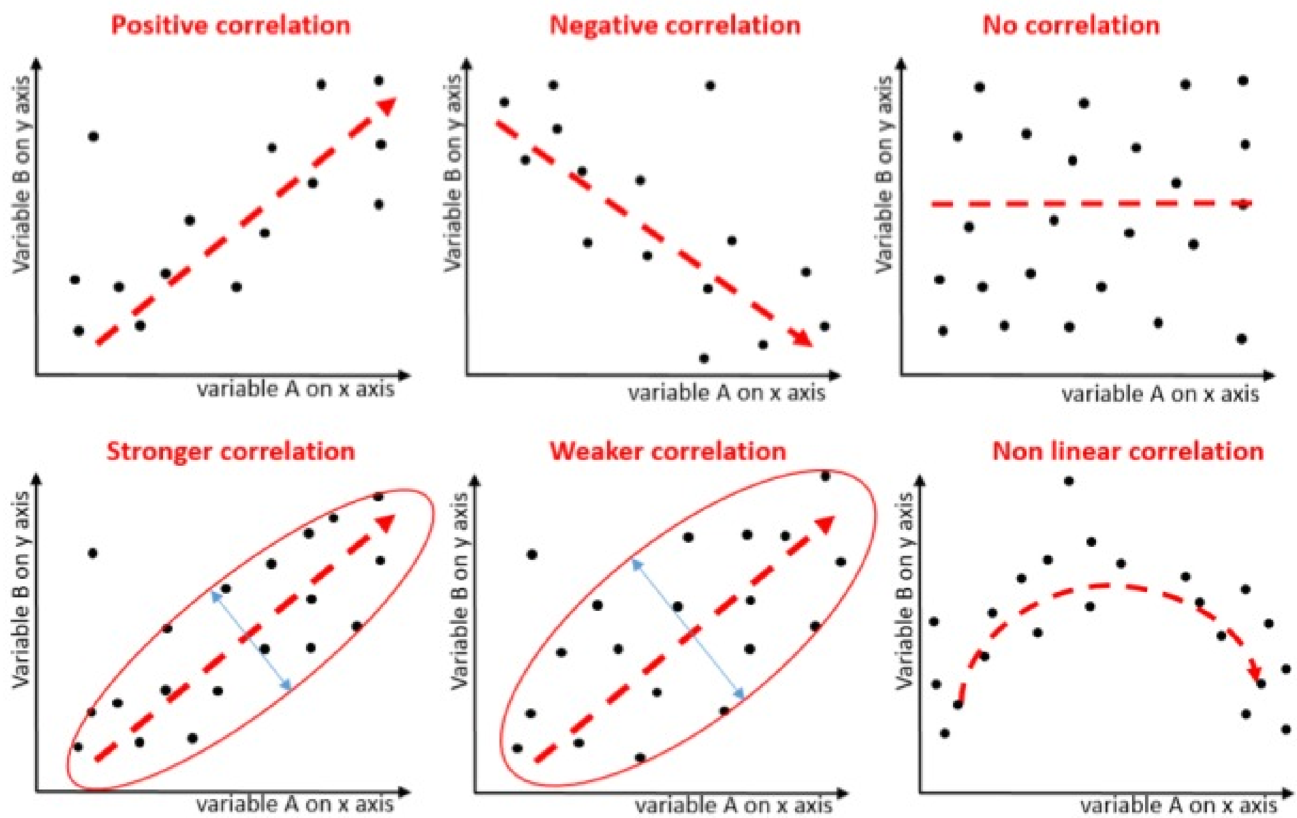


Figure 3.6.2 "Correlation based on direction, form, and dispersion strength" by Sunil Kumar, CC BY 4.0

Figure 3.6.2 consists of six scatter plot diagrams demonstrating correlations between variables A (on the x-axis) and B (on the y-axis).

- *Positive correlation*: A scatter plot with points roughly following an upward-sloping line from the bottom left to the top right. The red dashed line indicates a positive slope.
- *Negative correlation:* A scatter plot with points roughly following a downward-sloping line from the top left to the bottom right. The red dashed line indicates a negative slope.
- *No correlation:* A scatter plot with points scattered randomly with no discernible pattern. The red dashed line is flat, indicating no correlation.
- *Stronger correlation:* A scatter plot where points are tightly clustered around a red dashed upward-sloping line. The points are enclosed within a narrow ellipse.
- *Weaker correlation:* A scatter plot where points are more loosely clustered around a red dashed upward-sloping line. The points are enclosed within a wider ellipse.
- *Non-linear correlation:* A scatter plot where points follow a curved pattern, suggesting a quadratic relationship. The red dashed line forms an upward arch, indicating a non-linear correlation.

Applications in Operations Management

Associative forecasting methods are widely used in operations management for various purposes, including:

1. *Demand forecasting*: Predicting future demand for products or services by considering advertising expenditure, competitor pricing, economic indicators, and demographic variables.
2. *Capacity planning*: Estimating the required production capacity by analyzing the relationships between demand, production rates, and other operational factors.
3. *Inventory management*: Forecasting inventory levels by considering factors such as demand patterns, lead times, and supply chain dynamics.
4. *Resource allocation*: Optimizing the allocation of resources (e.g., workforce, materials, equipment) based on forecasted demand and operational constraints.
5. *Supply chain management*: Predicting supply chain performance metrics (e.g., lead times, costs, service levels) by considering factors such as supplier performance, transportation modes, and logistics networks.

(Frenzel, 2023).

Associative forecasting methods provide a powerful tool for operations managers to make informed decisions by accounting for the complex relationships between various factors and the variables of interest. However, it is crucial to ensure the validity of the underlying assumptions, the quality of the data, and the appropriate selection and evaluation of the forecasting models.

Common Forecasting Assumptions

1. Forecasts are rarely, if ever, perfect. It is nearly impossible to estimate 100% accurately what the future will hold. Firms need to understand and expect some errors 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.

3.7 TIME SERIES MODELS

Time series data plays a fundamental role in forecasting. A time series collects data points meticulously ordered along a time axis. These data points can be recorded at consistent or irregular intervals. Examples of time series data include ocean tide heights, sunspot counts, and daily closing values of stock market indices. Line charts are a prevalent method for visualizing time series data.

Excel offers a forecast function that can be used for forecasting. The following video shows how it is done.

Video: "The Excel FORECAST Function" by Technology for Teachers and Students [5:31] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

The application of time series analysis extends across numerous disciplines, including statistics, signal processing, pattern recognition, econometrics, mathematical finance, weather forecasting, earthquake prediction, and various domains of applied science and engineering that involve temporal measurements. By leveraging time series data, these fields can uncover hidden patterns, trends, and seasonality within the data, enabling the formulation of data-driven forecasts for future outcomes (Singla, 2018).

Selecting the Appropriate Time Interval for Data Collection

A critical aspect of forecasting accuracy lies in determining the optimal time interval for data collection. The chosen interval directly impacts the level of data fluctuation observed. This fluctuation can manifest as trends, seasonal patterns, cyclical variations, or random noise. Understanding the specific fluctuation behaviour of the data is instrumental in selecting the most suitable forecasting technique.

It's important to remember that time intervals are inherently relative. Terms like "short-term," "medium-term," and "long-term" are context-dependent. Table 3.7.1 overviews various forecasting techniques, categorized based on their typical time horizons. Generally, short-term forecasts involve data collected over less than three months, while medium-term forecasts encompass three months to 2 years. Long-term forecasts, however, deal with data collected over a timeframe exceeding two years.

Table 3.7.1 Selecting the Appropriate Time Interval for Data Collection (Singla, 2018)

Time Period	Data Pattern	Forecasting Technique
Short term: less than 3 months	Data does not show any particular pattern or variation	• Simple Moving Average, • Weighted moving average and • Exponential Smoothing
Medium-term: 3 months to two years	Data either repeats periodically or moves in a particular direction, i.e. upward or downward.	• Seasonal and Trend Variation
Long-term: more than 2 years	Data shows a repeated pattern but at irregular intervals with irregular intensity.	• Cyclical method

Time Period Selection and Forecast Accuracy

The chosen time period for data collection plays a crucial role in forecast accuracy. While a longer timeframe may intuitively suggest more reliable results, older data may lose relevance in the present context. Conversely, relying solely on recent data might not provide a sufficient historical foundation for generating dependable forecasts. This highlights the importance of striking a balance between the time period selected and the availability of relevant data within that timeframe. Ultimately, the optimal time horizon depends on the specific forecasting problem and the nature of the data itself.

Trend Analysis

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

- *Trend* – This component represents a consistent upward or downward movement in the data over time. The product life cycle often plays a role in shaping this trend. A new product might exhibit a rising sales trend, while a mature product might show a declining trend.
- *Cyclical* – Cyclical patterns are characterized by recurring fluctuations in the data that typically span more than a year. These cycles can be linked to factors like interest rates, political climates, consumer confidence, or broader market dynamics.
- *Seasonal* – Many products exhibit seasonal patterns, featuring predictable changes in demand that recur annually. Fashion apparel and sporting goods are prime examples of products significantly impacted by

seasonality. Demand for winter coats surges during the cold season, while swimwear sales peak during summer.

- *Irregular variations* – Unforeseen events or series of events can influence demand in unpredictable ways. These irregular variations, often referred to as outliers, are not expected to be repeated in the future. Examples include extreme weather events, labour strikes, or power outages. These events can cause sudden spikes or dips in demand data.
- *Random variations* – Random variations, also referred to as noise, represent the unexplained fluctuations in demand that persist even after accounting for all other identifiable components. These variations are inherent in any time series data and cannot be attributed to any specific cause.

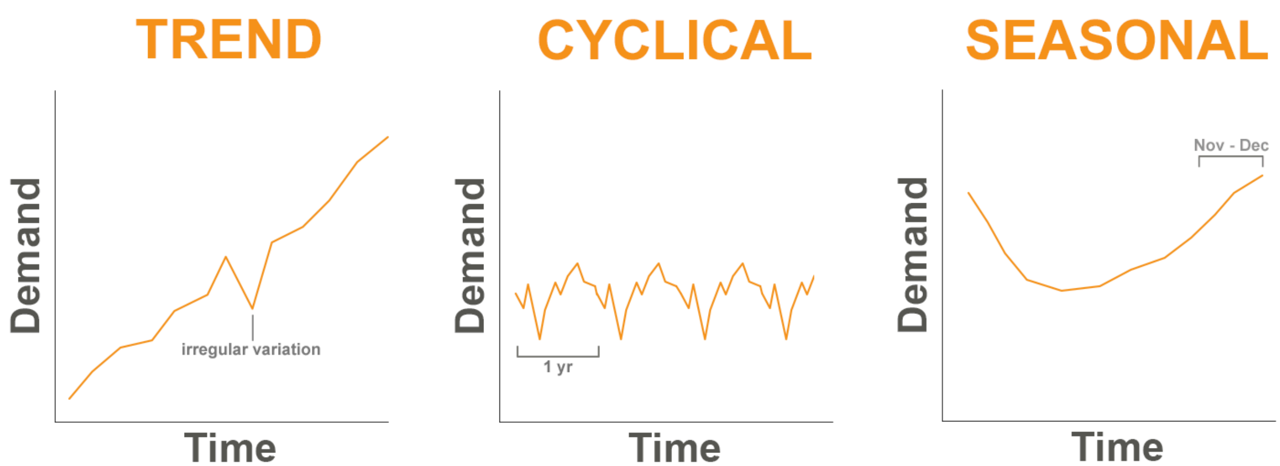


Figure 3.7.1: Diagram of trend, cyclical, and seasonal demand patterns.

Naïve Method

The **naive approach**, also known as naive forecasting or naïve method, is one of the simplest forecasting techniques used in operations management. It involves using the actual value from the previous period as the forecast for the next period without considering any other factors or patterns in the data.

The naive approach is based on the assumption that the future value of a variable will be the same as its most recent observed value. Its characteristics include simplicity, no trend or seasonality consideration, and limited data requirements. (What do you need to know about naïve forecasting?, 2024)

Advantages	Disadvantages
Easy to implement	Ignores patterns and trends
It can serve as a baseline or benchmark for comparison	Unsuitable for new products/services
Suitable for stable demand	Reactive rather than proactive

Simple Moving Average

The **simple moving average method** is fundamental for forecasting future values based on historical data. It operates by calculating the average of the data points from the most recent n periods. The selection of the appropriate value for n is crucial and can be influenced by various factors, such as the underlying data characteristics and the desired forecast accuracy. For instance, a manager might leverage demand data from the past four periods (n = 4) to generate a 4-period moving average forecast for the upcoming period.

This method is advantageous due to its simplicity and ease of computation. However, it also has limitations. By assigning equal weight to all data points within the window, it may not adequately capture recent trends or sudden shifts in the data. More sophisticated moving average methods address this limitation by incorporating weights that prioritize the most recent data points, placing greater emphasis on their influence on the forecast.

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

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 × D4 + 0.3 × D3 + 0.2 × D2) = (0.5 × 40 + 0.3 × 34 + 0.2 × 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.

Exponential Smoothing

The **exponential smoothing method** integrates the most recent actual demand and the previous forecast to generate the forecast for the upcoming period. This approach offers several advantages. Firstly, it often yields more accurate forecasts. Secondly, it is a straightforward method that enables forecasts to adapt to new trends or changes in demand patterns swiftly. A notable benefit of exponential smoothing is that it does not necessitate a large volume of historical data.

Exponential smoothing employs a smoothing coefficient, denoted as Alpha (α). The value of Alpha determines the rate at which the forecast responds to fluctuations in demand. Consequently, Alpha is also referred to as the Smoothing Factor. A higher value of Alpha implies that the forecast will react more rapidly to changes in demand, while a lower value will result in a more gradual response, effectively smoothing out the fluctuations.

In essence, the exponential smoothing method balances the most recent demand observation and the previous forecast, with the smoothing coefficient Alpha governing the relative weights assigned to each component. This approach enables the forecast to adapt to evolving demand patterns while mitigating the impact of random fluctuations, thereby enhancing forecast accuracy and responsiveness.

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

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 forecasts for any of the past periods, we would 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 the 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 four first. However, a similar issue exists for period four 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 assumptions 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 two 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 3.7.2: Solution for Exponential Smoothing Version 1

Accessible format for Figure 3.7.2

Version #2:

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

Example

Assume you are given an alpha of 0.3

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 3.7.3: Solution for Exponential Smoothing Version 2

Accessible format for Figure 3.7.3

Seasonal Index

A **seasonal index** is a statistical tool used in forecasting to quantify and account for recurring seasonal patterns or demand fluctuations over a specific period.

It helps to identify and measure the impact of seasonal factors (e.g. holidays, weather, etc.) on demand for a product or service so that the organizations adjust forecasts to account for predictable seasonal variations.

The seasonal index is calculated by comparing demand during a specific season/period to the average demand across all seasons/periods. It is typically calculated as a ratio or percentage, with an index value above one indicating higher than average demand and below 1 indicating lower demand.

Historical demand data is deseasonalized by dividing it by the respective seasonal index to remove seasonal effects. Forecasting methods like moving averages or exponential smoothing are applied to the deseasonalized data. The resulting forecast is then re-seasonalized by multiplying it with the appropriate seasonal indexes.

Seasonal indexing is useful for products/services with recurring seasonal demand patterns like holidays, back-to-school, weather changes, etc. It helps to plan inventory levels, staffing, promotions, and other operations aligned with expected seasonal fluctuations (Singla, 2018).

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's annual demand will be 2500 units.

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

3.8 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).

Mean Absolute Deviation (MAD)

The **Mean Absolute Deviation (MAD)** measures the average magnitude of the forecast errors without considering their direction (positive or negative). It is calculated as the arithmetic mean of the absolute differences between the forecasted and actual values:

$$MAD = \frac{\sum |\text{Actual Value} - \text{Forecasted Value}|}{n}$$

Where n is the number of observations.

MAD is expressed in the same units as the data, making it easy to interpret and understand. A lower MAD value indicates better forecast accuracy.

To obtain the MAD of the given data, the following steps should be followed:

Step 1: Calculate forecast errors, i.e. find the difference between forecast and actual data.

Step 2: Take an absolute of forecast error, i.e. consider the positive of even those negative forecast error values.

Step 3: Find the average of these absolute values. (Singla, 2018)

Mean Square of Errors (MSE)

The **Mean Squared Error (MSE)** is a measure that squares the forecast errors before averaging them. This squaring process gives more weight to larger errors, making MSE more sensitive to outliers compared to MAD:

$$MSE = \frac{\sum (\text{Actual Value} - \text{Forecasted Value})^2}{n}$$

MSE is expressed in squared units of the data, which can make interpretation more difficult. However, it is a statistically valuable measure as it is used in many advanced forecasting models and optimization techniques.

To obtain the MSE of given data, the following steps should be followed:

Step 1: Calculate forecast errors, i.e. find the difference between forecast and actual data.

Step 2: Take a square of each forecast error value.

Step 3: Find the average of these squared values. (Singla, 2018)

Mean Absolute Percent Error (MAPE)

The **Mean Absolute Percentage Error (MAPE)** is a relative measure that expresses the forecast errors as a percentage of the actual values. It is particularly useful when working with data from different scales or units:

$$MAPE = \frac{\frac{\sum |\text{Actual Value} - \text{Forecasted Value}|}{\text{Actual Value}} \times 100\%}{n}$$

MAPE is expressed as a percentage, making it easy to interpret and compare across different data sets. However, it can be problematic when dealing with actual values close to zero, resulting in extremely high or undefined MAPE values.

To obtain MAPE of given data, the following steps should be followed:

Step 1: Calculate forecast errors, i.e. find the difference between forecast and actual data.

Step 2: Take an absolute of forecast error, i.e. consider the positive of even those negative forecast error values.

Step 3: Divide each absolute value by actual demand value and multiply it by 100 to get data in percentage terms.

Step 4: Find the average of these calculated percentage values. (Singla, 2018)

The computation of methods of forecast error has been illustrated in the following 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] × 100%
1	63	68				
2	59	65				
3	54	61				
4	65	59				

Here are the steps:

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] × 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%

3.9 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 × .5 + 319 × .3 + 357 × .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 × .6 + 158 × .3 + 162 × .1 = **146.4**	130 + .3 × (138 – 130) = **132.4**
5	182	(138 + 190) ÷ 2 = **164**	190 × .6 + 138 × .3 + 158 × .1 = **171.2**	132.4 + .3 × (190 – 132.4) = **149.7**
6	177	(190 + 182) ÷ 2 = **186**	182 × .6 + 190 × .3 + 138 x .1 = **180**	149.7 + .3 × (182 – 149.7) = **159.4**
7		(182 + 177) ÷ 2 = **179.5**	177 × .6 + 182 × .3 + 190 × .1 = **179.8**	159.4 + .3 × (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 × (348 – 360) = **355.2**
2017	311	355.2 + .4 × (372 – 355.2) = **361.9**
2018	371	361.9 + .4 × (311 – 361.9) = **341.6**
2019	365	341.6 + .4 × (371 – 341.6) = **353.3**
2020		353.3 + .4 × (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	IerrorI	Forecast #2	IerrorI
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**

3.10 CHAPTER SUMMARY & REVIEW

Summary

The chapter focuses on the essential role of forecasting in business, especially in marketing strategy implementation. Forecasting involves predicting future trends based on historical and current data, employing both formal statistical methods and less formal judgmental approaches. It helps businesses anticipate market changes and adapt accordingly. The chapter emphasizes the importance of accurate forecasting in aligning marketing strategies with corporate goals, particularly through sales forecasting, which guides production, inventory management, and resource allocation. It also discusses the critical nature of accurate forecasts to avoid overestimation or underestimation of product demand, both of which can have significant financial repercussions.

Furthermore, the chapter explores different types of forecasts—economic, technological, and demand—and their applications in operations management. It explains various forecasting horizons (long-term, medium-term, and short-term) and their respective uses. The chapter also delves into qualitative and quantitative forecasting methods, highlighting techniques such as executive judgment, market surveys, regression analysis, and time series analysis. Each method has its unique advantages and is selected based on the availability of data and the specific forecasting requirements. Additionally, it addresses common forecasting assumptions and the importance of selecting appropriate time intervals for data collection to enhance forecast accuracy.

OpenAI. (2024, June 7). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than two paragraphs. Reviewed by authors.*

Review Questions

1. What is the importance of forecasting in maintaining a competitive position for a profit-seeking firm, especially in a dynamically changing market environment?
2. Describe the role of forecasting in aligning marketing strategies with corporate strategies. Why is sales forecasting particularly crucial in this alignment?
3. Explain the three main types of forecasts (economic, technological, and demand) discussed in the chapter. How do these forecasts contribute to operational planning within an organization?
4. Discuss the differences between qualitative and quantitative forecasting methods. Provide examples of when each type would be most appropriately used.
5. What are the main challenges associated with long-term forecasting, and how do businesses typically address these challenges?
6. How does the concept of 'market potential' differ from 'sales potential,' and why is it important for companies to understand both when creating sales forecasts?
7. What is the impact of inaccurate sales forecasts on a company's operations and financial performance? Provide examples of both overestimation and underestimation scenarios.
8. Define and compare the three forecasting horizons: short-term, medium-term, and long-term. Give an example of a business decision that would be influenced by each horizon.
9. Discuss the role of regression analysis in associative forecasting methods. How does it help in understanding the relationships between different variables?
10. Explain the significance of forecast accuracy measures such as Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). Why is it important to use these measures in evaluating forecasting models?

OpenAI. (2024, June 7). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

3.11 KEY TERMS

Key Terms

- **Associative Model Forecasting Methods**, also known as causal or econometric forecasting methods, are quantitative techniques used in operations management to predict future values of a variable by analyzing its relationship with other related variables.
- **Correlation analysis** is often used with regression analysis to measure the strength and direction of the linear relationship between the dependent and independent variables.
- **Demand forecasts**, also known as sales forecasts, estimate consumers' future demand for a company's products or services.
- **Economic forecasts** address the overall business cycle and predict economic indicators such as housing starts, inflation rates, money supply, and others.
- **Exponential Smoothing Method** integrates the most recent actual demand and the previous forecast to generate the forecast for the upcoming period.
- **Forecasting** is the process of predicting future events or trends by analyzing historical and contemporary data.
- **Long-term forecasting**, typically encompassing a timeframe exceeding two years, is often undertaken at the strategic level of an organization.
- **Mean Absolute Deviation (MAD)** measures the average magnitude of the forecast errors without considering their direction (positive or negative.
- **Mean Absolute Percentage Error (MAPE)** is a relative measure that expresses the forecast errors as a percentage of the actual values.
- **Mean Squared Error (MSE)** is a measure that squares the forecast errors before averaging them.
- **Medium-term forecasting**, also referred to as intermediate-term forecasting, typically spans from several months to two years into the future.
- **Naive Approach**, also known as naive forecasting or naïve method, is one of the simplest

forecasting techniques used in operations management. It involves using the actual value from the previous period as the forecast for the next period without considering any other factors or patterns in the data.

- **Qualitative forecasting** techniques, unlike their quantitative counterparts, rely on subjective judgments and opinions rather than historical data.
- **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.
- **Regression analysis** involves constructing a mathematical equation that relates the dependent variable to one or more independent variables.
- **Seasonal Index** is a statistical tool used in forecasting to quantify and account for recurring seasonal patterns or demand fluctuations over a specific period.
- **Short-term forecasting** focuses on a timeframe ranging from daily to a few months. These forecasts are primarily employed for operational decision-making processes, such as inventory management, production scheduling, and workforce allocation.
- **Simple Moving Average Method** is fundamental for forecasting future values based on historical data. It operates by calculating the average of the data points from the most recent n periods.
- **Technological forecasts** monitor the rates of technological progress and trends.

CHAPTER 4: STRATEGIC CAPACITY PLANNING

Chapter Overview

4.0 LEARNING OUTCOMES

Learning Objectives

At the end of this chapter, students will be able to:

- Explain the importance of strategic capacity planning and its role in aligning production capabilities with market demand.
- Analyze the broader organizational effects of capacity decisions and evaluate their strategic implications.
- Apply key capacity measures and performance indicators to assess and optimize operational performance.
- Select and justify appropriate capacity measures for different contexts to ensure accurate capacity assessment.
- Identify and analyze the determinants that influence effective capacity in an organization.
- Outline the steps in the capacity planning process and apply them to develop effective capacity strategies.
- Identify bottlenecks in sequential processes and propose strategies to mitigate their impact on overall process capacity.
- Analyze the bottleneck phenomenon and its implications for process capacity and throughput.
- Perform break-even analysis to evaluate capacity alternatives and make informed capacity decisions.
- Explain the relationship between capacity planning and economies of scale and evaluate their impact on long-term capacity decisions.

4.1 INTRODUCTION

Businesses develop strategies to increase their market share based on their competitive advantage, recognition of the forces in the business environment, how these forces have shaped the demand in the past, and how it can change in the future. In other words, they are trying to find what products and services they should produce to win more customers. Knowing what needs to be produced is the first step. The more critical question for them is whether they have what it takes to do so. Do they have the resources (capacity) they need to meet the demand in the market, and if not, what should change in their operations to make that happen?

This chapter delves into the critical role of strategic capacity planning for products and services. **Strategic capacity planning** aims to achieve an optimal balance where production capabilities align seamlessly with demand. Capacity requirements encompass diverse elements, including equipment, physical space, and skilled workforce. Failure to match production capabilities with demand can have severe repercussions, leading to escalating costs, resource constraints, and potential customer attrition. Given the enduring commitment of resources required, it is imperative to recognize that capacity planning necessitates a long-term perspective.

Strategic capacity planning is a multifaceted endeavour that demands a holistic approach, considering the intricate interplay of various factors. Effective capacity planning ensures operational efficiency and contributes to organizational competitiveness, customer satisfaction, and long-term sustainability. By proactively aligning capacity with demand, organizations can mitigate risks, optimize resource utilization, and position themselves for growth and success in dynamic market environments. Consequently, strategic capacity planning emerges as a critical function that transcends operational considerations and holds profound implications for an organization's overall strategic direction.

4.2 ORGANIZATIONAL IMPACT OF CAPACITY DECISIONS

Capacity decisions have far-reaching implications that extend beyond operational boundaries. Managers must be cognizant of the broader organizational effects of such decisions and their potential to influence various aspects of the business. Capacity strategies are not merely operational choices but strategic levers that can shape an organization's competitive position and long-term trajectory.

Among the commonly employed capacity strategies are:

1. **Leading Capacity Strategy**: This proactive approach involves increasing capacity and anticipating expected demand. By augmenting production capabilities ahead of time, organizations aim to position themselves favourably to meet future demand effectively and efficiently.
2. **Following Capacity Strategy**: In contrast, this reactive strategy only expands capacity after increased demand. Organizations adopting this approach prioritize minimizing excess capacity and associated costs, opting to scale up operations once demand patterns justify capacity expansions.
3. **Tracking Capacity Strategy**: This incremental approach involves gradually adding capacity over time to align with evolving demand patterns. Organizations employing this strategy seek to maintain a dynamic equilibrium between capacity and demand, adjusting capacity in measured increments as market conditions evolve.

Each strategy carries distinct advantages and trade-offs, influencing factors such as responsiveness to market dynamics, resource utilization, risk exposure, and competitive positioning. Consequently, capacity decisions should be carefully evaluated within the broader organizational context, considering their potential impact on financial performance, operational agility, customer satisfaction, and long-term strategic objectives.

Video: "The 3 Strategies for Capacity Planning" by ClickTime [5:14] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

4.3 KEY CAPACITY MEASURES AND PERFORMANCE INDICATORS

In capacity planning, two critical measures are invaluable tools for assessing and optimizing operational performance: design capacity and effective capacity.

Design Capacity represents the maximum theoretical output rate or capacity as envisioned by the system's design specifications. It is a benchmark for the absolute upper limit of production capabilities under ideal conditions.

Effective Capacity, on the other hand, is a more pragmatic measure that accounts for real-world constraints and allowances. It is derived by subtracting factors such as planned downtime, maintenance, and other operational inefficiencies from the design capacity. Effective capacity provides a more realistic estimate of the achievable output rate, given the practical limitations of the production environment.

These two capacity measures are the foundation for calculating two essential performance indicators: efficiency and utilization.

Efficiency is a measure of how effectively the available effective capacity is being utilized. It is calculated as:

Efficiency = (Actual Output ÷ Effective Capacity) × 100%

Utilization, conversely, quantifies the extent to which the maximum design capacity is being leveraged. It is calculated as:

Utilization = (Actual Output ÷ Design Capacity) × 100%

By monitoring and analyzing these performance indicators, organizations can gain valuable insights into their operational performance, identify areas for improvement, and make informed decisions regarding capacity optimization strategies. High efficiency and utilization rates may indicate the need for capacity expansions, while low rates could signal the presence of bottlenecks, inefficiencies, or excess capacity that requires adjustment.

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 × 3 × 8) × (230) = 38,640 units per week
2. Utilization = 25,000 ÷ 38,640 = 64.7%
   Efficiency = 25,000 ÷ 28,000 = 89.3%

The following video summarizes the above concepts in capacity planning.

Video: "Capacity Planning – Overview and Key Concepts" by LeanVlog [2:55] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

4.4 CAPACITY PLANNING: A HOLISTIC APPROACH FOR PRODUCTS AND SERVICES

Capacity refers to a system's inherent potential to produce goods or deliver services within a specified time frame. Capacity planning is a multifaceted endeavour that encompasses both long-term and short-term considerations. Long-term considerations revolve around determining the overall level of capacity required. In contrast, short-term considerations address variations in capacity needs due to seasonal, random, and irregular fluctuations in demand patterns.

Excess capacity arises when actual production falls short of an organization's achievable or optimal level. This often indicates that market demand for the product or service is lower than the firm's potential supply capabilities. Excess capacity is inefficient, leading to increased costs for manufacturers.

Capacity can be categorized into two distinct domains:

Design Capacity and Effective Capacity.

Design Capacity represents the maximum theoretical output rate or capacity as envisioned by the system's design specifications, assuming ideal conditions.

Effective Capacity, on the other hand, is a more pragmatic measure that accounts for real-world constraints and allowances, such as planned downtime, maintenance, and operational inefficiencies.

In the capacity planning process, three key inputs must be addressed:

1. *Capacity Type:* Determining the specific type of capacity required, whether it pertains to production facilities, equipment, human resources, or a combination thereof.
2. *Capacity Quantity:* Quantifying the precise amount of capacity needed to meet anticipated demand effectively and efficiently.
3. *Capacity Timing:* Establishing the optimal timing for capacity expansions or adjustments to align with evolving market conditions and demand patterns.

By carefully considering these inputs and adopting a holistic approach to capacity planning, organizations can optimize their resource allocation, enhance operational efficiency, and position themselves for long-term success in dynamic market environments.

4.5 DEFINING AND MEASURING CAPACITY

When selecting a measure of capacity, choosing a metric that does not require frequent updating is advisable. For instance, using dollar amounts as a capacity measure can be problematic, as in the case of a restaurant with a capacity of "$1 million in annual sales." Such a measure becomes less reliable over time due to price fluctuations, necessitating constant updates.

In scenarios involving multiple products, measuring capacity in terms of each product is preferable. For example, stating that a firm's capacity is to produce either 100 microwaves or 75 refrigerators provides greater clarity than simply stating a capacity of 100 or 75 units. This approach avoids ambiguity and ensures accurate capacity assessments for each product line.

An alternative method of measuring capacity is referring to the availability of inputs. This approach can be particularly useful when dealing with diverse output types, as it allows for a more holistic assessment of the resources required for production.

It is crucial to recognize that no single measure of capacity can be universally applied across all situations. The appropriate capacity measure must be tailored to the specific context and requirements at hand. Factors such as the nature of the products or services, the production processes involved, and the organization's operational complexities should guide the selection of the most suitable capacity metric.

Organizations can gain a more accurate and actionable understanding of their production capabilities by adopting a context-specific approach to capacity measurement, enabling informed decision-making and effective capacity planning strategies. The following table shows examples of output and input 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.

4.6 DETERMINANTS OF EFFECTIVE CAPACITY

Effective capacity is influenced by many factors that span various aspects of an organization's operations and external environment. These determinants play a crucial role in shaping the actual output rate and must be carefully considered in capacity planning efforts.

- *Facilities:* The size and provision for expansion are critical factors in facility design. Other facility-related considerations include locational factors, such as transportation costs, proximity to markets, labour availability, and access to energy sources. Additionally, the layout of the work area can significantly impact the efficiency and smoothness of work processes.
- *Product and Service Factors:* The more uniform the output, the greater the opportunities for standardization of methods and materials, leading to increased capacity. Conversely, product or service diversity can introduce complexities that may constrain capacity.
- *Process Factors:* While quantity capability is an essential determinant of capacity, output quality is equally important. If the quality does not meet standards, the output rate decreases due to the need for inspection and rework activities. Process improvements that enhance quality and productivity can result in increased effective capacity. Another process factor to consider is the time required for changeovers between different products or services.
- *Human Factors:* The tasks involved in certain jobs, the array of activities, and the required training, skills, and experience all affect the potential and actual output. Employee motivation, absenteeism, and labour turnover also impact the output rate.
- *Policy Factors:* Management policies can influence capacity by allowing or disallowing capacity options such as overtime, second or third shifts, or alternative work arrangements.
- *Operational Factors:* Scheduling challenges may arise when an organization has differences in equipment capabilities or job requirements. Other areas impacting 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:* Capacity changes can have ripple effects on suppliers, warehousing, transportation, and distributors. If capacity is increased, the supply chain must be able to handle the increase. Conversely, if capacity is decreased, the impact on supply chain partners must be considered.
- *External Factors:* Minimum quality, performance standards, and regulatory requirements can restrict

management's options for increasing and utilizing capacity.

By understanding and addressing these determinants, organizations can optimize their effective capacity and align their production capabilities with demand more effectively.

Examples of Capacity Factors

- **Facility Factors:** Expansion potential, strategic location
- **Product & Service Factors:** Uniformity within the product manufactured or service executed
- **Process Factors:** Reducing inspections, efficient equipment adjustments
- **Human Factors:** High employee motivation, low absenteeism, low labour turnover
- **Policy Factors:** Opportunity for overtime and/or additional shifts
- **Operational Factors:** Well-stocked inventory, minimal scheduling delays
- **Supply Chain Factors:** Adaptable distributors
- **External Factors:** Minimal interference with quality and performance standards

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.

4.7 THE CAPACITY PLANNING PROCESS: A SYSTEMATIC APPROACH

Effective capacity planning is a systematic process involving several key steps to ensure alignment between an organization's production capabilities and strategic objectives. The capacity planning process can be outlined as follows:

1 Estimate Future Capacity Requirements

2 Evaluate Existing Capacity and Identify Gaps

3 Identify Alternatives for Meeting Requirements

4 Conduct Financial Analyses of Alternatives

5 Assess Qualitative Factors for Alternatives

6 Select the Optimal Long-Term Alternative

7 Implement the Selected Alternative

8 Monitor Results and Adjust

Figure 4.7.1 : The capacity planning process

1. *Estimate Future Capacity Requirements:* The first step involves estimating future capacity needs based

on demand forecasts, market trends, and organizational growth plans. This requires a comprehensive analysis of internal and external factors that may influence capacity requirements over the planning horizon.

2. *Evaluate Existing Capacity and Identify Gaps:* In this step, organizations assess their current capacity levels, including facilities, equipment, and human resources. By comparing existing capacity with forecasted requirements, organizations can identify potential gaps or surpluses that need to be addressed.
3. *Identify Alternatives for Meeting Requirements:* Based on the identified gaps or surpluses, organizations explore various alternatives to align capacity with future needs. These alternatives may include capacity expansions, facility upgrades, process improvements, outsourcing, or capacity reductions.
4. *Conduct Financial Analyses of Alternatives:* Each identified alternative is subjected to rigorous financial analysis to evaluate its economic viability. This includes assessing capital investments, operating costs, potential revenue streams, and financial metrics such as net present value (NPV), internal rate of return (IRR), and payback period.
5. *Assess Qualitative Factors for Alternatives:* In addition to financial considerations, organizations must evaluate qualitative factors for each alternative. These may include strategic alignment, operational flexibility, risk exposure, environmental impact, and organizational culture fit.
6. *Select the Optimal Long-Term Alternative:* Based on the financial analyses and qualitative assessments, organizations select the alternative that best aligns with their long-term strategic objectives, balancing financial viability with operational and strategic considerations.
7. *Implement the Selected Alternative:* Once the optimal alternative has been chosen, organizations develop and execute a comprehensive implementation plan. This may involve acquiring resources, modifying processes, training personnel, and managing change effectively.
8. *Monitor Results and Adjust:* The capacity planning process is iterative and requires continuous monitoring and adjustment. Organizations must track the performance of the implemented solution, monitor changes in demand patterns, and make necessary adjustments to ensure ongoing alignment between capacity and requirements.

By following this systematic approach, organizations can proactively manage their capacity levels, optimize resource utilization, and position themselves for long-term success in dynamic market environments.

4.8 THE SEQUENTIAL PROCESSES AND THE BOTTLENECK

Sequential processes are characterized by a series of steps performed in a specific order, where the output of one step becomes the input for the subsequent step. A classic example of such a process is the manufacturing assembly line, where each workstation receives inputs from the preceding workstation and passes its outputs to the next workstation. In these processes, it is typically assumed that each step is performed by a dedicated staff member, as is the case in assembly line operations.

In sequential processes, achieving a balanced cycle time across all steps is crucial. In other words, there should be minimal variation in the time required for different steps to process one unit of product. For instance, if step 1, step 2, and step 3 take 3, 10, and 5 minutes, respectively, to process one unit of product, two major issues can arise during production:

1. *Inventory Accumulation:* Since step 1 is significantly faster than step 2, products that have already been processed in step 1 will accumulate before step 2, waiting for their turn to be processed. This leads to a buildup of work-in-process inventory, which can be costly due to inventory holding costs and potential quality issues.
2. *Resource Idleness:* Step 3 will consistently need to wait for step 2 for an additional 5 minutes. This is because step 3 completes its work on the current unit in 5 minutes, but step 2 requires 10 minutes to finish its task and feed the output to step 3. As a result, step 3 experiences prolonged periods of idleness, which is costly for the company. Despite paying the staff assigned to step 3 for the entire duration, their productive output is reduced due to the slow input rate from step 2.

The root cause of these issues is the presence of a bottleneck, which is the step with the longest cycle time (in this case, step 2). The bottleneck effectively constrains the overall throughput of the entire process, leading to inefficiencies such as inventory buildup and resource idleness.

It is essential to identify and address the bottleneck step to optimize sequential processes. This may involve capacity expansions, process improvements, or alternative resource allocations to balance the cycle times across all steps. Organizations can improve process flow, reduce waste, and enhance overall operational efficiency by eliminating or mitigating the bottleneck.

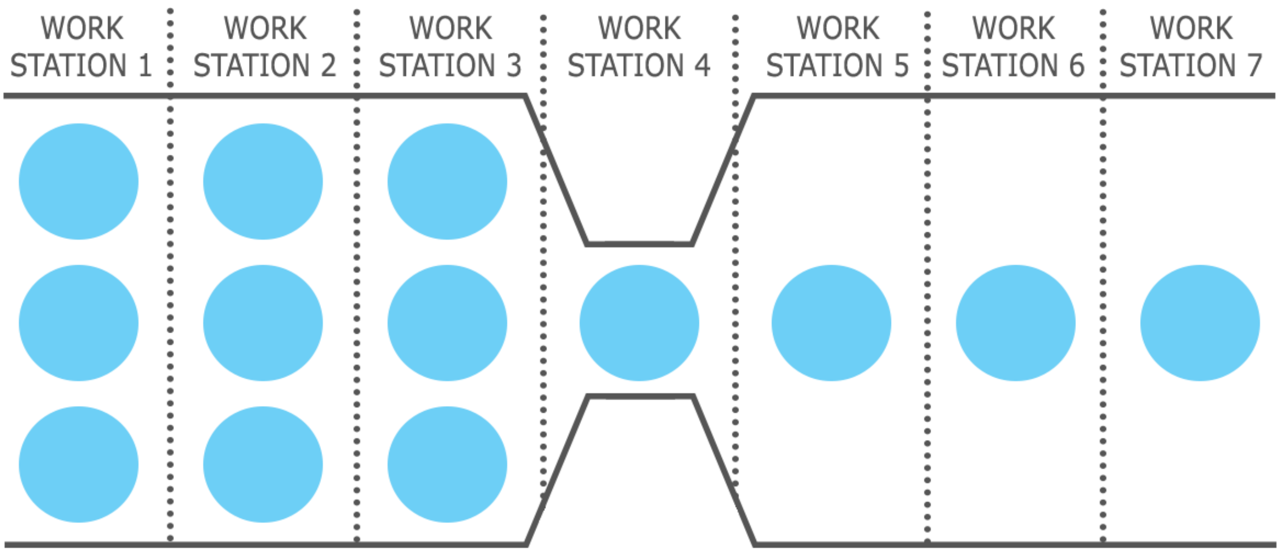


Figure 4.8.1: A diagram displaying the effects of a bottleneck.

Image Description

The image is a diagram of seven workstations arranged horizontally.

- Workstations 1 to 3 are on the left side, each containing three blue circles arranged vertically, indicating multiple tasks or items at each station.
- Workstation 4 is in the center and has a funnel-like shape, narrowing towards the middle, with one blue circle, suggesting a bottleneck or a point of convergence.
- Workstations 5 to 7 are on the right side, each containing one blue circle, indicating fewer tasks or items per station compared to Workstations 1 to 3.

The diagram visually highlights the congestion at Workstation 4, demonstrating that while the initial workstations handle multiple tasks, the central workstation significantly limits throughput before tasks continue to the final stations.

4.9 THE BOTTLENECK PHENOMENON AND ITS IMPACT ON PROCESS CAPACITY

The bottleneck is defined as the slowest step in a process or the slowest process in a system. The capacity of the bottleneck effectively determines the capacity of the entire process. In the previous example, step 2 was identified as the bottleneck due to its longer cycle time of 10 minutes. Consequently, the entire process, comprising steps 1 to 3, cannot achieve an output rate faster than one unit every 10 minutes, regardless of the capabilities of the other steps.

To illustrate this concept, consider an 8-hour shift per day, which equals 480 minutes. Assuming that step 1 has sufficient input to process during the day, its total output capacity would be 480 ÷ 3 = 160 units per day. Similarly, the capacity for step 2 is 480 ÷ 10 = 48 units, and the capacity for step 3 is 480 ÷ 5 = 96 units.

While step 1 can produce 160 units as input for step 2, the bottleneck step (step 2) can only process a maximum of 48 units per day. Consequently, only 48 units will be available as input for step 3. Despite step 3 having a capacity of 96 units per day, it will only process the 48 units received from step 2. Since step 3 is the final step in the process, its output of 48 units becomes the total output of the entire process per day.

The key observation is that the capacity of the bottleneck step (step 2) ultimately determines the capacity of the entire process. This concept holds significant practical implications. Organizations that fail to recognize and address the bottleneck may invest resources in non-bottleneck areas, resulting in no improvement in the overall process capacity.

Identifying and managing the bottleneck is crucial for optimizing process performance. Strategies such as bottleneck elimination, capacity expansion, or alternative resource allocation can be employed to alleviate the constraints imposed by the bottleneck. By addressing the bottleneck, organizations can unlock the full potential of their processes, enhance throughput, and improve overall operational efficiency.

Video: "5 production line Bottlenecks to anticipate" by Visufact Manufacturing [4:41] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

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)
4. Inspecting, packing, and labelling (5 min)

Step 1 (4 min ÷ unit) → **Step 2 (7 min ÷ unit)** → **Step 3 (10 min ÷ unit)** → **Step 4 (5 min ÷ unit)**

Figure 4.9.1 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

(Based on 7×60 = 420 min per day)

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

When evaluating capacity alternatives to select the most suitable option, organizations must consider both economic and non-economic factors. This comprehensive approach ensures that the chosen alternative aligns with financial objectives while accounting for broader organizational and societal implications.

Economic Considerations

Economic considerations revolve around assessing the financial viability and potential return on investment for each capacity alternative. The following techniques are commonly employed for economic evaluation:

1. **Break-Even Analysis:** This technique determines the point at which the total revenue from an alternative equals the total costs associated with implementing and operating that alternative. Break-even analysis provides insights into the minimum level of output or utilization required to recover the investment.
2. **Payback Period:** This method calculates the time required for the cumulative cash inflows from an alternative to equal the initial investment. It helps assess the liquidity and risk associated with each

alternative.

3. **Net Present Value (NPV):** The NPV technique discounts the future cash flows of an alternative to their present value, accounting for the time value of money. Alternatives with a positive NPV are considered financially viable, as they generate returns exceeding the required rate of return.

While this chapter focuses primarily on break-even analysis, it is essential to recognize that a comprehensive economic evaluation may involve employing multiple techniques to gain a holistic understanding of the financial implications of each capacity alternative.

Non-economic Considerations

In addition to economic factors, organizations must consider non-economic aspects that can significantly impact the success and acceptance of a capacity alternative. These non-economic considerations include:

1. **Public Opinion:** The perception and sentiment of the general public towards a particular capacity alternative can influence its viability and acceptance.
2. **Employee Reactions:** The attitudes and reactions of employees towards a capacity alternative can affect its implementation and long-term success. Employee buy-in and engagement are crucial factors to consider.
3. **Community Pressure:** Local communities may exert pressure on organizations to adopt or reject certain capacity alternatives based on their potential impact on the environment, local economy, or social fabric.

By carefully evaluating both economic and non-economic factors, organizations can make informed decisions that balance financial objectives with broader organizational and societal considerations, ultimately selecting the capacity alternative that best aligns with their strategic goals and stakeholder expectations.

4.10 BREAK-EVEN ANALYSIS: A FUNDAMENTAL TOOL FOR CAPACITY EVALUATION

Break-even analysis is a fundamental tool used to evaluate capacity alternatives by determining the point at which total revenue equals total costs. Since capacity utilization typically involves fixed costs, the objective is to identify the output quantity that generates sufficient revenue to cover both fixed and variable costs.

The break-even point (BEP) or break-even quantity (QBEP) represents the volume of output at which total revenue (TR) equals total cost (TC). At this point, the organization neither realizes a profit nor incurs a loss. Mathematically, at QBEP, the following equation holds:

$$TC = FC + VC$$

TC = total cost

FC = total fixed cost

VC = total variable cost

Fixed costs are incurred regardless of the output quantity and remain constant within the relevant range of production. Examples of fixed costs include rental expenses, property taxes, equipment costs, heating and cooling expenses, and certain administrative costs.

To calculate the break-even point, the following notation and relationships are used:

$$TC = FC + VC$$

$VC = Q \times v$ (Variable Cost = Quantity × Variable Cost per Unit)

$TR = Q \times r$ (Total Revenue = Quantity × Revenue per Unit)

$P = TR - TC = Q \times r - (FC + Q \times v)$ (Profit = Total Revenue – Total Cost)

$Q_{BEP} = FC \div (r - v)$ (Break-Even Quantity = Fixed Cost ÷ (Revenue per Unit – Variable Cost per Unit))

By rearranging the equations and substituting the appropriate values, organizations can determine the break-even quantity (QBEP) for a given capacity alternative. This quantity represents the minimum output level required to recover the fixed costs associated with that alternative.

Break-even analysis provides valuable insights into the viability of capacity alternatives by quantifying the relationship between costs, revenue, and output levels. It serves as a crucial decision-making tool, enabling organizations to assess the potential risks and returns associated with each alternative and make informed choices aligned with their financial objectives and operational capabilities.

Example

The management of a pizza place would like to add a new line of small pizza, which will require leasing 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. $Q_{BEP} = FC \div (r - v) = 4000 \div (9 - 4) = 800$ pizzas month
2. $\text{total revenue} - \text{total cost} = 1200 \times 9 - 1200 \times 4 - 4000 = \$2000$ (i.e. a profit)
3. $P = \$10000 = Q(r - v) - FC$;

Solving for Q will give us: $Q = (10000 + 4000) \div (9 - 4) = 2800$

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.

Break-Even Analysis for "Make" or "Buy" Decisions

Organizations often face the strategic decision of whether to produce a product or service in-house ("make") or outsource it to an external supplier ("buy"). Break-even analysis can provide valuable insights to guide this decision by identifying the quantity at which the total cost of making a product in-house equals the total cost of buying it from a supplier.

The key question to be addressed is: "For what quantities would buying the product be preferred to making it in-house, and vice versa?"

Let's define the following variables:

v_m = per unit variable cost of "make"
v_b = per unit variable cost of "buy"
FC = Fixed cost associated with in-house production

To determine the break-even quantity (Q), we set the total cost of "make" equal to the total cost of "buy":

Total Cost of "Make" = Total Cost of "Buy"

$$Q \times v_m + FC = Q \times v_b$$

Rearranging the equation, we get:

$$FC = Q \times (v_b - v_m)$$
$$Q = FC \div (v_b - v_m)$$

The break-even quantity (Q) represents the output level at which the total cost of making the product in-house is equal to the total cost of buying it from a supplier.

If the required quantity is greater than the break-even quantity ($Q > FC \div (v_b - v_m)$), it would be more cost-effective to make the product in-house. Conversely, if the required quantity is less than the break-even quantity ($Q < FC \div (v_b - v_m)$), it would be more economical to buy the product from a supplier.

By calculating the break-even quantity and comparing it to the anticipated demand, organizations can make informed decisions regarding the "make" or "buy" strategy that minimizes costs and maximizes profitability. This analysis considers the trade-off between the fixed costs associated with in-house production and the variable costs of outsourcing.

It is important to note that while break-even analysis provides valuable insights, it should be complemented with other factors, such as quality considerations, supply chain risks, strategic alignment, and long-term implications, to arrive at a comprehensive decision that aligns with the organization's overall objectives.

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 will it be better to make the product in-house?

Solution

1. $Q_{BEP} = FC \div (v_b - v_m) = 160,000 \div (150 - 100) = 3200$
2. $\textbf{Total cost of "make"} = 1000 \times 100 + 160,000 = \$260,000$;
   $\textbf{Total cost of "buy"} = 1000 \times 150 = \$150,000$
   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

Break-Even Analysis for Capacity Choice: Machine A vs. Machine B

When faced with multiple options for producing a product, organizations must evaluate the trade-offs between fixed and variable costs to determine the most cost-effective solution. Break-even analysis can provide valuable insights to guide this decision by identifying the output quantity at which the total cost of using one machine equals the total cost of using another.

The key question to be addressed is: "For what quantities would Machine A be preferred over Machine B, and vice versa?"

Let's define the following variables:

FC_A = Fixed cost associated with Machine A
v_A = Variable cost per unit of using Machine A
FC_B = Fixed cost associated with Machine B
v_B = Variable cost per unit of using Machine B
Q = Output quantity

To determine the break-even quantity (Q), we set the total cost of using Machine A equal to the total cost of using Machine B:

Total Cost of A = Total Cost of B

$$Q \times V_A + FC_A = Q \times V_B + FC_B$$

Rearranging the equation, we get:

$$FC_A - FC_B = Q \times (v_B - v_A)$$
$$Q = (FC_A - FC_B) \div (v_B - v_A)$$

The break-even quantity (Q) represents the output level at which the total cost of using Machine A is equal to the total cost of using Machine B.

If the required quantity is greater than the break-even quantity ($Q > (FC_A - FC_B) \div (v_B - v_A)$), it would be more cost-effective to use Machine A. Conversely, if the required quantity is less than the break-even quantity ($Q < (FC_A - FC_B) \div (v_B - v_A)$), it would be more economical to use Machine B.

It is recommended that the total cost expressions for each option be written down and simplified to ensure that no additional cost factors are overlooked. The total cost expressions can provide a comprehensive view of all cost components, including fixed costs, variable costs, and other relevant factors specific to the production process or machines under consideration.

By calculating the break-even quantity and comparing it to the anticipated demand, organizations can make informed decisions regarding the most cost-effective machine or production option, minimizing costs and maximizing profitability while aligning with their operational requirements and strategic objectives.

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. $Q_{BEP} = (FC_B – FC_A) \div (V_A – V_B) = (200,000 – 160,000) \div (150 – 100) = 40,000 \div 50 = 800$
2. $\text{Total cost of Supplier A} = 1000 \times 150 + 160,000 = \$310,000$;
   $\text{Total cost of Supplier B} = 1000 \times 100 + 200,000 = \$300,000$
   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.

4.11 CAPACITY PLANNING AND ECONOMIES OF SCALE

The Challenge of Matching Capacity to Demand

Manufacturing firms face a significant challenge in capacity planning: aligning production capacity with fluctuating demand. Unlike perfect scenarios with constant growth, demand often exhibits peaks and troughs. Capacity decisions, however, are long-term. Expanding capacity through machinery and labour acquisition is a relatively inflexible process, especially considering the substantial upfront investments involved.

Economies of Scale: Balancing Fixed and Variable Costs

The concept of economies of scale offers a valuable framework for navigating this challenge. It posits that the average unit cost decreases as the number of units produced increases. This stems from the principle of spreading fixed costs, like machinery depreciation, salaries, and rent, over a larger output volume. Imagine a fixed cost for a single machine. Producing 10 units with that machine will result in a higher average cost per unit compared to producing 100 units.

Leveraging Economies of Scale: Multi-Shift Operations

Manufacturing firms often exploit economies of scale by operating in multiple shifts. By utilizing the same resources (machinery and labour) for extended periods, they can produce more units, driving down the average fixed cost per unit. However, it's crucial to recognize the impact on variable costs, which rise with increased production. These include expenses like electricity, consumables, and temporary labour. Operating multiple shifts necessitates higher utility consumption and additional workforce, leading to an increase in variable costs.

Finding the Optimal Capacity Level

The goal is to identify the optimal capacity level that minimizes total cost (fixed + variable) while maximizing production. This sweet spot represents the point where the decrease in fixed cost per unit due to increased production is offset, but not outweighed, by the increase in variable cost.

Diseconomies of Scale: The Perils of Overexpansion

It's important to note that the cost benefits of economies of scale have limitations. Fixed cost reduction through increased output holds true only until a certain threshold. Beyond this point, additional production necessitates further investments in machinery and labour, leading to a rise in fixed costs. This phenomenon, known as Diseconomies Of Scale, results in an increase in the average unit cost. Diseconomies can arise due to complexities associated with managing a large-scale operation, including potential loss of focus, inefficiencies in resource allocation, and bureaucratic hurdles. These factors can inflate production costs and negate the initial benefits of economies of scale.

Capacity planning in a manufacturing environment requires a nuanced understanding of both economies and diseconomies of scale. By carefully considering the interplay between fixed and variable costs, firms can establish an optimal production capacity that maximizes efficiency and minimizes overall costs while remaining flexible enough to adapt to fluctuating demand.

Example: Economies and Diseconomies of Scale: LED TV Manufacturing

Imagine an LED TV manufacturer, London TV Inc. They are considering expanding their production capacity to meet rising demand. Let's analyze how economies and diseconomies of scale might influence their decision.

Economies of Scale:

- Scenario 1: Single Shift (Low Production Volume): London TV Inc. currently operates in a single shift, producing 1,000 LED TVs per day. Fixed costs (factory rent, machinery depreciation) are spread over a smaller output, resulting in a higher average fixed cost per unit (AFCU). Variable costs (raw materials, direct labour) are also lower due to the limited production volume.
- Scenario 2: Double Shift (Increased Production Volume): London TV Inc. decides to implement a double shift, effectively doubling their production to 2,000 LED TVs per day. The fixed costs remain relatively constant but are now spread over a larger output. This leads to a significant decrease in AFCU. Variable costs will increase due to additional labour and utility consumption, but likely at a lower rate compared to the fixed cost reduction. The overall

average cost per unit (ACU) decreases due to economies of scale.

Diseconomies of Scale:

- Scenario 3: Triple Shift (Excessive Production Volume): Enticed by continued demand growth, London TV Inc. pushes for a triple shift, aiming for 3,000 LED TVs daily. While AFCU continues to decrease, additional challenges arise. Managing a larger workforce and complex logistics can lead to inefficiencies. More equipment might necessitate additional factory space, increasing fixed costs. Variable costs for raw materials, labour, and utilities soar. The overall ACU might start to increase due to diseconomies of scale.

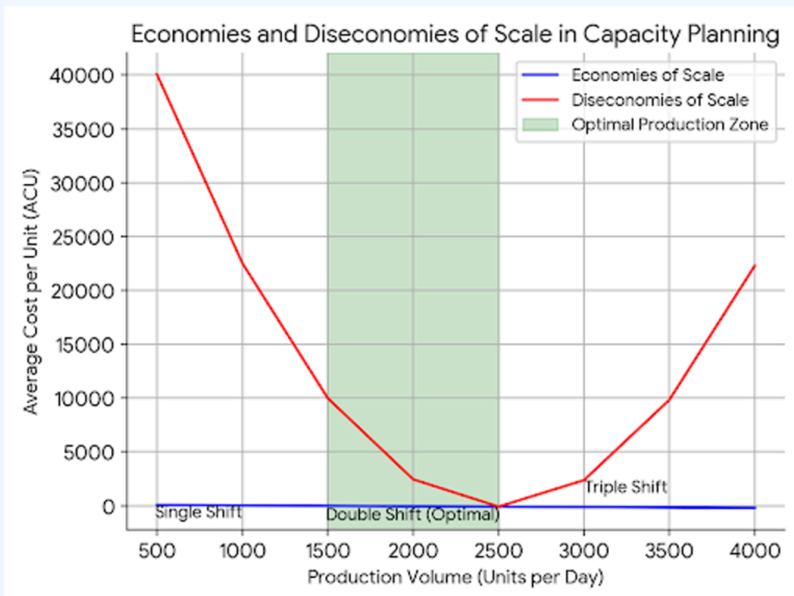


Figure 4.11.1: Economies and Diseconomies of Scale. Microsoft. (2023). *Copilot* [Large language model]. https://copilot.microsoft.com/ Prompt details provided below.

Prompt Detail

Prompt: Can you share an example with a figure for 'Economies and diseconomies of scale' in capacity planning? I need a figure with an example

mport matplotlib.pyplot as plt

import numpy as np

Define production volume

production_volume = np.arange(500, 4001, 500)

```
# Simulate average cost per unit (ACU) with economies and diseconomies of scale
acu_economies = 100 – 0.075 * production_volume # Decreasing cost due to economies of scale
acu_diseconomies = acu_economies + 0.01 * (production_volume – 2500)**2 # Increasing cost due to diseconomies
# Plot ACU vs production volume
plt.plot(production_volume, acu_economies, label=’Economies of Scale’, color=’blue’)
plt.plot(production_volume, acu_diseconomies, label=’Diseconomies of Scale’, color=’red’)
plt.xlabel(‘Production Volume (Units per Day)’)
plt.ylabel(‘Average Cost per Unit (ACU)’)
plt.title(‘Economies and Diseconomies of Scale in Capacity Planning’)
plt.legend( )
# Indicate optimal production zone
plt.axvspan(1500, 2500, alpha=0.2, color=’green’, label=’Optimal Production Zone’)
plt.legend( )
# Add annotations for key points
plt.annotate(‘Single Shift’, xy=(1000, acu_economies[1]), # Point A
arrowprops=dict(facecolor=’black’, shrink=0.05),
horizontalalignment=’right’, verticalalignment=’top’)
plt.annotate(‘Double Shift (Optimal)’, xy=(2000, acu_economies[3]), # Point B
arrowprops=dict(facecolor=’black’, shrink=0.05),
horizontalalignment=’center’, verticalalignment=’top’)
plt.annotate(‘Triple Shift’, xy=(3000, acu_diseconomies[5]), # Point C
arrowprops=dict(facecolor=’black’, shrink=0.05),
horizontalalignment=’left’, verticalalignment=’top’)
plt.grid(True)
plt.show( )
```

The optimal production level for London TV Inc. lies in the zone of economies of scale (Scenario 2), where the Average Cost per Unit curve reaches its minimum point. Beyond this point (Scenario 3), diseconomies of scale set in, causing the Average Cost Per Unit to rise.

Video: “Economies of Scale in One Minute: Definition/Theory, Explanation and Examples” by One Minute Economics [1:44] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Microsoft. (2024, June 4). *Copilot* [Large language model]. https://copilot.microsoft.com/.

4.12 CHAPTER SUMMARY & REVIEW

Summary

Chapter 4 on Strategic Capacity Planning delves into the critical importance of aligning production capabilities with market demand, emphasizing a long-term perspective for effective resource utilization. It discusses key capacity strategies—leading, following, and tracking—that organizations can adopt based on anticipated demand, and highlights the significance of choosing the right strategy to ensure responsiveness and efficiency. Additionally, the chapter introduces essential capacity measures such as design capacity (the maximum theoretical output) and effective capacity (accounting for real-world constraints), along with performance indicators like efficiency and utilization that help assess operational performance.

The chapter further explores the capacity planning process, outlining a systematic approach to estimate future capacity requirements, evaluate existing capacity, identify and analyze alternatives, and select and implement the optimal solution. This process ensures that organizations can proactively manage their capacity levels, optimize resource allocation, and enhance operational efficiency. Key steps include estimating future capacity needs, evaluating current capacity, identifying gaps, conducting financial and qualitative analyses of alternatives, and continuously monitoring and adjusting capacity plans to adapt to changing demand patterns.

Moreover, the chapter discusses the bottleneck phenomenon and its impact on process capacity, illustrating how bottlenecks constrain overall throughput and necessitate targeted interventions to balance cycle times and improve efficiency. Strategies for evaluating capacity alternatives, including break-even analysis for economic decision-making, are also covered. The chapter concludes with a discussion on economies and diseconomies of scale based on average long-term total cost, emphasizing the balance between fixed and variable costs to find the optimal capacity level while avoiding the pitfalls of overexpansion. Through these insights, organizations can align capacity with strategic objectives, ensuring long-term competitiveness and sustainability.

OpenAI. (2024, June 7). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than three paragraphs. Reviewed by authors.*

Review Questions

1. What are the three common capacity strategies organizations can adopt? Discuss the advantages and disadvantages of each.
2. How do you calculate efficiency and utilization in capacity planning? Provide examples of how these measures can be used to identify areas for improvement in an organization.
3. Identify and explain at least three factors that influence effective capacity. How can these factors impact an organization's overall production capacity?
4. Outline the key steps in the capacity planning process. Why is it important for organizations to continuously monitor and adjust their capacity plans?
5. Explain the concept of a bottleneck in a sequential process. How does a bottleneck affect overall process capacity, and what strategies can be employed to manage it?
6. Describe how break-even analysis can be used to evaluate capacity alternatives. What are the key components of the break-even point calculation?
7. Using break-even analysis, how can an organization determine whether to produce a product in-house or outsource it to a supplier? Provide a detailed example to illustrate your explanation.
8. What are economies of scale, and how do they affect capacity planning decisions? Discuss the potential pitfalls of diseconomies of scale and provide an example scenario.
9. Beyond economic factors, what non-economic considerations should organizations consider when evaluating capacity alternatives? How can these considerations impact decision-making?

10. How can organizations determine the optimal capacity level that balances fixed and variable costs while maximizing production efficiency? Discuss the challenges of matching capacity to fluctuating demand.

OpenAI. (2024, June 7). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

4.13 KEY TERMS

Key Terms

- **Leading capacity:** Where capacity is increased to meet expected demand.
- **Following capacity:** Where companies wait for demand increases before expanding capabilities.
- **Tracking capacity:** This adds incremental capacity over time to meet demand.
- **Design capacity:** Refers to the maximum designed capacity or output rate.
- **Effective capacity:** This is the design capacity minus personal and other allowances.
- **Sequential process:** Any process with several steps, one after another.
- **Bottleneck:** The slowest step in each process or the slowest process in a system.
- **Economic considerations:** Consider the cost, useful life, compatibility, and revenue for each alternative.
- **Non-economic considerations:** Include public opinion, employee reactions, and community pressure.

CHAPTER 5: FACILITY LOCATION

Chapter Overview

5.0 LEARNING OUTCOMES

Learning Objectives

At the end of this chapter, students will be able to:

- Explain the strategic importance of facility location decisions and their long-term implications on an organization's profitability and competitiveness.
- Analyze the key factors influencing facility location decisions, including proximity to raw materials, labour considerations, transportation infrastructure, utility costs, tax incentives, customer proximity, and community factors.
- Differentiate the location decision factors for manufacturing and service organizations, recognizing each industry's unique priorities and considerations.
- Apply quantitative methods, such as the Location Factor Rating (Weighted Scoring Model) and the Centre of Gravity method, to evaluate and compare potential facility locations based on specific operational requirements and strategic objectives.
- Assess the impact of e-commerce and web-based retail industries on facility location decisions, particularly for service-oriented companies.
- Develop a comprehensive facility location strategy that aligns with the organization's objectives, optimizes operational efficiency, minimizes costs, and enhances responsiveness to customer demands.

5.1 LOCATION STRATEGY: A CRITICAL DECISION

Although operations managers may not be directly involved in selecting a new site, determining the geographic location of operations is a crucial strategic decision every organization must make systematically across all sectors. This choice has long-term implications for profitability, as it involves substantial capital investment that accounts for a significant portion of operating costs. In the retail industry, for instance, where companies purchase or lease physical spaces, location expenses can constitute over 40% of total operating expenditures.

Factors Influencing Location Decisions

The factors influencing location decisions vary depending on whether the organization is engaged in manufacturing or service provision. Service-oriented businesses like fast-food chains, banks, ATMs, and movie theatres must be near their customer base. In contrast, manufacturers operating at the production end of the supply chain, such as those in agriculture, mining, or soap manufacturing, are less constrained by customer proximity and are instead driven by factors like access to raw materials and the availability of affordable labour.

Consequently, an organization's location decision is shaped by numerous factors, considering:

- The nature of the industry (manufacturing or service)
- The type of product or service offered

The Rise of E-Commerce and Its Impact

It is essential to consider the establishment of web-based retail industries and their tremendous growth. Services provided by companies like Amazon and numerous other players can be accessed from anywhere, at any time of the day. As a result, these companies' provision of services is much less dependent on location decisions. Numerous service companies are adopting strategies to reduce operating costs by eliminating the need for traditional brick-and-mortar facilities. Banks encourage customers to access various services through their websites; clothing can be purchased online, and other needs can be fulfilled through e-commerce platforms. However, this trend is predominantly applicable to service-oriented companies. Manufacturing organizations still need to produce goods, so making location decisions is a critical strategic consideration.

Prioritizing Location Factors for Optimal Performance

The decision of where to locate an organization's facilities is influenced by numerous factors. However, the relative importance of these factors varies depending on the specific situation and how the facility location impacts the organization's overall performance. When a company needs to establish a new manufacturing facility, for instance, several key factors come into play to determine the optimal location that minimizes operating costs while ensuring a high level of responsiveness to the market.

5.2 KEY FACTORS IN FACILITY LOCATION DECISION-MAKING

When deciding on the optimal location for a facility, organizations must carefully evaluate several critical factors that can significantly impact their operational efficiency, cost structure, and market responsiveness. The following are some of the key determinants that drive facility location decisions:

1. *Proximity to Raw Materials and Suppliers:* Organizations that process bulk raw materials often prioritize locating their facilities near the sources of supply. This strategic positioning helps minimize transportation costs associated with procuring raw materials. Examples include paper mills near forests, canneries in farming regions, and fish processing plants near harbours where fishing vessels dock.
2. *Labour:* Research indicates that labour factors are among many organizations' most influential determinants in facility location decisions. Key labour considerations include prevailing wage rates for similar jobs in the area, the availability of a qualified workforce, the average education level of the local population, the degree of union activity, and the community's general work ethic and productivity. Other factors, such as absenteeism rates and employee retention, can significantly impact an organization's location strategy.
3. *Transportation Infrastructure:* Efficient transportation networks, including roads, railways, and ports, are essential for the timely and cost-effective distribution of finished goods to the target market.
4. *Utility and Energy Costs:* The cost and reliability of utilities, such as electricity, water, and natural gas, can significantly impact the overall operating expenses of a manufacturing facility.
5. *Tax Incentives and Regulations:* Local and regional tax incentives and regulatory environments can influence a particular location's financial viability and operational feasibility.
6. *Proximity to Customer Market:* For certain industries, being close to end customers is crucial. Service firms like grocery stores, gas stations, fast-food restaurants, and hospitals

must be conveniently accessible to their target markets. Additionally, products with high transportation costs or perishable nature may necessitate locating production facilities near the final consumer markets to reduce logistics expenses and maintain product quality. Examples include concrete manufacturing plants and bakeries.

7. *Community Factors:* Local communities can play a significant role in attracting businesses by offering incentives such as tax waivers or reductions, access to infrastructure (roads, water, sewer, and utilities), and other enticements. Furthermore, community attitudes towards specific industries can influence location decisions. While some communities may discourage firms associated with potential environmental or social impacts, others may actively welcome them for the economic benefits they bring, including job creation, tax revenue, and economic diversification.

By carefully evaluating and prioritizing these factors based on the specific manufacturing requirements and market conditions, organizations can make informed location decisions that balance cost efficiency and market responsiveness, ultimately enhancing their overall performance and competitiveness.

Video: "Plant location, Factors affecting Plant Location [Animated video]" by Educationleaves [5:33] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

5.3 METHODS FOR FINDING THE BEST FACILITY LOCATION

Location Factor Rating Method

One effective method for assisting in the selection of the optimal facility location is the Location Factor Rating, also known as the Weighted Scoring Model. This approach involves the following steps:

1. *Identify Key Location Factors:* Determine the various factors that are crucial in the facility location decision, such as proximity to suppliers, business environment, wage rates, community characteristics, proximity to customers, availability of labour pool, and accessibility to transportation hubs.
2. *Assign Weights:* Assign a weight between 0 and 1.0 to each factor, reflecting its relative importance in the decision-making process. The sum of all weights should equal 1.0.
3. *Score Potential Locations:* Evaluate each potential location site against each factor and assign a score, typically on a scale of 0 to 100, with higher scores indicating better performance for that particular factor.
4. *Calculate Weighted Scores:* For each potential location, multiply the score for each factor by its corresponding weight to obtain the weighted score for that factor.
5. *Determine the Optimal Location:* Sum the weighted scores for each potential location. The location with the highest total weighted score is considered the most attractive option based on the collective evaluation of all factors.

Example

Let's consider an example with three potential locations (Site #1, Site #2, and Site #3) and the following location factors and weights:

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

By calculating the weighted scores for each site, we obtain the following results:

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 exhibits the highest total weighted score when evaluated against Site #1 and Site #3. Therefore, based on the collective assessment of all factors, Site #2 would be considered the most attractive location for the facility.

The **Location Factor Rating Method** provides a structured and quantitative approach to facility location decisions, allowing organizations to objectively evaluate and compare potential sites based on their specific operational requirements and strategic priorities.

Centre of Gravity Method

When the primary objective is to minimize transportation costs, the **Centre of Gravity Method** can be employed to determine the optimal location for a facility that serves multiple areas or other facilities, such as a warehouse or distribution center. This method utilizes an (X-Y) coordinate system to represent the geographical map of the areas under consideration. It 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.

Visual Representation

Imagine a scenario where each blue star in the following figure represents a market area that needs to be served, and the size of the area corresponds to the demand quantity for that market. The goal is to determine the optimal location (i.e., $\bar{x}$ and $\bar{y}$) for our facility to be set up to serve all these markets while minimizing the total transportation costs.

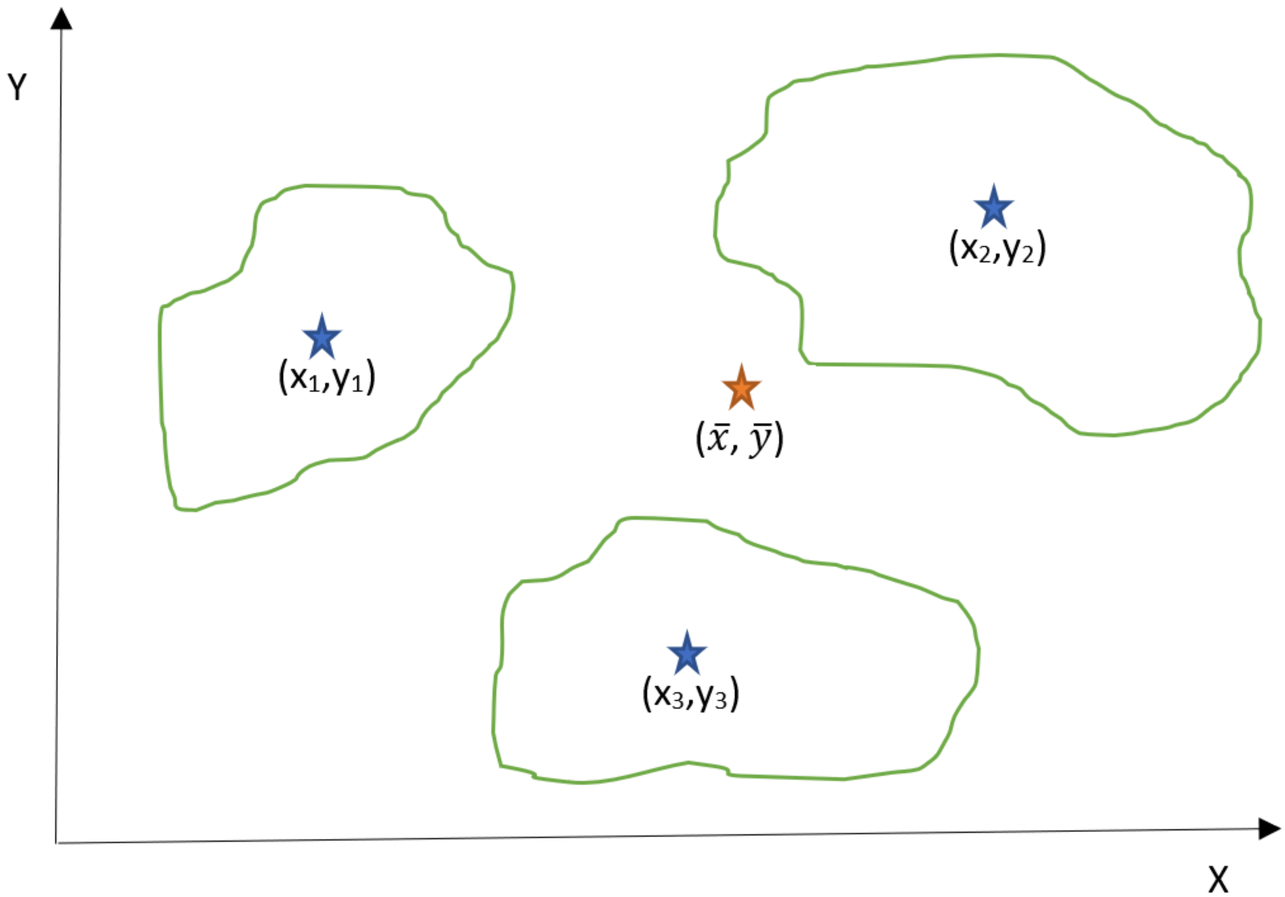


Figure 5.3.1: Three market areas on an X-Y coordinate axis.

Mathematical Formulation

The Centre of Gravity method employs the following formulas to calculate the x and y coordinates for the new facility:

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

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

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

Where:

$\bar{x}$ = 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

Consider the following information about potential markets and their respective locations:

Market	Volume	X	Y
London	600	1	2
Toronto	400	3	4
Kingston	550	6	4
Barrie	800	2	6

Using the Centre of Gravity method, we can determine the optimal location for the new facility to minimize the total transportation cost:

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

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

By substituting the given values into the formulas, the x and y coordinates for the new facility can be calculated, representing the location that minimizes the total transportation cost while serving all the markets.

The Centre of Gravity method provides a quantitative approach to facility location decisions, specifically when the primary objective is to minimize transportation costs associated with serving multiple areas or facilities. Considering the demand volumes and geographical coordinates, this method helps organizations identify the optimal location that optimizes transportation efficiency and reduces overall logistics costs.

Break-Even Method

A common practice in selecting a business site is to compare the cost of production between multiple locations. The fixed costs (land, building, rent) and variable costs (labour, material, utility, etc.) would be different in each location. What is common between these sites is that they should produce the forecasted quantity that is demanded in the market. The forecasted demand could be a single quantity (e.g. 10,000 bikes) or fall within a range (e.g. 10,000-20,000 bikes). To determine which location should provide the demanded quantity or quantities, we use a break-even analysis of their production costs or projected profit levels. This can be done by formulating the total cost of each location in a simple linear equation and depicting the total cost graph of all locations or using Excel to do the same. The following video explains the procedure.

Video: "Locational Break Even Analysis" by Stephanie Powers [13:03] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

5.4 STRATEGIC SIGNIFICANCE OF FACILITY LOCATION DECISIONS

Determining the geographical location of operations is a critical strategic decision for every organization, as it carries far-reaching financial implications. In today's highly competitive business landscape, this decision has gained increasing importance for firms operating in both manufacturing and service sectors. This chapter has provided an in-depth exploration of the factors governing facility location decision-making.

Recognizing that no single factor is the sole determinant in the location decision-making process is important. Identifying the most important factors is directly associated with the organization's objectives. A firm focused on cost minimization would consider different factors for its plant location compared to a firm that prioritizes profit maximization. The relative importance of factors varies depending on the specific industry, operational requirements, and strategic objectives of the organization. Effective facility location decisions require a holistic evaluation of these factors, aligning them with the organization's long-term goals and competitive positioning.

By carefully considering and prioritizing the relevant factors, organizations can make informed decisions regarding the optimal location for their facilities, ultimately enhancing operational efficiency, cost-effectiveness, and responsiveness to customer demands. This chapter has provided a comprehensive framework for understanding and navigating the complexities of facility location decisions, equipping operations managers with the knowledge and tools necessary to make strategic choices that drive organizational success.

5.5 CHAPTER SUMMARY & REVIEW

Summary

The chapter on Facility Location highlights the strategic significance of choosing the right geographical location for an organization's operations, which has profound implications for profitability and competitiveness. It explores various factors influencing location decisions, such as proximity to raw materials and suppliers, labour availability, transportation infrastructure, utility costs, tax incentives, and proximity to customer markets. The chapter also addresses the impact of e-commerce, noting that while service-oriented companies can often operate with less dependency on physical locations, manufacturing firms still require strategic considerations for their production and distribution facilities.

To aid in making informed location decisions, the chapter presents quantitative methods such as the Location Factor Rating method, which evaluates potential sites based on weighted factors, and the Centre of Gravity method, which aims to minimize transportation costs. It emphasizes that effective facility location decisions require a holistic evaluation of these factors, aligned with the organization's strategic objectives. By systematically assessing and prioritizing these elements, organizations can enhance operational efficiency, cost-effectiveness, and responsiveness to market demands, ultimately achieving a competitive advantage.

OpenAI. (2024, June 11). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than two paragraphs. Reviewed by authors.*

Review Questions

1. How do facility location decisions impact an organization's long-term profitability and competitiveness? Provide examples of how different industries might prioritize different factors in their location decisions.
2. Identify and discuss the key factors that influence facility location decisions for both manufacturing and service organizations. How do these factors differ, and why?
3. How has the rise of e-commerce and web-based retail industries affected facility location decisions, particularly for service-oriented companies? What are the implications for traditional brick-and-mortar businesses?
4. Explain the Location Factor Rating method (Weighted Scoring Model) and how it is used to evaluate potential facility locations. What are the advantages and limitations of this method?
5. Describe the Centre of Gravity method and its application in determining the optimal location for a facility. How does this method help in minimizing transportation costs?
6. Discuss how organizations can balance cost efficiency and market responsiveness when making facility location decisions. Provide examples of trade-offs that might need to be considered in this process.

OpenAI. (2024, June 11). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create six discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

5.6 KEY TERMS

Key Terms

- **Centre of Gravity Method** can be employed to determine the optimal location for a facility that serves multiple areas or other facilities, such as a warehouse or distribution center. This method utilizes an (X-Y) coordinate system to represent the geographical map of the areas under consideration.
- **Location Factor Rating Method** provides a structured and quantitative approach to facility location decisions, allowing organizations to objectively evaluate and compare potential sites based on their specific operational requirements and strategic priorities.
- **Key Factors for Location Selection** can be Proximity (to raw material, suppliers, customers market, competition), Cost (labour, production elements, utility and energy, transportation) and regional considerations (government incentives, infrastructure, cultural, societal and legal).

CHAPTER 6: MANAGING QUALITY

Chapter Overview

6.0 LEARNING OUTCOMES

Learning Objectives

At the end of this chapter, students will be able to:

- Differentiate between design quality and process quality and explain their significant interaction in achieving overall product quality.
- Describe the historical evolution of quality management practices and articulate how consumer perceptions influence product quality and business success.
- Identify key figures in the field of quality management that contributed to the modern field of quality.
- Categorize and explain the various costs associated with quality management, including prevention costs, appraisal costs, internal failure costs, and external failure costs.
- Explain the principles and practices of Total Quality Management (TQM), ISO standards, and Six Sigma.
- Demonstrate the use of quality improvement tools such as control charts and Pareto charts in real-world scenarios.

6.1 INTRODUCTION TO QUALITY

The Pursuit of Quality

Businesses worldwide strive relentlessly to provide quality products and services to consumers. A good quality product is considered a given by the consumer. The success of a business depends on reading and understanding consumers' perceptions regarding the quality of the product or service provided by the company. The aim of the company is to bridge any gap between the consumer's expectations regarding the quality of a product and its performance.

Defining Quality from the Consumer's Perspective

To fill or at least reduce the above-mentioned gap, the emphasis should be on identifying how a consumer measures the quality of a product or service. Similarly, how is the quality of a pen measured? Should it be measured in terms of its longevity, its price, or its performance? This chapter specifically discusses various consumer-oriented definitions of quality.

Historical Perspective

Prior to the 1980s, quality was not a primary concern for North American manufacturers. However, as high-quality goods began to flood the North American markets from Japan, it became evident that North American companies had fallen behind in this regard. Japanese products, particularly in the automotive industry, gained preference among consumers who recognized their superior level of quality.

Quality in Operations Management

In the contemporary business landscape, quality can be broadly defined as the degree to which a product or service meets or surpasses the customer's expectations. This concept holds significant importance in the field of operations management.

Determinants of Product Quality

For any product, the quality is determined by two primary factors: Design Quality and Process Quality:

Design 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, and the features it has, not to mention the way it looks, feels and lasts. Below are some facets of product quality (Garvin, 1987).

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

Process Quality

Process quality, on the other hand, focuses on the manufacturing or service delivery processes involved in producing the product or service. It involves ensuring that the processes are efficient, consistent, and capable of meeting the design specifications. Factors such as process control, quality control measures, and continuous improvement efforts contribute to achieving high process quality.

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

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 by which customers evaluate service performance.

Element	Description
Tangibles	Any physical products used during the service
Reliability	Capability, well maintained, flexibility
Convenience	Experience, training, ability level
Responsiveness	Matches the application
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

6.2 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 A. Shewhart (1891-1967): Pioneer of Statistical Quality Control

"Walter Shewhart", Public Domain

Dr. Shewhart, an American physicist, engineer, and statistician, is widely regarded as the father of statistical quality control (SQC). Throughout his career, he extensively researched process variation and is credited with developing the first control chart. His groundbreaking work centred on the importance of reducing variation to achieve quality improvement.

Shewhart's legacy includes the fundamental concepts of assignable and common causes of variation. All production processes exhibit some level of variation, which intuitively leads to decreased quality with increased variability. **Assignable variation** arises from identifiable and addressable causes, such as employee error, software malfunction, or equipment failure. In contrast, **common variation**, also known as chance variation, is inherent to the process and generally expected. Minimizing or eliminating either type of variation directly translates to enhanced product quality.

W. Edwards Deming (1900-1993): Champion of Quality Management

Arguably the most prominent figure among the "Quality Gurus," Dr. Deming was an American engineer, statistician, professor, and prolific author. Following World War II, his expertise in statistical process control led him to Japan, where he was recruited to aid with their national census. From 1950 onwards, Deming's significant contribution involved training thousands of Japanese engineers, managers, and academics in fundamental statistical process control techniques. This pivotal role is widely credited with propelling Japan to become a global leader in quality manufacturing.

In recognition of Deming's profound impact, the Deming Prize, Japan's most prestigious quality award, was named in his honour. While Dr. Deming authored numerous publications, his enduring legacy is likely secured through his renowned Deming's 14 Points and the Deming Cycle, both of which continue to be foundational principles within quality management practices.

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, 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. In 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 workforce, 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 workforce.

    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 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.

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.

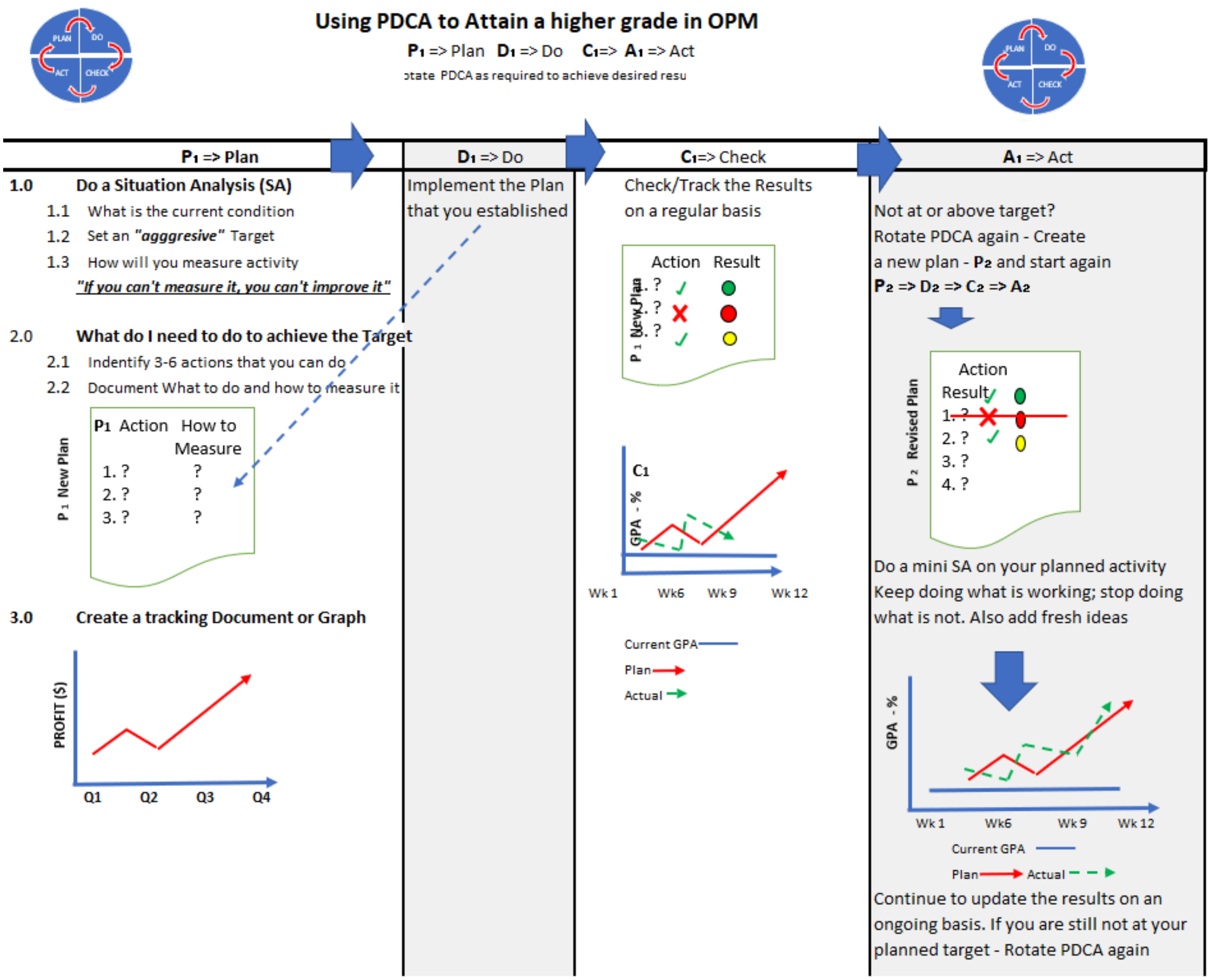


Figure 6.2.1: "An example utilizing PDCA to attain a higher grade in OPM" by Jim Philips

Accessible format for Figure 6.2.1

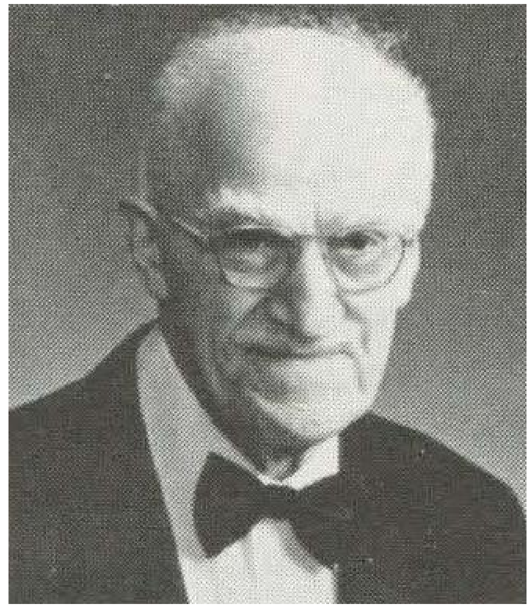
Image Description

Figure 6.2.1 shows a diagram that is divided into four main sections labelled Plan (P1), Do (D1), Check (C1), and Act (A1), each represented by arrows flowing sequentially from one to the next, forming a continuous loop. The diagram emphasizes the iterative nature of the PDCA cycle, with smaller versions of the PDCA cycle shown at the top corners.

- Plan (P1):
  - Do a Situation Analysis (SA):
    - 1.1 What is the current condition?
    - 1.2 Set an aggressive target.

        - 1.3 How will you measure the activity? (Quote: "If you can't measure it, you can't improve it")
    - What do I need to do to achieve the target?
        - 2.1 Identify 3-6 actions that you can take.
        - 2.2 Document what to do and how to measure it.
    - Create a tracking document or graph:
        - Example graph shows progress over four quarters (Q1 to Q4) with a rising trend.
- Do (D1):
    - Implement the Plan that you established
- Check (C1):
    - Check/Track the Results on a regular basis: Track progress using a document or graph.
- Act (A1):
    - Not at or above target? Rotate PDCA again:
        - Create a new plan (P2) and start again.
        - Do a mini SA on your planned activity.
        - Keep doing what is working; stop doing what is not.
        - Add fresh ideas.
        - Continue to update the results on an ongoing basis.
        - If you are still not at your planned target – Rotate PDCA again.

Joseph M. Juran (1904-2008): Quality Management Authority



"J. M. Juran", Public Domain

Juran, a Romanian-born American engineer, established himself as a giant in the quality management field. His foundational work includes the widely influential *Quality Control Handbook*, first published in 1951. Juran championed a three-pronged approach to quality, known as the Juran Trilogy: quality planning, quality control, and quality improvement. A prolific author, he contributed hundreds of papers and 12 books to the field. Notably, Juran is credited with the concept of the **cost of quality**, a framework for understanding and managing the financial implications of quality.

Juran's influence extends beyond his own contributions. He recognized the value of Vilfredo Pareto's (1848-1923) work and popularized the **Pareto Principle**, also known as the 80/20 rule. This principle, originally an observation by Pareto that 80% of Italy's land was owned by 20% of the population, has become a cornerstone of problem-solving and continuous improvement efforts in quality management. The principle suggests that a significant portion of problems (around 80%) often stem from a relatively small number of root causes (around 20%). This realization allows organizations to focus their improvement efforts on the most impactful areas.

The Pareto Principle finds numerous applications within quality management:

- *Defect concentration:* It's widely accepted that 80% of defects can be traced back to a small number (20%) of root causes. Firms benefit by prioritizing the identification and rectification of these root causes.
- *Profit distribution:* In many companies, 80% of profits might be generated by just 20% of the products or services offered. Identifying and nurturing these high-performing offerings can significantly improve overall profitability.
- *Employee engagement:* Sometimes, just 20% of employees might be responsible for generating 80% of the continuous improvement ideas. Recognizing and encouraging these valuable contributors can foster a culture of innovation within the organization.

Philip Crosby (1926-2001): Champion of "Zero Defects"

"Philip Crosby", used under fair dealing for educational purposes (Canada).

Crosby, an American businessman and author, gained recognition for his 1979 book *Quality is Free*. He challenged the prevailing notion that quality comes at a premium, arguing instead that the true costs of quality are often significantly underestimated. Crosby is credited with coining the term **zero defects**, a philosophy emphasizing the elimination of errors from the outset. He maintained that preventing defects is far more cost-effective than relying on extensive inspection, rework, and repairs after the fact.

Armand Feigenbaum (1920-2014): Architect of Total Quality Management

Dr. Feigenbaum, an American quality engineer and businessman, served as the Director of Manufacturing Operations at General Electric from 1958 to 1968. He is credited with pioneering the concept of total quality control, which later evolved into the widely adopted total quality management (TQM) philosophy. Feigenbaum also introduced the thought-provoking concept of the "**hidden plant**", which refers to the untapped productive capacity lost due to inefficiencies, defects, and rework. His work highlighted the significant potential for improvement that lies within existing operations.

6.3 COST OF QUALITY

Organizations that deliver high-quality goods and services can achieve a competitive edge and distinguish themselves in the marketplace. These companies often experience higher profitability, as they incur minimal losses and additional expenses related to poor productivity, rework, inspections, and scrap.

The costs associated with maintaining and improving quality can be categorized into four main types: prevention costs, appraisal costs, and failure costs. Failure costs are further divided into internal failure costs and external failure costs. Understanding and managing these cost categories is crucial for optimizing quality management and enhancing overall operational efficiency.

Prevention costs

Prevention costs encompass all expenditures aimed at proactively avoiding the occurrence of defects or non-conformities in products or services. These costs are incurred through initiatives such as quality improvement programs, employee training and development, equipment upgrades, implementation of quality management systems, and proactive design modifications. Investing in prevention activities can significantly reduce the likelihood of defects and associated costs further down the production process.

Appraisal costs

Appraisal costs refer to the resources dedicated to inspecting, testing, and evaluating products or services during the production or delivery process. These costs include wages for quality inspectors, expenses related to testing laboratories and equipment, gauging and measurement activities, and process control mechanisms. Appraisal activities aim to identify and eliminate defects before they reach the customer, thereby preventing potential failure costs.

Internal failure costs

Internal failure costs arise when defects or non-conformities are detected within the organization before the product or service is delivered to the customer. These costs encompass rework efforts to rectify identified defects and the costs associated with scrapping or disposing of products that cannot be repaired or reworked.

Internal failure costs include potential disruptions to production schedules, expedited manufacturing efforts to compensate for scrapped products, and the associated opportunity costs.

External failure costs

External failure costs are incurred when defective products or non-conforming services reach the customer. These costs can be substantial and may include expenses related to product replacements, expedited shipping, product recalls, potential legal liabilities, and the detrimental impact on customer satisfaction and future business opportunities. External failure costs are often challenging to quantify precisely due to the intangible nature of lost customer goodwill and its long-term implications on an organization's reputation and market position.

By understanding and effectively managing these cost categories, organizations can optimize their quality management efforts, minimize defects and non-conformities, and ultimately enhance customer satisfaction while reducing overall operational costs.

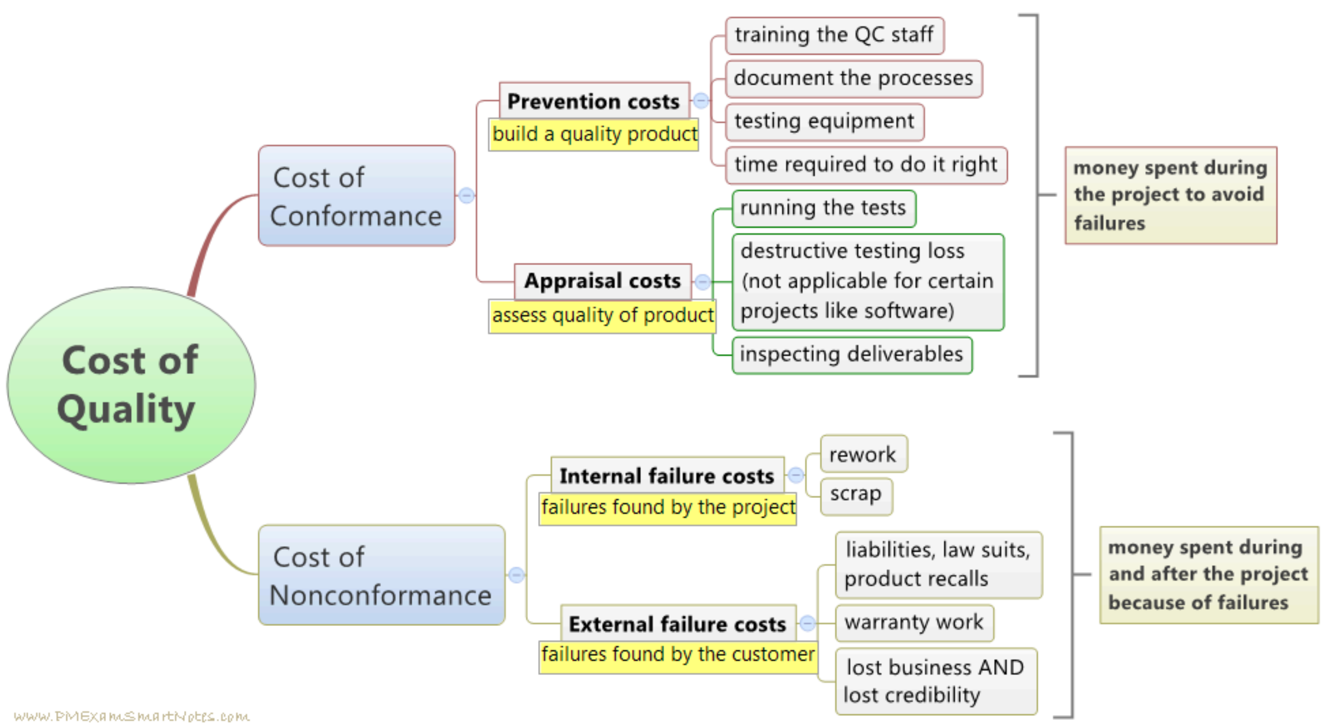


Figure 6.3.1: "Cost of Quality" by pmexamsmartnotes.com, CC BY-NC-ND 2.0

Image Description

Cost of Quality

1. **Cost of Conformance**: Money spent during the project to avoid failures.

  - **Prevention Costs**: Costs to build a quality product.
    - Training the QC staff
    - Documenting the processes
    - Testing equipment
    - Time required to do it right
  - **Appraisal Costs**: Costs to assess the quality of the product.
    - Running the tests
    - Destructive testing loss (not applicable for certain projects like software)
    - Inspecting deliverables

2. **Cost of Nonconformance**: Money spent during and after the project because of failures.

  - **Internal Failure Costs**: Failures found by the project.
    - Rework
    - Scrap
  - **External Failure Costs**: Failures found by the customer.
    - Liabilities, lawsuits, product recalls
    - Warranty work
    - Lost business and lost credibility

6.4 QUALITY SYSTEMS

Many organizations employ various quality systems to manage and enhance their quality standards. Three common quality systems are Total Quality Management (TQM), ISO 9001, and Six Sigma.

Total Quality Management (TQM)

In today's competitive environment, companies must deliver high-quality goods and services that meet or exceed customer expectations. **Total Quality Management (TQM)**, also known as quality assurance, encompasses all the steps a company takes to ensure its products or services align with customer-defined specifications and maintain high quality. TQM principles generally focus on three key areas:

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

Let's delve deeper into these principles.

Customer Satisfaction

Organizations committed to TQM recognize that the primary goal of a business is to generate profit by fulfilling customer needs. They allow customers to define quality by identifying and offering product features that meet their requirements. These companies actively seek customer feedback to understand how to produce goods and services that function correctly and meet expectations.

To ensure quality is integrated into every aspect of their operations—from design and product planning to sales and service—companies often use surveys and other methods to monitor customer satisfaction. By tracking feedback over time, they can identify areas for improvement.

Employee Involvement

Effective TQM requires the commitment of everyone in the organization, not just upper management, to satisfy the customer. For instance, if customers experience long wait times at a drive-through, multiple employees are responsible, not just the manager. Similarly, a defective DVD is not solely the responsibility of the quality control department but of every employee involved in its design, production, and shipping.

Managers must communicate the importance of quality to all employees and motivate them to focus on customer satisfaction. Employees need proper training to perform their jobs effectively and to identify and correct quality issues. In many organizations, employees working in similar roles form teams, often called quality circles, to identify work-related problems, propose solutions, and collaborate with management to implement their recommendations.

Continuous Improvement

A core component of TQM is continuous improvement, which involves a commitment to constantly enhancing the design, production, and delivery of goods and services. There are always opportunities to increase efficiency, reduce costs, and improve customer service and satisfaction. Everyone in the organization is encouraged to seek ways to do things better.

By adhering to these TQM principles, organizations can consistently deliver high-quality products and services that meet customer needs and maintain a competitive edge in the market.

ISO Standards

The International Organization for Standardization (ISO) is an independent, non-governmental organization that develops and publishes voluntary international standards. Founded in 1947 and headquartered in Geneva, Switzerland, ISO operates in 164 countries and is the largest developer of international standards.

The primary objective of ISO standards is to promote global proprietary, industrial, and commercial standards that facilitate trade and ensure the safety, reliability, and quality of products and services. By enabling direct comparisons between products from different markets, these standards assist businesses in entering new markets and contribute to developing fair global trade practices.

Additionally, ISO standards serve to safeguard consumers and end-users by ensuring that certified products and services conform to internationally established minimum standards. Using these standards helps organizations create safe, reliable, and high-quality offerings while increasing productivity and minimizing errors and waste.

Video: "What ISO standards do for you" by ISO [2:05] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

Steps in Obtaining ISO Certification

To obtain ISO certification, an organization must follow a structured process:

1. *Documentation and Implementation:* The organization must document and implement its quality management systems, including policies, procedures, and work instructions. This documentation process can be time-consuming and requires collaboration from all employees.
2. *Quality Manual:* The organization must develop a Quality Manual that outlines how it will ensure the quality of its goods and services.
3. *Employee Training:* All employees involved in the documented processes must receive comprehensive training to gain a full understanding of the new work procedures and documentation.

The cost and duration of this process depend on the size and complexity of the organization. Many firms choose to engage external consultants to guide and assist them throughout the process, which typically takes 12 to 18 months. ISO certification is valid for three years, after which the organization must undergo a recertification process.

While some organizations pursue ISO certification primarily due to customer requirements, the intrinsic motivation should be a genuine desire to improve internal performance and quality standards.

News Article: Does ISO certification improve financial performance?

What Benefits Are There to Obtaining ISO Certification?

ISO (International Organization for Standardization) certification is a globally recognized standard demonstrating an organization's commitment to quality, efficiency, and continuous improvement. Pursuing and maintaining ISO certification can provide organizations with the following benefits:

- *Enhanced Quality Management:* ISO standards, such as ISO 9001, provide a framework for establishing a robust quality management system (QMS). Organizations can streamline their processes by implementing these standards: identify and monitor key performance indicators and maintain consistent quality standards across their operations. This leads to improved product or service quality, increased customer satisfaction, and a competitive advantage in the market.
- *Operational Efficiency and Cost Savings:* Adhering to ISO standards encourages organizations to optimize processes, reduce waste, and improve overall efficiency. Organizations can achieve cost savings, increased productivity, and a more agile and responsive operational structure by identifying and

eliminating non-value-adding activities.
- *Risk Management and Compliance:* ISO standards emphasize risk-based thinking and provide guidelines for identifying, assessing, and mitigating potential risks. Organizations can proactively manage risks, ensure regulatory compliance, and protect their employees, assets, and reputation by implementing standards like ISO 31000 (Risk Management) and ISO 45001 (Occupational Health and Safety Management System).
- *Expanded Market Access:* ISO certifications serve as a globally recognized symbol of quality and compliance. Organizations that achieve ISO certifications, such as ISO 9001 or ISO 13485 (Medical Devices), demonstrate their commitment to meeting internationally recognized standards. This enhances credibility and opens doors to new markets by reassuring customers, suppliers, and partners about the organization's dedication to quality and industry best practices.
- *Continuous Improvement Culture:* ISO standards foster a culture of continuous improvement by promoting the Plan-Do-Check-Act (PDCA) cycle. Organizations that embrace ISO standards are encouraged to regularly evaluate their processes, measure performance, and implement corrective actions. This iterative approach drives ongoing optimization, innovation, and the pursuit of excellence within the organization.
- *Increased Customer Confidence:* ISO standards instill confidence by ensuring organizations follow standardized processes, prioritize customer satisfaction, and deliver reliable products or services. Standards like ISO 27001 (Information Security Management System) and ISO 22301 (Business Continuity Management System) address data security and business continuity, strengthening customer trust in handling sensitive information and ensuring uninterrupted operations.
- *Improved Communication and Corporate Culture:* Implementing ISO standards promotes better communication and alignment within the organization. By having a set of standardized processes and quality objectives, employees clearly understand their roles and responsibilities, leading to improved collaboration and a stronger corporate culture focused on quality and customer satisfaction.

By pursuing and maintaining ISO certification, organizations can enhance their operations, reduce risks, and gain a competitive edge in the market, making it a valuable investment for operations management professionals. (Diesing, 2023; Onspring, n.d.)

Read the article below from the Business Development Bank of Canada.

Short Article: Seven ways ISO certification can help your business

Hazard Analysis Critical Control Point (HACCP)

HACCP is a quality management system specifically designed for organizations in the food processing industry. Implementing a HACCP program can yield several significant benefits:

- *Gain Customer Confidence:* Demonstrating a commitment to food safety can enhance customer trust.
- *Sharpen Competitive Edge and Develop New Export Opportunities:* Adhering to HACCP standards can differentiate your business and open up new markets.
- *Achieve More Rigorous Quality Control:* Implementing HACCP ensures stringent quality control measures are in place.
- *Reduce Waste and Spoilage:* Effective management of food safety risks can minimize waste and spoilage.
- *Control Contamination Risks and Recall Processes:* HACCP helps identify and control contamination risks, thereby streamlining recall processes if necessary.
- *Build Awareness of Hygiene and Safety for Employees:* Training employees on HACCP principles increases their awareness of hygiene and safety practices.
- *Eliminate Potential Allergen Issues:* HACCP helps identify and manage potential allergen risks.

The Seven Principles of HACCP

The seven principles of HACCP outline the steps necessary to manage and control food safety risks within a business:

1. *Conduct a Hazard Analysis:* Identify potential hazards affecting food safety.
2. *Identify Critical Control Points (CCPs):* Determine the points in the process where hazards can be prevented, eliminated, or reduced to safe levels.
3. *Establish Critical Limits:* Set maximum or minimum limits for each CCP to ensure food safety.
4. *Monitor Critical Control Points:* Implement procedures to monitor CCPs and ensure they remain within the established limits.
5. *Establish Corrective Actions:* When monitoring indicates a CCP is not within the established limits, define actions to be taken.
6. *Establish Record-Keeping Procedures:* Maintain documentation and records to demonstrate compliance with HACCP principles.
7. *Establish Verification Procedures:* Implement procedures to verify that the HACCP system is working effectively.

Ensuring the safety of customers is paramount for any food business. Organizations can control food safety risks and protect against foodborne illness outbreaks by implementing a successful HACCP program. Since

2005, it has been mandatory for federally registered meat and poultry establishments to become HACCP-certified. The Canadian Food Inspection Agency also recommends HACCP compliance certification for all businesses within the food supply chain.

Video: "HACCP – Making Food Products Safe, Part 1" by Alberta Agriculture and Irrigation [15:06] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

Six Sigma

In your career, you may find yourself working in an organization that has adopted a Six Sigma program. **Six Sigma** is a comprehensive set of techniques and tools designed for process improvement. It was introduced by engineer Bill Smith at Motorola in 1980. The primary goal of Six Sigma is to achieve business success by minimizing variation in business processes. The term "Six Sigma quality" refers to a process that is so well-controlled that it produces no more than 3.4 defects per million opportunities.

The concept of Six Sigma is rooted in statistics, where "sigma" denotes standard deviation, a measure of variation within a dataset. Typically, a company process might operate at a 3-sigma quality level, meaning that 99.73% of all output falls within plus or minus three standard deviations from the mean. This results in 0.27% of all outputs being non-conforming or defective, which equates to 2,700 defects per million opportunities. Such a defect rate is unacceptable in industries where quality is critical to customer safety, such as manufacturing aircraft, automobiles, or medical devices. In contrast, a Six Sigma process achieves 99.99966% defect-free outputs.

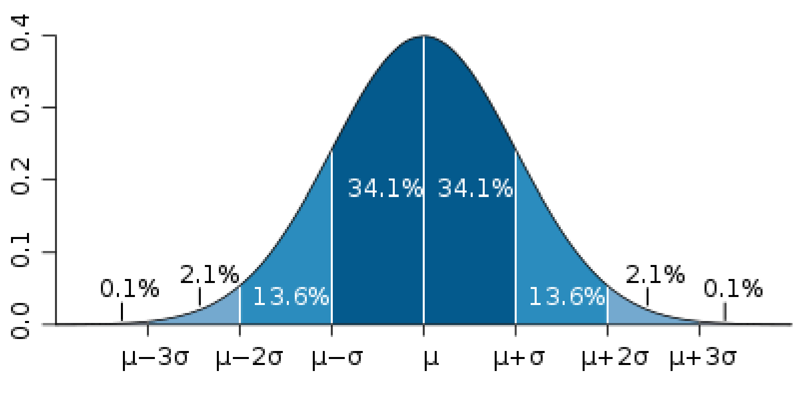


Figure 6.4.1: "Normal distribution diagram utilizing Six Sigma" by Ainali, CC BY-SA 3.0

The DMAIC Improvement Model

Unique to Six Sigma is the **DMAIC Improvement Model**, which stands for Define, Measure, Analyze, Improve, and Control. In Six Sigma, improvements are driven by project teams assembled to address quality issues, streamline existing processes, or develop new processes. The DMAIC model guides these teams through a structured approach to process improvement (American Society for Quality, n.d.):

1. *Define:* Identify the problem by understanding who the customer is, what their needs are, and what is most important to them. Determine the most suitable project to improve and meet customer requirements.
2. *Measure:* Assess current process performance by collecting data and comparing it to the desired state. Use tools like Pareto charts to analyze the frequency of problems or causes.
3. *Analyze:* Investigate the process to identify why defects are occurring and determine the causes of variation and poor performance. Conduct root cause analysis to pinpoint these issues.
4. *Improve:* Enhance process performance by eliminating the causes of defects. Modify the process and measure the results to ensure the problem has been resolved.
5. *Control:* Implement a plan to maintain the improved process and ensure that the gains are sustained over time.

By following the DMAIC model, organizations can systematically improve their processes, reduce defects, and enhance overall quality, leading to increased customer satisfaction and business success.

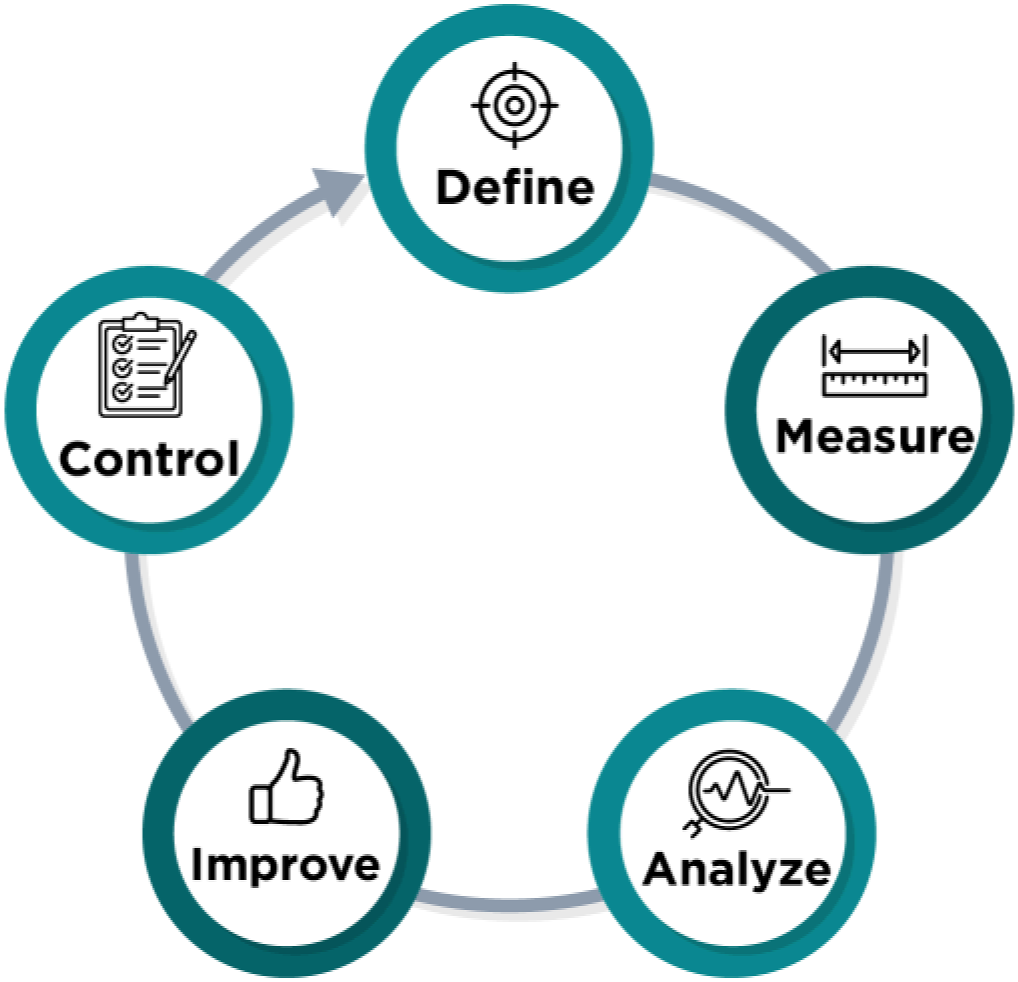


Figure 6.4.2: "Cyclical diagram of the DMAIC model" by Sanaz Habib, CC BY-NC-SA 4.0.

Six Sigma Belt Levels

Another unique aspect of Six Sigma is the use of a belt system, similar to martial arts, to symbolize an individual's level of expertise and proficiency in Six Sigma methodologies. The belt levels are as follows:

- **Green Belt:** A Green Belt designation indicates that an individual has received Six Sigma training. Green Belts typically have full-time roles within the organization but are called upon to assist with Six Sigma projects part-time. They support project teams by applying Six Sigma tools and techniques under the guidance of more experienced Black Belts.
- **Black Belt:** A Black Belt is a full-time position within the quality department, where the individual works exclusively as a coach and leader for Six Sigma projects. Black Belts possess extensive experience in Six Sigma methodologies and spend the majority of their time leading project teams, providing guidance, and ensuring the successful implementation of Six Sigma initiatives.

- **Master Black Belt:** A Master Black Belt is a full-time position within the Six Sigma team, with extensive experience managing and overseeing Six Sigma projects. Master Black Belts serve as coaches and mentors to Black Belts, providing advanced training, guidance, and support in implementing complex Six Sigma projects.
- **Champion:** A Champion is typically a senior manager or executive overseeing the Six Sigma program and its associated personnel. Champions are responsible for determining which projects should be prioritized, ensuring proper allocation of resources, and removing any roadblocks that may hinder the success of Six Sigma initiatives. They play a crucial role in promoting and supporting the Six Sigma culture within the organization.

This belt system recognizes an individual's level of expertise and defines their roles and responsibilities within the Six Sigma program. It fosters a structured approach to continuous improvement. It ensures that Six Sigma projects are led by qualified and experienced professionals, ultimately contributing to the organization's overall quality and operational excellence.

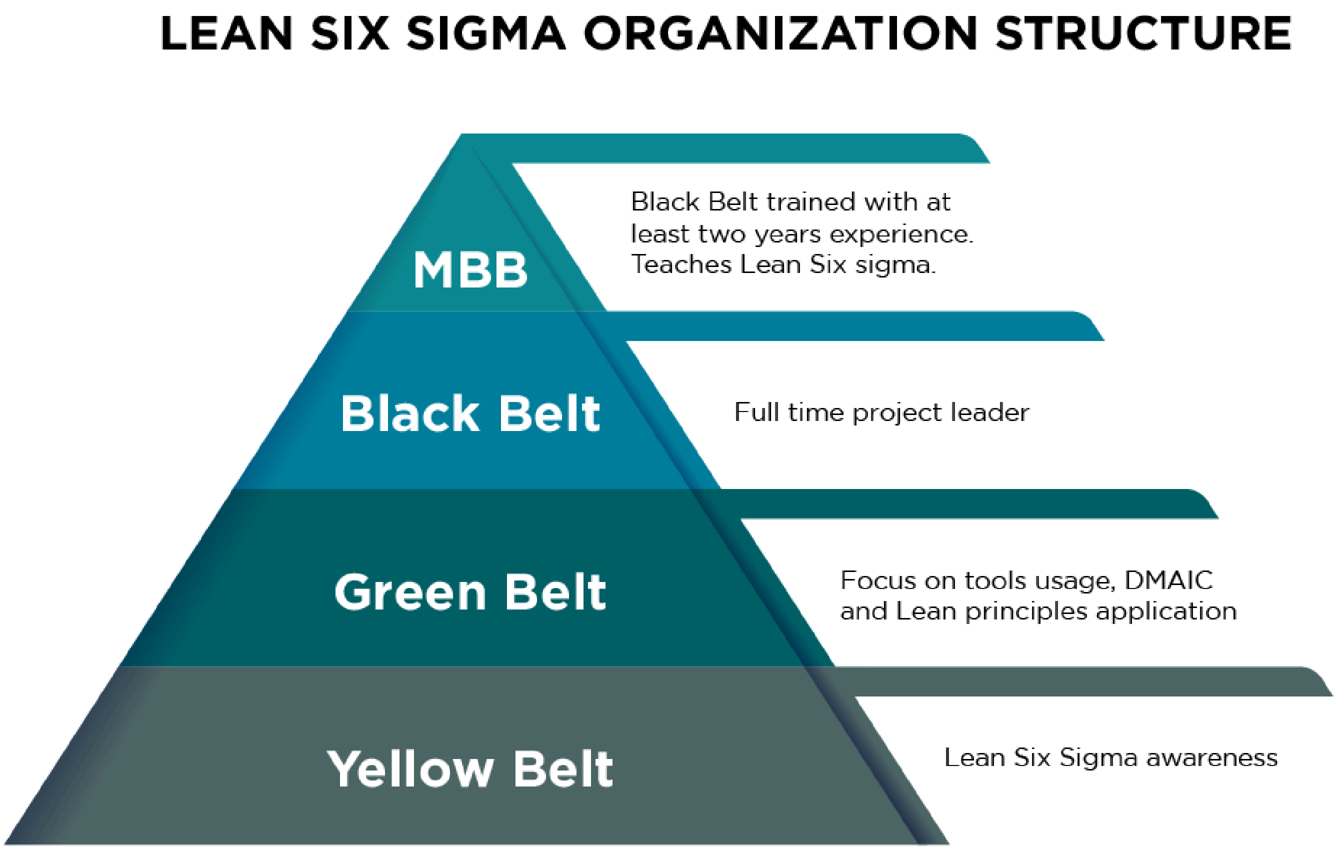


Figure 6.4.3: "Variation of belt colours associated with Six Sigma" by Zirguezi, CC0 1.0. Mods: re-coloured by Fanshawe College

6.5 TOOLS FOR QUALITY IMPROVEMENT

In any quality improvement initiative, data collection and evaluation play a critical role. Several basic, generic tools are commonly used to facilitate data analysis and drive continuous improvement efforts. These tools include check sheets, histograms, control charts, Pareto charts, scatter diagrams, and cause-and-effect diagrams.

Check Sheets

A **check sheet** is a custom-designed form used to record the frequency or number of occurrences of a particular event or outcome of interest. It can capture various types of information, such as the number of incidents, timing, or measurements that deviate from the desired specifications. Check sheets provide a structured way to collect and organize data, enabling further analysis and identification of patterns or trends.

Example

Motor Assembly Check Sheet

Name of Data Recorder: Lester B. Rapp
Location: Rochester, New York
Data Collection Dates: 1/17 – 1/23

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

Histograms

A **histogram** is a graphical representation that displays the distribution of a dataset by grouping the data into bins or intervals along the horizontal axis and showing the frequency or count of observations in each bin on the vertical axis. Histograms are useful for visualizing a dataset's shape, central tendency, and spread, which can help identify potential issues or areas for improvement.

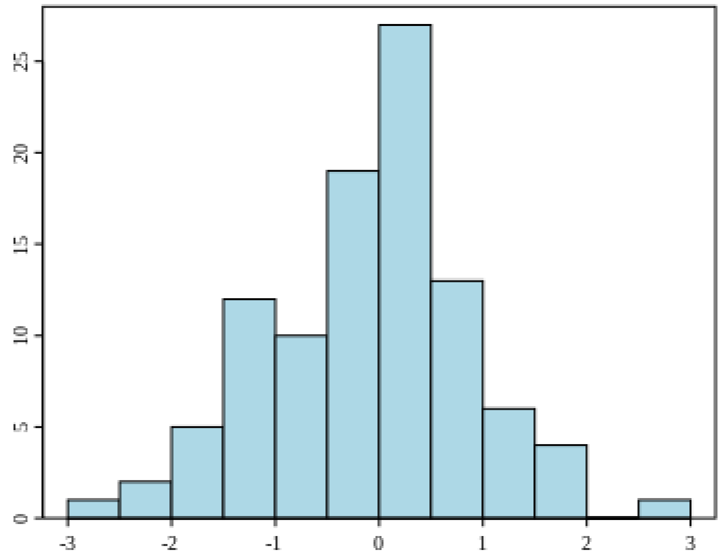


Figure 6.5.1: "Histogram diagram example"

Pareto Charts

A **Pareto char**t is a specialized type of bar chart that displays the frequency of occurrences for various characteristics, arranged in descending order from highest to lowest. The X-axis represents each characteristic, while the Y-axis on the left side indicates the number of times each occurrence was recorded. Additionally, a cumulative percentage line is plotted to show the cumulative contribution of each category to the total. The Y-axis on the right side of the chart corresponds to the percentage values on this line.

In quality management, it is crucial for managers to allocate resources effectively to address the most frequently occurring problems. Pareto analysis helps focus attention on the most common defects, enabling managers to prioritize and allocate resources to rectify these issues efficiently. This approach is based on the Pareto principle, which suggests that a small number of causes often account for a large proportion of the effects.

Video: "How to Make a Pareto Chart in Excel" by David McLachlan [12:16] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

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
Long wait time	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.

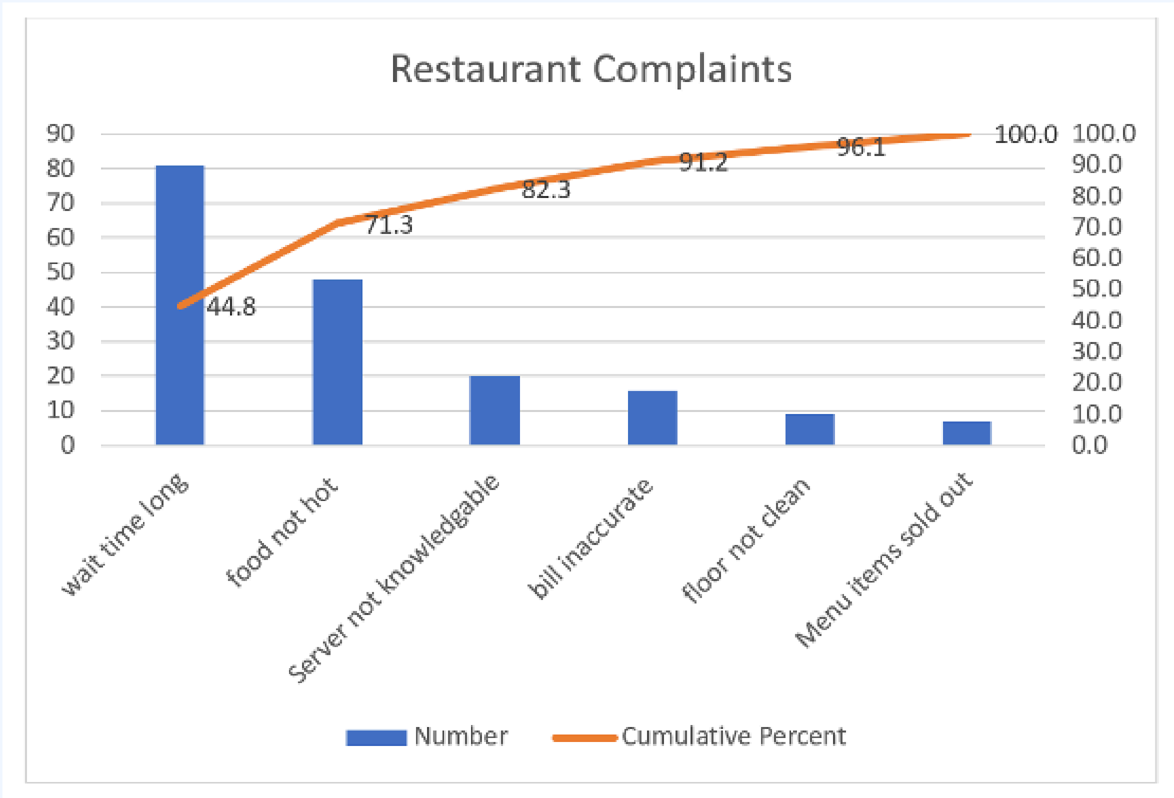


Figure 6.5.2: "Pareto Analysis of Restaurant Complaints"

Scatter Diagrams

A **scatter diagram** is a graphical representation that displays the relationship between two variables by plotting their values as a series of points on a Cartesian coordinate system. Scatter diagrams can reveal patterns, trends, or correlations between the variables, which can aid in identifying potential causes or factors influencing a particular outcome.

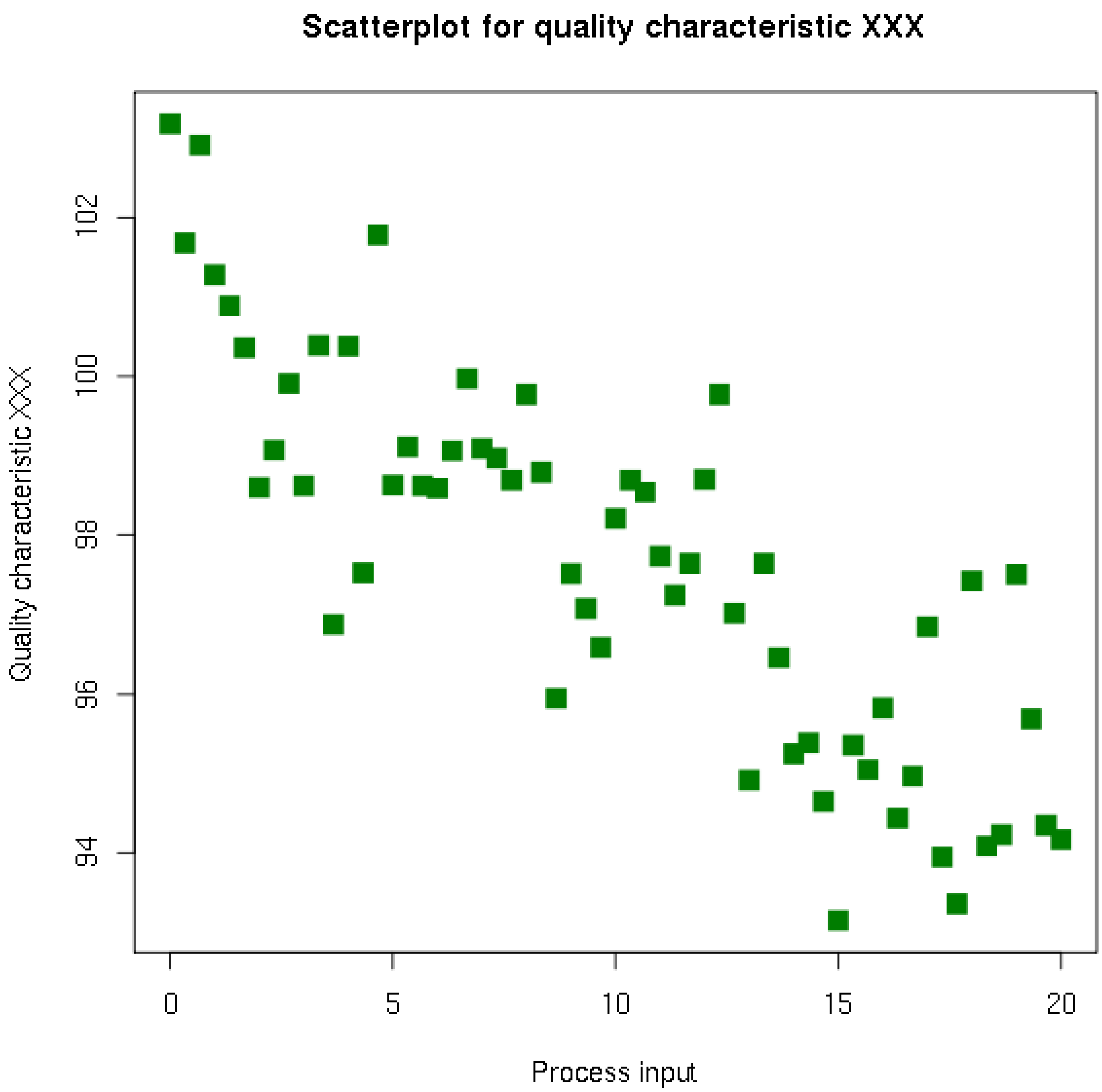


Figure 6.5.3: "Scatter diagram example" by DanielPenfield, CC BY-SA 3.0

Cause and Effect Diagrams

Also known as Fishbone diagrams, **cause-and-effect diagrams** were developed by Dr. Kaoru Ishikawa to help identify the root causes of a problem. The diagram's overall shape resembles a fish's, with the "head" pointing to the effect or problem being analyzed. Each "rib" of the fishbone represents a major cause or category that could potentially contribute to the problem.

Common categories used in Fishbone diagrams include:

- *Man (People):* Factors related to human resources, such as skills, training, and behaviour.

- *Method:* Factors related to processes, procedures, and techniques.
- *Material:* Factors related to raw materials, components, and supplies.
- *Machine:* Factors related to equipment, tools, and technology.
- *Environment:* Factors related to the physical and organizational environment.

Specific factors that fall under each category are written along the corresponding rib. This structured approach helps teams systematically explore and organize potential causes, facilitating a comprehensive analysis of the problem and aiding in the identification of root causes.

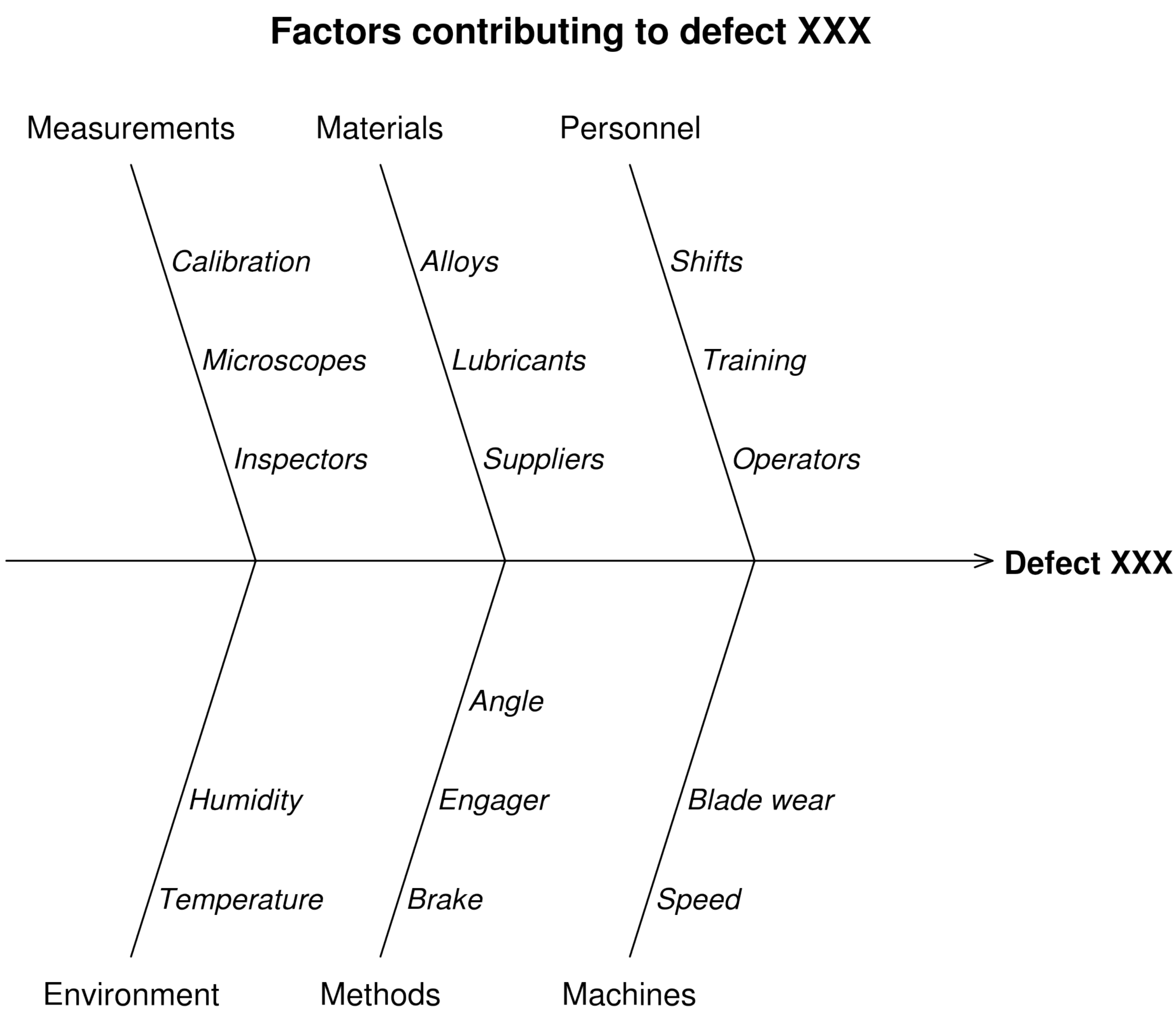


Figure 6.5.4: "Cause and effect diagram example" by DanielPenfield, CC BY-SA 3.0

Control Charts

A **control chart** is a statistical tool used to monitor and control the quality of a product or process. It is a graphical representation that depicts whether sample quality falls within the normal range of variation. The normal range of variation is defined by control chart limits. Control charts were first devised by Dr. Walter A. Shewhart in 1924, also known as Shewhart charts.

A control chart has upper and lower control limits within which deviations from the mean value are allowed. The process is considered out of control if the data plotted reveals that one or more samples fall beyond the control limits. The two lines on the control chart indicate the tolerance limits within which the variation of quality is acceptable.

The upper and lower control limits separate common-cause variation inherent to the process from assignable causes of variation, which are special causes requiring investigation and corrective action. If the plotted points fall outside the tolerance limits (UCL and LCL), the process is considered out of control, and the sample is rejected. This situation warrants the determination of assignable causes, such as poor material quality, operator negligence, or defective machinery, and immediate actions are initiated to improve the quality.

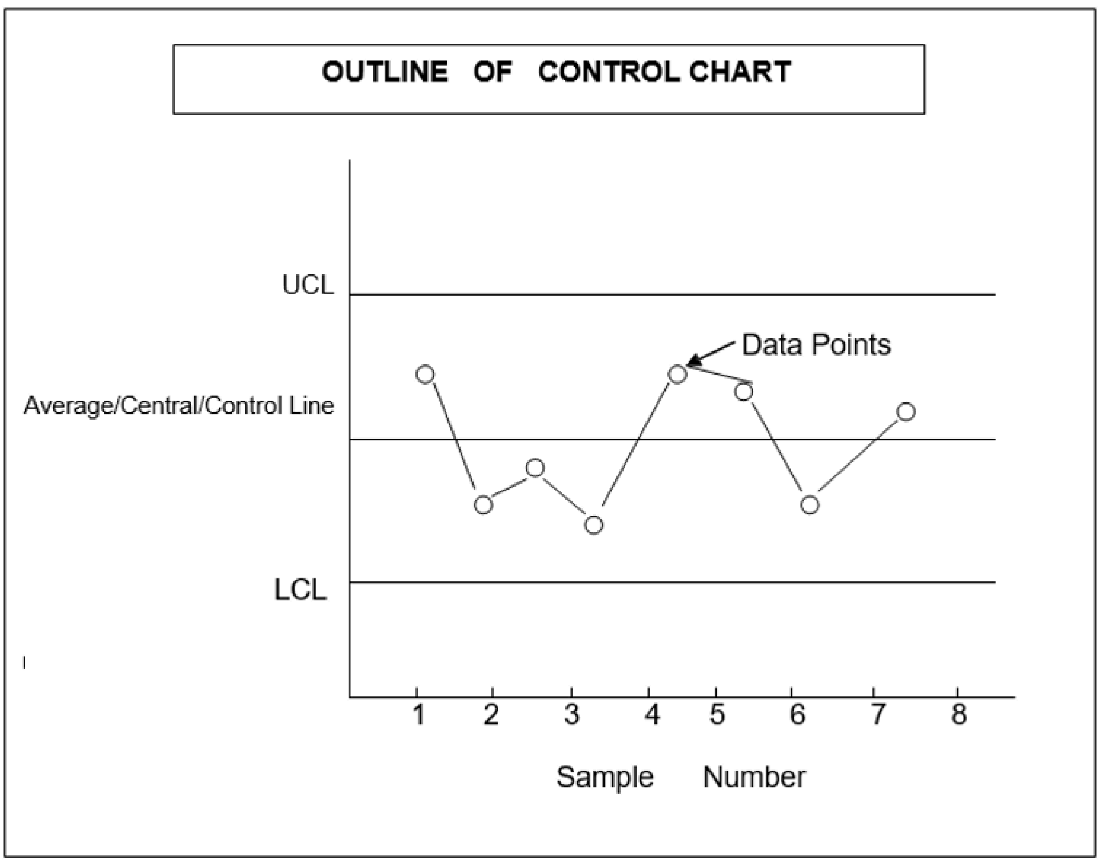


Figure 6.5.5: "Control Chart Example" by Kajal Kiran, CC BY-NC 4.0.

There are two main types of control charts:

1. Control Charts for Variables
2. Control Charts for Attributes

The following video shows how to construct a control chart:

Video: "Making a Control Chart in Excel (with dynamic control lines!)" by David McLachlan [11:03] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Control Charts for Variables

Control charts for variables are used when the quality characteristic of a product can be measured and expressed in specific units, such as height, weight, density, or diameter. These charts are based on measurable quality characteristics.

Control charts for variables are further classified into three types:

1. **Mean ($\bar{X}$) Chart:** This chart monitors the process mean or average value of the quality characteristic.
2. **Range (R) Chart:** This chart monitors the range or the difference between the highest and lowest values within a sample or subgroup.
3. **Standard Deviation (σ) Chart**: This chart monitors the process variability by tracking the standard deviation of the quality characteristic.

Control charts are powerful tools for monitoring process performance, detecting deviations from expected behaviour, and enabling timely corrective actions to maintain quality standards.

Control Charts for Attributes

When the quality characteristic of a product cannot be quantified or measured on a continuous scale, control charts for attributes are used. Attributes are parameters that can only be identified by their presence or absence from the product, such as air bubbles, scratches, or defective prints on cloth.

Control charts for attributes are classified into three types:

1. Control Charts for Proportion of Defective Units (P-Chart)
2. Control Charts for Number of Defectives (np-Chart)
3. Control Charts for Number of Defects (C-Chart)

Control Charts for Proportion of Defective Units (P-Chart)

P-charts, or fraction defective charts, are useful when the quality characteristic cannot be quantified, such as holes in cloth or the absence of picture quality. These charts are designed to control the percentage or proportion of defective units in a lot or sample.

The P-chart monitors the fraction or proportion of defective items in a sample or subgroup, allowing for the detection of shifts or trends in the process performance. It helps identify when the proportion of defective units deviates from the expected or acceptable level, enabling corrective actions to be taken.

Control Charts for Number of Defectives (np-Chart)

The **np-chart** monitors the number of defective items or units in a sample or subgroup of constant size. It is particularly useful when the sample size varies, as it accounts for the varying sample sizes by plotting the actual number of defective units.

The np-chart helps detect shifts or trends in the number of defective units, indicating when the process deviates from the expected or acceptable level of defectives. It aids in identifying potential issues and taking corrective actions to maintain the desired quality level.

Control Charts for Number of Defects (C-Chart)

The **C-chart**, or count chart, monitors the number of defects or non-conformities in a sample or subgroup of constant size. It is particularly useful when the quality characteristic of interest is the number of defects or non-conformities rather than the number of defective units.

The C-chart helps detect shifts or trends in the number of defects or non-conformities, indicating when the process deviates from the expected or acceptable level. It aids in identifying potential issues and taking corrective actions to reduce the number of defects and maintain the desired quality level.

By using the appropriate control chart for attributes, organizations can effectively monitor and control quality characteristics that cannot be measured continuously, ensuring that products or services meet the desired quality standards.

Identifying and Elimination of Variations

One of the primary goals of using control charts is to monitor and improve process quality by identifying and eliminating sources of variation. Variations can be categorized into two types: common causes and special causes.

Understanding and distinguishing between these types is essential for effective quality control and improvement.

Common Causes

Common causes, also known as chance causes or noise, are the natural and random fluctuations inherent in a stable and predictable process. These variations affect every observation and are unavoidable unless the process itself is changed. Examples include slight differences in raw materials, temperature, humidity, or machine settings. A process influenced only by common causes is considered to be in control.

Special Causes

Special causes, also known as assignable causes or signals, are abnormal and non-random fluctuations due to external factors. These variations affect only some observations and are avoidable by identifying and addressing the root causes. Examples include a broken machine, defective raw materials, power outages, or human errors. A process affected by special causes is considered to be out of control.

Detecting Special Causes

Control charts plot process data over time and compare it with control limits, representing the expected range of variation due to common causes. If data points fall within the control limits, the process is in control and only affected by common causes. If data points fall outside the control limits or show a non-random pattern, the process is out of control and affected by special causes. Identifying these patterns allows for timely corrective actions to improve process quality. (FasterCapital, n.d.)

Exercise

In one of the previous semesters, students were assigned to produce a greeting card shown below:

Figure 6.5.6: "Greeting card"

Using simple tools like markers and plain A4 paper, they produced 54 batches of cards. The quality of their cards was examined in terms of the shape of the box, the position of the happy face, and the symmetry/size of the text. The following table summarizes the defects detected:

Sample number	Imperfect box	Face not centered	Big/skewed text
1	1	0	0
2	2	1	1
3	0	0	0
4	0	0	1
5	3	2	2
6	0	0	0
7	1	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	1	0
13	0	0	1
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	1
20	0	0	0
21	0	0	0
22	0	0	0
23	1	1	0
24	0	0	0
25	0	0	0
26	0	0	0
27	0	0	0
28	0	1	0
29	2	0	0
30	0	0	0

31	0	0	0
32	0	0	0
33	0	0	0
34	0	0	0
35	0	0	0
36	0	0	0
37	1	0	1
38	0	0	0
39	0	0	0
40	1	0	0
41	0	0	0
42	1	0	0
43	0	0	0
44	0	0	0
45	0	0	0
46	0	0	2
47	0	0	0
48	0	0	0
49	0	0	0
50	0	0	0
51	0	0	0
52	0	0	0
53	0	0	2
54	0	0	0

Based on the above data:

Create a check sheet, a Pareto Chart for the defects, and a control chart and determine how the students' production quality with respect to each variable (Box, Face, Text) changed over time.

6.6 CHAPTER SUMMARY & REVIEW

Summary

Chapter 6, "Managing Quality," delves into the critical aspects of ensuring quality in products and services. It begins by defining quality from the consumer's perspective, emphasizing that a product's success hinges on meeting or exceeding customer expectations. This chapter highlights the historical shift towards quality in operations management, particularly noting how Japanese manufacturers set high standards that North American companies had to catch up with. It distinguishes between design quality, which focuses on the product's inherent characteristics, and process quality, which ensures that manufacturing processes consistently produce defect-free products.

The chapter also introduces several key figures in the field of quality management, known as the quality gurus. These include Walter Shewhart, who pioneered statistical quality control; W. Edwards Deming, whose principles transformed Japanese manufacturing; Joseph Juran, known for the Juran Trilogy; Philip Crosby, an advocate for "zero defects"; and Armand Feigenbaum, who developed the concept of total quality management (TQM). Each guru's contributions helped shape modern quality management practices, emphasizing continuous improvement, customer satisfaction, and employee involvement.

Moreover, the chapter outlines various quality systems and methodologies such as TQM, ISO standards, and Six Sigma. It discusses the costs associated with maintaining quality, categorized into prevention, appraisal, internal failure, and external failure costs. Additionally, it describes quality improvement tools like check sheets, histograms, Pareto charts, scatter diagrams, cause and effect diagrams, and control charts. By implementing these tools and adhering to established quality frameworks, organizations can effectively monitor, control, and enhance their processes, ultimately leading to higher customer satisfaction and operational efficiency.

OpenAI. (2024, June 13). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than three paragraphs. Reviewed by authors.*

Review Questions

1. How do design quality and process quality differ, and why are both essential for achieving high product quality?
2. Discuss how consumer perceptions of quality can impact a company's success. Provide examples of how companies can bridge the gap between consumer expectations and product performance.
3. Explain the historical context that led North American companies to improve their quality standards. How did Japanese manufacturing practices influence this shift?
4. Compare and contrast the contributions of W. Edwards Deming and Joseph Juran to the field of quality management. How did their philosophies and methodologies shape modern quality practices?
5. Define and differentiate between prevention costs, appraisal costs, internal failure costs, and external failure costs. How can understanding these costs help a company manage its overall quality?
6. Describe the key principles of Total Quality Management (TQM). How do customer satisfaction, employee involvement, and continuous improvement contribute to TQM?
7. What are ISO standards, and why are they important for businesses? Discuss the steps involved in obtaining ISO certification and the benefits it can bring to an organization.
8. Explain the Six Sigma methodology and its DMAIC improvement model. How does Six Sigma help organizations reduce defects and improve quality?
9. Select two quality improvement tools (e.g., Pareto charts, control charts) and discuss how they are used in practice. Provide examples of how these tools can identify and solve quality issues.
10. Consider a product or service you are familiar with. Discuss how the principles and tools of

quality management could be applied to improve its quality. What steps would you take to implement these improvements?

OpenAI. (2024, June 13). *ChatGPT*. [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

6.7 KEY TERMS

Key Terms

- **Appraisal costs** refer to the resources dedicated to inspecting, testing, and evaluating products or services during the production or delivery process.
- **Assignable Variation** arises from identifiable and addressable causes, such as employee error, software malfunction, or equipment failure.
- **Black Belt:** A Black Belt is a full-time position within the quality department, where the individual works exclusively as a coach and leader for Six Sigma projects.
- **C-chart**, or count chart, monitors the number of defects or non-conformities in a sample or subgroup of constant size.
- **Cause-and-effect Diagrams,** also known as Fishbone diagrams, were developed by Dr. Kaoru Ishikawa to help identify the root causes of a problem. The diagram's overall shape resembles a fish's, with the "head" pointing to the effect or problem being analyzed. Each "rib" of the fishbone represents a major cause or category that could potentially contribute to the problem.
- **Champion:** A Champion is typically a senior manager or executive overseeing the Six Sigma program and its associated personnel.
- **Check Sheet** is a custom-designed form used to record the frequency or number of occurrences of a particular event or outcome of interest.
- **Common causes**, also known as chance causes or noise, are the natural and random fluctuations inherent in a stable and predictable process.
- **Common Variation**, also known as chance variation, is inherent to the process and generally expected.
- **Control Chart** is a statistical tool used to monitor and control the quality of a product or process. It is a graphical representation that depicts whether sample quality falls within the normal range of variation.

- **Cost of Quality**, a framework for understanding and managing the financial implications of quality.
- **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.
- **DMAIC Improvement Model** stands for Define, Measure, Analyze, Improve, and Control. Six Sigma's improvement method utilizes project teams to define problems, measure performance, analyze root causes, implement solutions, and establish controls for sustained improvement.
- **External failure costs** are incurred when defective products or non-conforming services reach the customer.
- **Green Belt:** A Green Belt designation indicates that an individual has received Six Sigma training.
- **HACCP** is a quality management system specifically designed for organizations in the food processing industry.
- **Hidden Plant**, refers to the untapped productive capacity lost due to inefficiencies, defects, and rework.
- **Histogram** is a graphical representation that displays the distribution of a dataset by grouping the data into bins or intervals along the horizontal axis and showing the frequency or count of observations in each bin on the vertical axis.
- **Internal failure costs** arise when defects or non-conformities are detected within the organization before the product or service is delivered to the customer.
- **Master Black Belt:** A Master Black Belt is a full-time position within the Six Sigma team, with extensive experience managing and overseeing Six Sigma projects.
- **Mean ($\bar{X}$) Chart:** This chart monitors the process mean or average value of the quality characteristic.
- **np-chart** monitors the number of defective items or units in a sample or subgroup of constant size.
- **P-charts**, or fraction defective charts, are useful when the quality characteristic cannot be quantified, such as holes in cloth or the absence of picture quality.
- **Pareto Char**t is a specialized type of bar chart that displays the frequency of occurrences for various characteristics, arranged in descending order from highest to lowest.
- **Pareto Principle**, also known as the 80/20 rule. This principle, originally an observation by Pareto that 80% of Italy's land was owned by 20% of the population, has become a cornerstone of problem-solving and continuous improvement efforts in quality

management. The principle suggests that a significant portion of problems (around 80%) often stem from a relatively small number of root causes (around 20%).

- **Prevention costs** encompass all expenditures aimed at proactively avoiding the occurrence of defects or non-conformities in products or services.
- **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.
- **Range (R) Chart:** This chart monitors the range or the difference between the highest and lowest values within a sample or subgroup.
- **Scatter Diagram** is a graphical representation that displays the relationship between two variables by plotting their values as a series of points on a Cartesian coordinate system.
- **Six Sigma** is a comprehensive set of techniques and tools designed for process improvement.
- **Special causes**, also known as assignable causes or signals, are abnormal and non-random fluctuations due to external factors.
- **Standard Deviation (σ) Chart**: This chart monitors the process variability by tracking the standard deviation of the quality characteristic.
- **The International Organization for Standardization (ISO)** is an independent, non-governmental organization that develops and publishes voluntary international standards.
- **Total Quality Management (TQM)**, also known as quality assurance, encompasses all the steps a company takes to ensure its products or services align with customer-defined specifications and maintain high quality.
- **Zero Defects** is a philosophy emphasizing the elimination of errors from the outset.

CHAPTER 7: SUPPLY CHAIN MANAGEMENT

Chapter Overview

7.0 LEARNING OUTCOMES

Learning Objectives

At the end of this chapter, students will be able to:

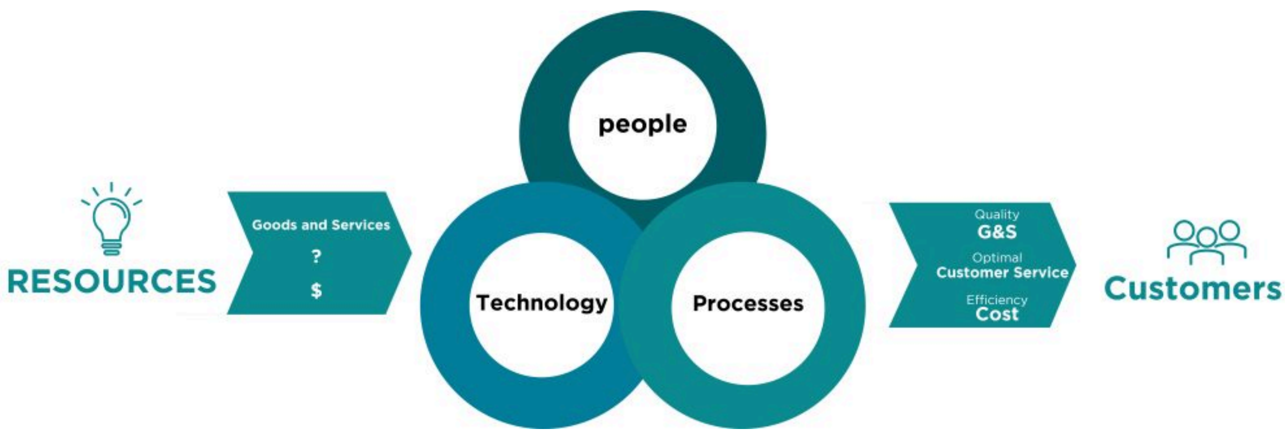
- Explain the fundamental concepts of supply chain management and its significance in fulfilling customer demands efficiently.
- Explain the material/goods flow, cash flow, and information flow within a supply chain and discuss their significance in maintaining efficient operations.
- Identify and explain the four key elements of supply chain management: supply management, internal operations management, distribution management, and integration management.
- Analyze different supply chain design strategies and assess how companies balance efficiency and responsiveness based on customer needs.
- Evaluate various inventory management practices and justify the reasons for maintaining different types of inventory within a supply chain.
- Compare different modes of transportation and discuss how companies choose the most appropriate mode for various types of shipments.
- Explain the role of technologies such as EDI, barcodes, QR systems, and RFID in enhancing supply chain operations and improving data capture and inventory management.
- Discuss collaborative practices like Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR) and their benefits for optimizing supply chain performance.
- Identify and explain the elements of socially responsible supply chain management by embracing ethically, socially, and environmentally sustainable practices along with economic gain.

7.1 INTRODUCTION

Supply Chain: A Collaborative Network

Supply chain refers to the interconnected network of organizations involved in fulfilling a customer order, from sourcing raw materials to delivering the final product. In contemporary marketplaces, customers demand quality goods and services, but not at high prices, and optimal customer service before and after they buy those products or services. They do not care how all this would be done for them, but on the other side of the spectrum, there are people with resources (goods, services, information, capital, etc.) that must be converted to the goods and services demanded in the market.

To make this possible, many participating operations would get involved, each connected with and adding value to the previous operations. The following figure shows that the elements linking these operations are people, processes and technology.



"Supply Chain Network" by Sanaz Habibi, CC BY-NC-SA 4.0

Each participant plays a crucial role in adding value for the end consumer. The supply chain encompasses suppliers, manufacturers, transporters, distribution centers, wholesalers, retailers, and end-consumers. Consider them as loops in a chain; if one operation does not add value to the previous one or does not support the next one, the chain will break.

The Strength of the Chain

The effectiveness of a supply chain is determined by its weakest link. This principle underscores the importance of supply chain management, which extends beyond a company's internal operations. Organizations must actively collaborate with their supply chain partners to ensure optimal performance at every stage.

Ripple Effect of Inefficiencies

A weakness in any link of the supply chain can have far-reaching consequences. For instance, if a retailer fails to replenish inventory promptly, it can lead to product unavailability for end-consumers, resulting in lost sales. This ripple effect propagates upstream, with fewer orders placed with manufacturers and, consequently, reduced demand for raw materials from suppliers. Ultimately, the entire supply chain suffers financial implications due to a single weak link.

Collaborative Optimization

To mitigate such risks and maximize efficiency, organizations must adopt a collaborative approach to supply chain management. Regular communication and coordination with supply chain partners are essential to identify and address potential bottlenecks proactively. By fostering a culture of continuous improvement and leveraging advanced technologies, companies can optimize their supply chain operations, ensuring timely delivery of products and services while minimizing waste and maximizing customer satisfaction.

For example, if a retail store is not doing a good job at replenishing its 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 been 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 they could if the retailer ordered the right quantity at the right time.

7.2 MANAGING MAIN FLOWS IN THE SUPPLY CHAIN

Supply chains are governed by three fundamental flows: the flow of materials/goods, the flow of money/cash, and the flow of information. These flows are intrinsically linked and essential for the efficient operation of any supply chain.

Material/Goods Flow

The **material/goods flow** represents the physical movement of products along the supply chain. It typically follows a forward direction, originating from higher-tier suppliers (upstream) and progressing toward the end consumer (downstream). However, in returns or reverse logistics cases, a reverse flow of materials/goods occurs in the opposite direction.

Cash Flow

The **cash flow**, or the flow of money, moves in the opposite direction to the material/goods flow. It originates from downstream entities, such as retailers, who pay distributors or manufacturers for the goods received. This flow continues upstream, with each participant in the supply chain receiving payment for their contributions.

Information Flow

The flow of information is bidirectional, enabling effective communication and coordination among supply chain partners. Organizations share various types of information, including demand forecasts, inventory levels, production schedules, and logistics data. This exchange of information facilitates better decision-making and optimizes the overall performance of the supply chain.

Synchronization and Optimization

Effective supply chain management requires the seamless integration and synchronization of these three flows. By aligning the material/goods flow with the cash flow and leveraging the flow of information, organizations can streamline operations, reduce waste, and enhance customer satisfaction. Advanced technologies and collaborative practices enable real-time monitoring and optimization of these flows, driving efficiency and competitiveness within the supply chain.

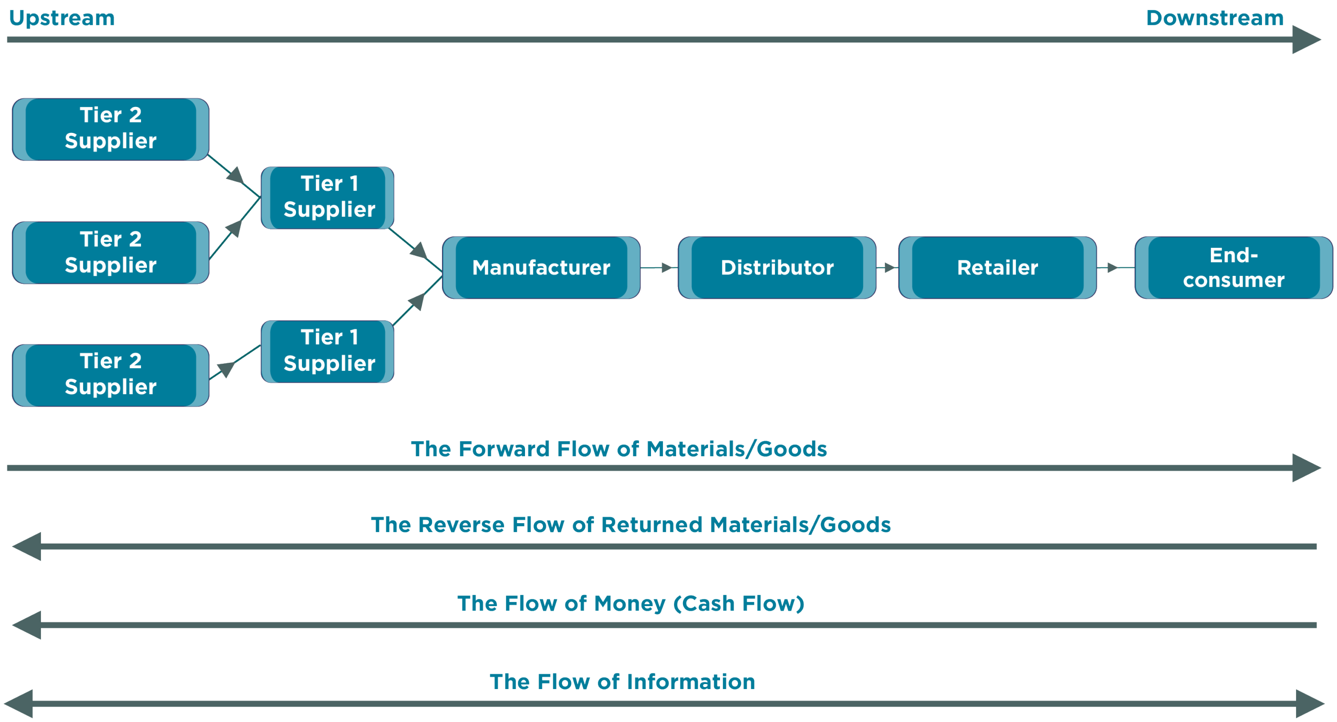


Figure 7.2.1: Upstream and downstream of a supply chain and its flows. Mods: recoloured by Fanshawe College

Image Description

This diagram illustrates the various stages and flows within a supply chain, highlighting the upstream and downstream activities. The diagram is organized as follows:

1. Upstream (on the left side of the diagram):
    - Tier 2 Suppliers: There are three boxes labelled "Tier 2 Supplier," indicating the suppliers that provide raw materials or components to the Tier 1 suppliers.
    - Tier 1 Suppliers: Two boxes labelled "Tier 1 Supplier" receive inputs from Tier 2 Suppliers and pass their outputs to the manufacturer.
2. Downstream (on the right side of the diagram):
    - Manufacturer: The manufacturer receives components from Tier 1 Suppliers, processes them, and forwards the products to the distributor.

- Distributor: The distributor receives products from the manufacturer and distributes them to retailers.
- Retailer: The retailer receives products from the distributor and sells them to the end-consumer.
- End-consumer: The final recipient of the product in the supply chain.

3. Flow Descriptions:

    - The Forward Flow of Materials/Goods: An arrow at the top indicates the movement of materials and goods from upstream to downstream.
    - The Reverse Flow of Returned Materials/Goods: An arrow below the forward flow indicates the movement of returned goods from the end-consumer back up the supply chain.
    - The Flow of Money (Cash Flow): An arrow indicates the flow of money in the opposite direction, from the end-consumer to the upstream suppliers.
    - The Flow of Information: An arrow at the bottom indicates the bidirectional flow of information throughout the supply chain.

Video: "What is Supply Chain Management? Definition, Introduction, Process & Examples | AIMS UK" by AIMS Education, UK [12:07] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

7.3 FOUNDATIONAL ELEMENTS OF SUPPLY CHAIN MANAGEMENT

For organizations within a supply chain, effective management hinges on four key elements: supply management, internal operations management, distribution management, and integration management. These elements form the foundational pillars that enable harmonious collaboration among all participants in the supply chain. Figure 7.3.1 illustrates the interplay of these elements within a company's supply chain.

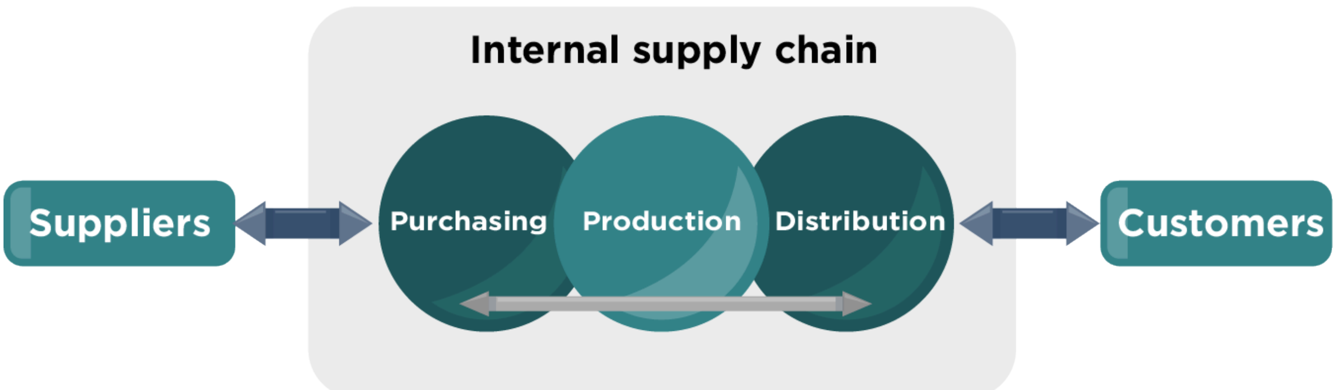


Figure 7.3.1: "A company's supply chain" by Stern, CC BY-SA 3.0. Mods: re-coloured by Fanshawe College. The internal supply chain starts with suppliers providing the raw materials purchased, manufactured into goods and distributed to the customers.

Supply Management

Supply management encompasses the procurement and management of suppliers and the cultivation of strong relationships with them. This element involves activities such as supplier selection, contract negotiation, and performance monitoring to ensure a reliable and efficient flow of materials or services.

Internal Operations Management

Internal operations management focuses on the processes and activities through which a company adds value to its products or services. For a manufacturer, this may include production planning, inventory management (both raw materials and finished goods), human resource management, and quality control processes.

Distribution Management

Distribution management involves managing customer relationships and developing a deep understanding of their needs and preferences. This element ensures that the right products or services are delivered to the right customers at the right time, fostering customer satisfaction and loyalty.

Integration Management

Integration management serves as the glue that binds the other elements together. It leverages technologies such as Enterprise Resource Planning (ERP) systems to facilitate seamless collaboration and information sharing among the various components of the supply chain. This integration enables accurate and efficient coordination, enhancing overall supply chain performance.

By effectively managing these four foundational elements, organizations can optimize their supply chain operations, reduce waste, and enhance customer satisfaction. Successful supply chain management requires a holistic approach, where each element is carefully orchestrated to support the overarching goals of the supply chain network.

Video: “Module 6: Supply Chain Integration – ASU’s W. P. Carey School” by W. P. Carey School of Business [4:40] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

7.4 SUPPLY CHAIN DESIGN

Supply chain design is a strategic decision that determines various entities' roles, responsibilities, and geographical locations within the supply chain network. Companies adopt different supply chain structures to align with their business objectives and customer preferences. For instance, Walmart traditionally relied on brick-and-mortar stores to serve customers, while Amazon has leveraged an online platform to direct shipments from distribution centers.

Balancing Efficiency and Responsiveness

When designing a supply chain, two critical factors must be considered: efficiency (cost reduction) and responsiveness. The balance between these two factors varies across companies, depending on customer preferences. If customers are willing to wait 5-7 days for online orders, a company can consolidate inventory in fewer locations and leverage longer transportation times. However, if customers demand immediate product availability, the company may need to establish multiple retail locations and maintain sufficient inventory at each site to respond promptly to customer needs.

Vertical and Horizontal Integration

Companies can choose to outsource certain supply chain functions or maintain control over various stages through vertical and horizontal integration strategies.

- **Vertical Integration:** Vertical integration occurs when a firm owns more than one portion of its supply chain. For a manufacturer, this could involve owning distributors or retail stores for forward integration (reaching end-consumers directly) or acquiring suppliers for backward integration (controlling the sourcing of materials or components).
- **Horizontal Integration:** Horizontal integration involves a business expanding its holdings by acquiring or merging with another firm operating in the same market. Examples include the 2015 merger of Kraft Foods and Heinz, and Marriott International's acquisition of Starwood Hotels in 2016.

Tailoring the Supply Chain Design

By carefully designing their supply chain structure, companies can optimize operational efficiency, enhance responsiveness, and align with customer expectations. This strategic decision involves evaluating factors such as product characteristics, market dynamics, and competitive landscape, ultimately shaping supply chain entities' roles, responsibilities, and locations to achieve a competitive advantage.

Examples

Ford's Vertical Integration Strategy

In the early 20th century, Ford Motor Company embarked on a strategic vertical integration approach surrounding its Highland Park Plant. This complex included a power plant, machine shop, and foundry, enabling Ford to consolidate various stages of automobile manufacturing under its control.

"Fordlandia-Brazil", Amit Evron, CC BY-SA 3.0

By the 1920s, Ford had acquired a rubber plantation in Brazil, coal mines in Kentucky, timberlands and iron-ore mines in Michigan and Minnesota, a fleet of ships, and a railroad. These efforts aimed at vertical integration ensured a reliable supply of raw materials and parts, guaranteeing a continuously operating assembly line.

Ford's vertical integration strategy secured the necessary resources for production and enabled the company to profit from multiple processes involved in automobile manufacturing. This approach gave Ford greater control over its supply chain, reducing dependencies and enhancing operational efficiency (Parkhani, 2019; Stanford, n.d.).

Netflix's Backward Vertical Integration

Netflix exemplifies a significant backward vertical integration strategy in the entertainment industry. Initially, Netflix operated at the end of the supply chain as a platform for distributing films and TV shows created by other content creators.

"Netflix TV" by Stock Catalog & Quote Catalog, CC BY 2.0

While this business model was profitable, Netflix's leaders recognized the potential for greater revenue generation by creating their own original content. This strategic move would reduce their reliance on external content creators and cater to the growing demand among subscribers for original programming.

By leveraging their existing distribution platform, Netflix could effectively promote and deliver their original content to a captive audience. This backward vertical integration strategy has become crucial for Netflix's continued success as more film studios terminate their licensing agreements with the streaming giant. The company's original content has become a primary attractor for new subscribers, solidifying its highly competitive entertainment industry position.

Both examples illustrate how vertical integration strategies, whether forward or backward, can provide companies with greater control over their supply chains, secure access to critical resources, and create opportunities for revenue diversification and growth (Quain, 2018).

7.5 THE ROLE OF INVENTORY IN THE SUPPLY CHAIN

Inventory management is a critical activity within the supply chain, ensuring that materials and goods are available in the right quantities, at the right locations, and at the right time. Without proper inventory management, producing high-quality goods and meeting customer commitments is impossible.

Types of Inventories in the Supply Chain

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

Reasons for Holding Inventories

There are several reasons why organizations maintain inventory stocks:

1. *Seasonal Demand:* Manufacturers often build up inventories throughout the year to meet seasonal demand fluctuations. For example, a chocolate manufacturer may begin stockpiling inventory in late spring to fulfill the high demand during the Christmas season.
2. *Supply Chain Risks:* Companies may carry larger inventories to mitigate risks associated with their supply base, such as shortages, work stoppages, poor quality, or late deliveries from suppliers.
3. *Cost Optimization:* Organizations may be incentivized to purchase larger order quantities to take advantage of discounts or minimize transportation costs. Additionally, concerns about future price increases can prompt companies to build up their inventories.
4. *Customer Service:* Retailers carry inventory to ensure they can meet customer demand without running out of stock. Distributors and retailers strive to balance the cost of maintaining large inventories with

providing excellent customer service and minimizing disappointed customers.

5. *Supply Chain Synchronization:* Aligning the incoming flow of materials and goods with production schedules and customer shipments can be challenging. As a result, inventory may be stored at various locations along the supply chain, leading to additional costs and inefficiencies.

Effective inventory management is crucial for supply chain optimization. It involves balancing between maintaining sufficient stock levels to meet customer demand and minimizing the costs associated with carrying excess inventory. Advanced techniques, such as demand forecasting, inventory optimization, and supply chain visibility, can help organizations achieve this delicate balance and enhance overall supply chain performance.

7.6 LOGISTICS: COORDINATING THE MOVEMENT OF RESOURCES

Logistics refers to the coordination and movement of resources, particularly inputs into the transformation process and finished goods out to customers. Originally derived from military operations, logistics involves managing the flow of troops, equipment, and supplies. In a business context, logistics management encompasses the following decisions:

1. Determining whether to operate and manage the firm's transportation activities in-house or outsource them.
2. Selecting suppliers with the capability to ship goods safely and securely within the required time frame.
3. Choosing the appropriate mode of transportation and the most effective route.
4. Negotiating shipping rates.

Modes of Transportation

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

Trucking: The Backbone of Freight Transportation

Trucking plays a pivotal role in the movement of goods, with the majority of shipments relying on trucks either entirely or at some point during the transportation process. Trucking stands out as the most flexible mode of transportation, offering two primary categories:

1. Truck-Load (TL): In this category, an entire truck is hired and dedicated to a single shipment, ensuring direct delivery from origin to destination.
2. Less-than-Truckload (LTL): This approach involves consolidating multiple orders onto a single truck, thereby increasing the utilization of the vehicle and optimizing transportation costs.

Overcoming the driver shortage is crucial for maintaining the efficiency and reliability of the trucking sector, which serves as the backbone of freight transportation. By addressing this challenge proactively, the industry can ensure its continued ability to meet the ever-growing demand for timely and flexible goods movement, supporting the overall supply chain and economic growth.

Rail Transportation: Efficient Long-Haul Logistics

Rail offers a cost-effective solution for transporting containerized, bulky, and heavy goods over long distances. In Canada, rail plays a vital role in shipping diverse commodities like automobiles, fertilizers, food, forest products, grains, metals, minerals, and petroleum products.

Key advantages of rail include:

- Suitability for large-scale shipments, prompting manufacturers to locate near rail lines for efficient logistics.
- High energy efficiency compared to trucking, reducing environmental impact and highway congestion.
- Canada's well-established, extensive rail infrastructure supports nationwide cargo movement.

By leveraging rail's ability to move large volumes cost-effectively over long hauls, businesses can optimize supply chains, reduce transportation costs, and enhance sustainability. Rail's integration with other modes enables multimodal logistics solutions, boosting efficiency and flexibility in goods movement.

Airfreight: Rapid Transit for High-Value Cargo

Airfreight is the preferred mode for expensive, small, and lightweight goods where speed takes precedence over cost. Air carriers charge based on weight and dimensions, suiting high-value, time-sensitive shipments.

Key advantages:

- Unparalleled speed and reliability for rapid long-distance transport
- Beneficial for industries prioritizing timely delivery, like electronics and pharmaceuticals

Considerations:

- Higher environmental impact due to greenhouse gas emissions
- Firms should explore strategies like shipment consolidation, carbon offsetting, or alternative modes for non-urgent shipments

By balancing speed requirements with environmental concerns, businesses can leverage airfreight judiciously for high-value, time-critical cargo while promoting sustainable logistics practices.

Waterway Transportation: Cost-Effective for Bulk Shipments

Waterways are a common mode for shipping heavy commodities like chemicals, stone, cement, sugar, coal, and other bulk materials. Millions of containers travel by ship annually.

Key advantages:

- Cost-effectiveness, especially for low-cost, bulk products.
- Major systems like the Great Lakes St. Lawrence Seaway, a 3,700-kilometer marine highway opened in 1959, facilitate trade between Canada and the U.S., serving many industries to ship iron ore, coal, limestone, steel, grain and cement (The St. Lawrence Seaway Management Corporation, n.d.).
- Reduces road congestion and environmental impact by diverting freight from highways.

Waterway transportation offers an efficient and economical logistics solution for industries relying on bulk commodity movement or low-cost product shipments.

As global trade grows, the importance of waterways in optimizing supply chain costs and reducing environmental footprint remains significant.

Do you know what goods are transported through the ship?

Pipeline Transportation

Pipelines are the primary mode of transportation for crude oil, natural gas, and other petroleum products. Once the pipeline infrastructure is established, the cost per kilometre for shipping these commodities is relatively inexpensive.

However, the construction of new pipelines often faces significant opposition and concerns due to the potential risks of spills and leaks, which can lead to land and water contamination, posing environmental threats.

Multimodal/Intermodal Shipping: Integrated Logistics Efficiency

Multimodal and intermodal shipping leverage multiple transportation modes (e.g., truck/ship/rail) to move goods efficiently from origin to destination under a single contract. Intermodal shipping utilizes containers, minimizing handling during mode transfers.

Key benefits:

- Increased security and reduced loss/damage
- Enhanced speed through streamlined mode transfers
- Optimized efficiency by utilizing the strengths of each mode

With designated carriers responsible for each leg, these integrated solutions enable coordinated, accountable, and seamless logistics operations.

Multimodal/intermodal shipping combines various modes and provides businesses with flexible and efficient supply chain solutions for optimizing goods movement across diverse regions.

Figure 7.6.1: Diagram summarizing various modes of transportation.

Distribution Management: Orchestrating Efficient Product Flow

Distribution management refers to the process of overseeing the movement of goods from suppliers or manufacturers to the point of sale. It is a critical component of the business cycle for distributors and wholesalers, as their profitability hinges on the ability to rapidly turn over their inventory. The faster goods are sold, the higher the earnings, ensuring the business's future growth and success. Effective distribution management is essential for businesses to remain competitive and maintain customer satisfaction.

Distribution encompasses a diverse range of functions, including customer service, shipping, warehousing, inventory control, private trucking fleet operations, packaging, receiving, and materials handling, as well as strategic planning for plant, warehouse, and store locations. Additionally, the integration of information systems plays a crucial role in streamlining distribution processes.

The overarching goal of distribution management is to achieve ultimate efficiency in delivering raw materials, parts, and both partially and completely finished products to the right place, at the right time, and in the proper condition (Kenton, 2019).

The combination of distribution and transportation forms the backbone of logistics operations. In any logistics system, the most critical factor is the ability to deliver products quickly while maintaining their perfect condition. Companies like Amazon have leveraged their supply chain management expertise to fuel their rise to the top, demonstrating the importance of efficient distribution in achieving business success.

By effectively managing distribution processes, businesses can optimize inventory levels, reduce costs, and enhance customer satisfaction, ultimately driving profitability and competitiveness in their respective markets.

The combination of distribution and transportation is logistics. The most important factor in any logistics is quickly delivering the product in perfect condition.

How Amazon has used its supply chain management to fuel its rise to the top

Cross-docking: Streamlining Product Flow

Cross-docking involves transferring goods directly from inbound to outbound carriers, bypassing warehousing and storage. Products "cross the docks" from receiving to shipping areas.

Key benefits:

- Inventory savings by eliminating storage costs
- Accelerated delivery for improved customer service
- Reduced handling and risk of damage
- Optimized space utilization

Cross-docking streamlines supply chains by minimizing product movement time and resources is ideal for time-sensitive, perishable, or high-turnover goods.

Effective implementation requires synchronizing inbound/outbound shipments, collaborating with partners, and leveraging technologies like real-time tracking.

Through cross-docking, businesses can optimize operations, reduce inventory costs, and enhance timely, cost-effective product delivery for competitive advantage.

7.7 COMMUNICATION AND TECHNOLOGY IN THE SUPPLY CHAIN

Electronic Data Interchange (EDI): Enabling Seamless Business Communication

Electronic Data Interchange (EDI) is a computer-to-computer exchange of business documents, such as purchase orders and invoices, in a standardized electronic format between business partners. This technology facilitates the automated transfer of documents between organizations, eliminating the need for manual intervention.

EDI enables companies to seamlessly exchange critical business information, such as purchase orders, invoices, advance shipment notices, customs documents, inventory data, shipping status, payment documents, bills of lading, and sales/price catalogues.

The primary advantages of EDI include: (EDI Resource Center, n.d.)

1. *Speed and accuracy:* Information is transmitted in real-time, minimizing delays and eliminating errors that may occur during manual data entry processes.
2. *Automation:* By automating document exchange, EDI reduces the need for human intervention, streamlining business processes and improving operational efficiency.
3. *Cost savings:* Eliminating manual data entry and associated errors can lead to significant cost savings for businesses.
4. *Improved collaboration:* EDI enhances collaboration and communication between business partners by providing a standardized and secure platform for information exchange.
5. *Compliance and traceability:* EDI systems often incorporate robust security measures and audit trails, ensuring compliance with regulatory requirements and enabling traceability of transactions.

EDI plays a crucial role in supply chain integration in operations management, enabling seamless communication and coordination among suppliers, manufacturers, distributors, and retailers. By facilitating the real-time exchange of critical business documents, EDI supports efficient inventory management, production planning, and logistics operations, ultimately improving supply chain performance and customer satisfaction.

As businesses continue to embrace digital transformation and seek to optimize their operations, adopting

EDI becomes increasingly important, enabling organizations to streamline their processes, enhance collaboration, and gain a competitive edge in the marketplace.

Barcodes: Enabling Efficient Data Capture

Barcodes, widely adopted since the 1970s, display machine-readable data that can be scanned by barcode readers, containing information like pricing, product numbers, and descriptions.

Key advantages in retail operations:

- Accurate pricing and easy price changes
- Real-time inventory tracking and updates
- Identification of fast/slow-moving products for forecasting

Benefits across industries:

- Eliminates manual data entry errors
- Streamlines processes like inventory management and checkout
- Enables product traceability throughout the supply chain
- Supports inventory control and optimization
- Provides data for analysis and process improvements

Barcodes have become an integral part of modern supply chain and inventory management systems, driving operational efficiency, cost savings, and improved customer service through efficient data capture and tracking.

Quick Response (QR) Systems: Enabling Just-in-Time Retail Replenishment

QR systems leverage barcodes and EDI to provide vendors with real-time sales data for prompt replenishment of goods in the correct quantities – a just-in-time (JIT) approach for retail.

Key objectives:

- Reducing out-of-stock incidents through timely replenishment
- Optimizing inventory levels with smaller, frequent deliveries
- Enabling a responsive and agile supply chain
- Fostering retailer-vendor collaboration and coordination

Benefits include improved inventory management, reduced stockouts, lower operating costs, and better alignment of supply with demand.

As consumer expectations evolve, QR systems and JIT strategies become crucial for maintaining competitiveness and meeting customer demands effectively in the retail industry.

Radio Frequency Identification (RFID): Wireless Data Tracking

RFID utilizes radio waves to communicate data stored on tags attached to objects, such as product details, shipment information, and pricing. It requires a tag and reader, with active tags containing a power source for a longer range and passive tags relying on the reader's energy.

Key advantages over barcodes:

- No line-of-sight required for data transmission
- Enables flexible and efficient tracking processes

Applications across industries:

- Retail inventory management and theft prevention
- Shipping and asset tracking (tools, devices, luggage)
- Access control and identification (passports, toll payments)
- Race timing and event management

RFID technology streamlines operations, improves supply chain visibility, enhances security, and optimizes asset management through wireless data capture and real-time tracking capabilities.

As costs decrease, RFID adoption is expected to grow, enabling businesses to gain competitive advantages through improved data management and operational excellence.

7.8 SUPPLY CHAIN COLLABORATION

Vendor Managed Inventory (VMI)

VMI is an advanced supply chain relationship where a vendor manages and maintains agreed inventory levels at the customer's location, leveraging access to real-time inventory data.

Key benefits

For vendors:

- Motivation to ensure fully stocked shelves and discontinue slow movers
- Opportunity for comprehensive product training and support
- Improved inventory visibility and demand forecasting

For customers:

- Reduced workload in inventory management
- Fewer errors and faster goods flow through EDI integration
- Automated replenishment based on point-of-sale data
- Access to vendor expertise and on-site support

VMI fosters closer vendor-customer collaboration, enabling optimized inventory levels, reduced stockouts, and enhanced supply chain efficiency.

Successful implementation requires trust, transparency, effective communication, and robust information sharing between partners.

VMI represents a strategic approach to collaborative inventory management and operational excellence across the supply chain.

Collaborative Planning, Forecasting, and Replenishment (CPFR): Aligning Supply Chain Partners

CPFR enables trading partners (manufacturer and distributor/retailer) to collaborate on forecasting and order planning by:

- Sharing point-of-sale data, promotion plans, inventory status, and forecasts.
- Comparing shared data with manufacturer's forecasts and capacity.
- Collaboratively resolving discrepancies and agreeing on final forecasts/replenishment plans.

Key benefits

- Inventory optimization and reduced stockouts
- Improved demand visibility for better production planning
- Proactive problem-solving for potential issues
- Strengthened partner relationships and trust

Effective CPFR implementation requires commitment, trust, information sharing, and robust technology platforms between partners.

By aligning forecasts and replenishment strategies, CPFR helps optimize operations, reduce costs, and enhance customer service levels across the supply chain.

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 reduce problems such as shortages and capacity problems.

Measuring Supply Chain Performance

Video: "How to Measure Supply Chain Performance" by Skillsoft YouTube [3:11] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

Inventory Turnover: A Key Performance Indicator for Supply Chain Efficiency

Key Performance Indicators are measurements used to evaluate supply chain performance. One of the ways to evaluate the supply Key Performance Indicators (KPIs) are essential measurements used to evaluate supply chain performance. One crucial KPI is inventory turnover, which is calculated using the following formula:

$$\text{Inventory Turnover} = \frac{\text{Cost of Goods Sold}}{\text{Average Aggregate Inventory Value}}$$

The "**average aggregate inventory value**" refers to the total inventory held in stock, including raw materials, work-in-process, and finished goods, valued at cost.

Inventory turnover indicates an organization's policies and practices, reflecting its ability to purchase materials, produce, and sell products in a timely manner. A higher inventory turnover value signifies that the organization has more effectively replenished and sold its inventory within a given period, resulting in better cash flow.

It is important to note that the interpretation of high or low inventory turnover values is relative to the specific industry. For example, the dairy (milk) manufacturing industry typically has an annual inventory turnover of around 23, while grocery supermarkets have a turnover of 14.7, and the automotive industry has a turnover of 4.8. Industries with higher volume and lower margins generally have the highest inventory turnover.

Analyzing inventory turnover provides valuable insights into supply chain efficiency and inventory management practices. A high turnover rate may indicate effective inventory management and a well-optimized supply chain, while a low turnover rate could suggest potential issues such as overstocking, slow-moving inventory, or inefficient production processes.

By monitoring and optimizing inventory turnover, businesses can improve their cash flow, reduce carrying costs, and enhance overall supply chain performance. However, it is crucial to consider industry-specific factors and benchmarks when interpreting and setting targets for inventory turnover.

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:

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

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:

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) × 365 = 24.54

This measure can be thought of as the amount of inventory sitting in the building at any one time. A lower number is better for measuring the efficiency of the inventory. This implies that goods are purchased more frequently and that less time is spent 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, the 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: Embracing Ethical and Sustainable Practices

Socially responsible supply chain management encompasses a range of practices promoting ethical, environmentally conscious, and socially responsible operations throughout the supply chain.

The main areas of focus include:

- *Organizational practices:* Implementing policies and procedures that foster transparency, accountability, and good governance within the organization and its supply chain partners.
- *Ethical practices:* Adhering to ethical standards and codes of conduct that promote fair business

practices, anti-corruption measures, and responsible sourcing of materials and components.

- *Environmental practices:* Adopting environmentally sustainable practices, such as reducing carbon footprint, minimizing waste, and promoting the use of renewable resources and energy-efficient processes throughout the supply chain.
- *Human rights and working conditions:* Ensuring that supply chain partners respect and uphold human rights, provide fair working conditions, and prohibit practices such as child labour, forced labour, and discrimination.
- *Occupational health and safety:* Prioritizing the health and safety of workers by implementing robust occupational health and safety measures, providing appropriate training, and ensuring compliance with relevant regulations.
- *Community engagement:* Establishing positive relationships with local communities by supporting community development initiatives, promoting local employment, and minimizing negative environmental and societal impacts.

By embracing socially responsible supply chain management practices, organizations can mitigate risks associated with unethical or unsustainable practices and contribute to the well-being of society and the environment. This approach can enhance brand reputation, foster customer loyalty, and attract socially conscious investors and stakeholders.

Implementing socially responsible supply chain management requires a comprehensive strategy, strong leadership commitment, and collaboration with supply chain partners. It involves setting clear goals, establishing monitoring and reporting mechanisms, and continuously improving practices to align with evolving social and environmental standards.

Video: “Building A Sustainable (Responsible) Supply Chain Management System” by InterPraxis Sustainability [6:23] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

The following table (Ciliberti et al., 2008) summarizes activities and practices considered good examples for the CSR areas listed above.

Relevant CSR Areas	Sample Practices
Organizational Practices	• Determining CSR goals for the 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 the supplier selection process) • Not creating illegitimate pressures on suppliers • Not sharing price and service information about suppliers with other irrelevant stakeholders • Not favouring any particular supplier just because of managers' preferences and assuring a fair selection process • Assuring all departments meet ethical standards in the 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 to reduce waste (especially hazardous waste) • Putting special emphasis on producing recyclable and reversible materials in production and design • Meeting standards for protecting the 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 the 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 ensure 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 ensure 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 not-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 the 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: R. Edward Freeman at TEDxCharlottesville 2013" by TEDx Talks [17:38] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

7.9 CHAPTER SUMMARY & REVIEW

Summary

Chapter 7, "Supply Chain Management," focuses on the interconnected network of organizations involved in fulfilling customer orders, highlighting the collaborative nature of supply chains. It discusses the importance of each participant's role in adding value, from suppliers and manufacturers to retailers and end-consumers, and emphasizes that the chain's strength is determined by its weakest link. Inefficiencies at any stage can cause ripple effects throughout the supply chain, impacting the entire network's financial performance. To mitigate these risks, organizations must adopt collaborative optimization, involving regular communication and coordination with supply chain partners to identify and address potential bottlenecks proactively.

The chapter also explores the three main flows governing supply chains: materials/goods, cash, and information. The material/goods flow represents the physical movement of products, typically progressing from suppliers to end-consumers. The cash flow moves in the opposite direction, starting from downstream entities like retailers and moving upstream to suppliers. The information flow is bidirectional, enabling effective communication and coordination among supply chain partners. Synchronizing and optimizing these flows through advanced technologies and collaborative practices can drive efficiency, reduce waste, and enhance customer satisfaction. The chapter highlights key elements for effective supply chain management, including supply management, internal operations management, distribution management, and integration management, each playing a crucial role in optimizing operations and achieving supply chain goals.

Finally, the chapter delves into supply chain design, emphasizing the need to balance efficiency and responsiveness based on customer preferences. It discusses vertical and horizontal integration strategies, such as Ford's vertical integration and Netflix's backward integration, demonstrating how companies can control various stages of their supply chains to secure resources and enhance operational efficiency. The role of inventory management is also addressed, highlighting the reasons for holding inventories and the importance of effective logistics and transportation modes in coordinating resource movement. Additionally, the chapter covers the impact of communication and technology, such as EDI, barcodes, QR systems, and RFID, in streamlining supply chain operations, enhancing data capture, and enabling just-in-time inventory management. Collaborative practices like Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR) are also discussed, illustrating the benefits of aligning supply chain partners to optimize performance and ensure customer satisfaction.

OpenAI. (2024, June 14). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than three paragraphs. Reviewed by authors.*

Review Questions

1. Explain the concept of a supply chain as a collaborative network. How does each participant in the supply chain add value to the final product?
2. Discuss the ripple effect of inefficiencies in the supply chain. Provide an example of how a delay at one stage can impact the entire supply chain.
3. What are the key elements of collaborative optimization in supply chain management? How can regular communication and coordination with supply chain partners improve overall efficiency?
4. Describe the three fundamental flows in the supply chain: material/goods flow, cash flow, and information flow. How do these flows interrelate to ensure efficient supply chain operations?
5. Discuss the strategic decisions involved in supply chain design. How do companies balance efficiency and responsiveness, and what factors influence these decisions?
6. Compare and contrast vertical and horizontal integration strategies in supply chain

management. Provide examples from the chapter, such as Ford's vertical integration and Netflix's backward integration.

7. Why is inventory management critical in the supply chain? Discuss the different types of inventories and the reasons for holding them.
8. Explain the various modes of transportation discussed in the chapter (trucking, rail, airfreight, waterway, pipeline, and multimodal shipping). How do companies decide which mode to use for different types of shipments?
9. How do technologies like Electronic Data Interchange (EDI), barcodes, QR systems, and RFID enhance supply chain operations? Discuss their roles in improving data capture and inventory management.
10. What are Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR)? How do these collaborative practices benefit both suppliers and customers in the supply chain?

OpenAI. (2024, June 14). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

7.10 KEY TERMS

Key Terms

- **Average aggregate inventory value** refers to the total inventory held in stock, including raw materials, work-in-process, and finished goods, valued at cost.
- **Barcodes**, widely adopted since the 1970s, display machine-readable data that can be scanned by barcode readers, containing information like pricing, product numbers, and descriptions.
- **Cash flow**, or the flow of money, moves in the opposite direction to the material/goods flow.
- **Collaborative Planning, Forecasting, and Replenishment (CPFR):** enables trading partners (manufacturer and distributor/retailer) to collaborate on forecasting and order planning.
- **Cross-docking** involves transferring goods directly from inbound to outbound carriers, bypassing warehousing and storage.
- **Distribution management** refers to the process of overseeing the movement of goods from suppliers or manufacturers to the point of sale.
- **Electronic Data Interchange (EDI)** is a computer-to-computer exchange of business documents, such as purchase orders and invoices, in a standardized electronic format between business partners.
- **Horizontal Integration:** Horizontal integration involves a business expanding its holdings by acquiring or merging with another firm operating in the same market.
- **Integration management** serves as the glue that binds the other elements together. It leverages technologies such as Enterprise Resource Planning (ERP) systems to facilitate seamless collaboration and information sharing among the various components of the supply chain.
- **Internal operations management** focuses on the processes and activities through which a

company adds value to its products or services.

- **Inventory management** is a critical activity within the supply chain, ensuring that materials and goods are available in the right quantities, at the right locations, and at the right time.
- **Key Performance Indicators** are measurements used to evaluate supply chain performance.
- **Logistics** refers to the coordination and movement of resources, particularly inputs into the transformation process and finished goods out to customers.
- **Material/goods flow** represents the physical movement of products along the supply chain.
- **QR systems** leverage barcodes and EDI to provide vendors with real-time sales data for prompt replenishment of goods in the correct quantities – a just-in-time (JIT) approach for retail.
- **Radio Frequency Identification (RFID)** utilizes radio waves to communicate data stored on tags attached to objects, such as product details, shipment information, and pricing.
- **Socially responsible supply chain management** encompasses a range of practices promoting ethical, environmentally conscious, and socially responsible operations throughout the supply chain.
- **Supply chain design** is a strategic decision that determines various entities' roles, responsibilities, and geographical locations within the supply chain network.
- **Supply chain** refers to the interconnected network of organizations involved in fulfilling a customer order, from sourcing raw materials to delivering the final product.
- **Supply management** encompasses the procurement and management of suppliers and the cultivation of strong relationships with them.
- **Vendor Managed Inventory (VMI)** is an advanced supply chain relationship where a vendor manages and maintains agreed inventory levels at the customer's location, leveraging access to real-time inventory data.
- **Vertical Integration:** Vertical integration occurs when a firm owns more than one portion of its supply chain.

CHAPTER 8: INVENTORY MANAGEMENT

Chapter Overview

8.0 LEARNING OUTCOMES

Learning Objectives

By the end of this chapter, students will be able to:

- Explain the fundamental role of inventory management in balancing customer service levels and inventory costs.
- Classify and describe the different types of inventory managed by organizations.
- Analyze the various reasons for maintaining inventory and their impact on inventory management strategies.
- Identify and explain the components of inventory holding costs and their influence on inventory management decisions.
- Calculate the optimal order quantity using the EOQ formula and assess its impact on total relevant costs.
- Apply the EPQ model to determine the optimal production run size and its implications for inventory management.
- Calculate safety stock and reorder points based on demand variability and service level requirements.

8.1 INTRODUCTION TO INVENTORY MANAGEMENT

Inventory management plays a crucial role in industrial operations by overseeing the material resources that generate future revenue for an organization. This responsibility falls under the purview of the Operations Manager. Consider a retail store selling various products like packaged foods, groceries, apparel, and electronics. Typically, not all merchandise is stored within the store premises. A portion of the stock is kept in a warehouse facility. The combined inventory, comprising goods in the store and warehouse at any given time, constitutes the total inventory

This chapter will explore inventory management models that deal with certain or known demands. These models aim to address two fundamental questions:

1. How many units to order
2. When to place the order for those units

The primary objective of inventory control or inventory management is to achieve satisfactory levels of customer service while keeping inventory costs reasonably low. Therefore, there is a trade-off between the amount of inventory held and the level of customer service provided.

8.2 TYPES OF INVENTORY

Organizations typically manage several types of inventory, including:

1. **Raw materials or purchased parts:** These are the basic components or materials required for production or assembly processes.
2. **Work in process (WIP) or work in progress:** These are semi-finished or partially completed items found in the middle of assembly lines and manufacturing facilities.
3. **Finished goods or merchandise:** These are the final products ready for sale and distribution to customers, commonly found in retail stores and warehouses.
4. **Spare parts, tools, and supplies:** These are additional inventory items required for maintenance, repair, and operational purposes within the organization.

Understanding and effectively managing these different types of inventory is crucial for organizations to ensure smooth operations, meet customer demand, and maintain optimal inventory levels. The inventory management models discussed in this chapter will provide insights and techniques to help organizations make informed decisions regarding order quantities and timing, ultimately leading to improved customer service and cost efficiency.

8.3 REASONS FOR MAINTAINING INVENTORY

Organizations maintain inventory for various reasons, including:

- *In-Transit Inventory:* Inventory may be held simply because it is in transit and has not yet arrived at the facility. Since payment has been made for these goods, they are counted as part of the organization's inventory, referred to as in-transit inventory holding.
- *Preventing Stock-Outs:* One of the most common reasons for keeping inventory is to protect against stock-outs. When customers request to purchase a product, organizations aim to have sufficient stock available to meet the demand.
- *Leveraging Quantity Discounts:* Suppliers may offer quantity discounts for larger purchases. Although the organization may not immediately require the additional units, they may choose to purchase in bulk to take advantage of these discounts, resulting in excess inventory.
- *Smoothing Production Requirements:* Inventory can help organizations smooth out production requirements when demand fluctuates. During periods of low demand, they may produce more and stockpile inventory to avoid ramping up production excessively when demand increases again. This approach helps maintain a steadier production level, which is often more cost-effective.
- *Mitigating Operational Disruptions:* Maintaining inventory can help organizations cover for disruptions in specific production processes. In case of operational issues, having sufficient inventory on hand can prevent complete shutdowns or delays until the problem is resolved.
- *Cost Considerations:* In all these scenarios, organizations must carefully weigh the holding costs of inventory against other costs. For instance, if holding costs are high, they may prefer to risk occasional stock-outs rather than carrying excessive inventory. Alternatively, they may forgo supplier discounts if the total savings do not justify the additional inventory holding costs.
- *Inventory Management Models:* In inventory management, demand is classified as either known or steady versus uncertain. Several factors influence the choice of inventory model, including lead time and review time.
- *Lead Time:* Lead time refers to the duration between placing an order with a supplier and receiving the ordered goods. This factor plays a crucial role in determining the appropriate inventory model and ensuring timely replenishment.
- *Review Time:* Review time pertains to the frequency at which inventory levels are monitored. Two

common approaches exist:

- *Continuous Review:* In this method, an information system continuously tracks inventory levels and triggers a reorder notification or automatically places an order when stock reaches a predetermined reorder point. This automated process eliminates manual intervention and ensures timely order placement with pre-established suppliers.
- *Periodic Review (Fixed Order Interval):* Alternatively, inventory levels can be reviewed at fixed intervals. At the end of each interval, if the stock falls below a predetermined maximum level, an order is placed for the difference between the current stock and the maximum level. This approach allows for periodic adjustments based on actual demand patterns.
- *Additional Considerations:* Other factors, such as product perishability or obsolescence, may further complicate inventory models. For perishable items like food products, the product's lifespan must be carefully considered to avoid overstocking and subsequent waste or loss of inventory value due to expiration or obsolescence. Failing to account for these factors can result in significant financial losses.

While the above factors are fundamental to inventory management models, additional variables specific to an organization's operations or product characteristics may necessitate more intricate modelling approaches to optimize inventory levels and minimize costs.

8.4 RELEVANT COSTS

The costs are usually defined separately for each item or Stock Keeping Unit (SKU). As a result, the optimal order quantities and the time of order are determined for each item specifically. The relevant costs that we have in any inventory management are as follows:

Total Purchasing or Acquisition Cost

Total purchasing or acquisition costs refer to the total expenditure incurred by an organization in procuring an item over a specific period, such as a year, quarter, or month. The time unit used for measurement depends on the organization's operational requirements.

In certain inventory models, this cost component may remain constant. This scenario arises when the total demand for the item remains unchanged throughout the period, and the supplier does not offer any quantity discounts. In such cases, the total acquisition cost or purchasing cost is fixed, as it does not vary based on the order quantities placed.

Consequently, in these scenarios, the total acquisition cost is often excluded from the mathematical models used to determine optimal order quantities. Since this cost component is fixed and does not change based on the order size, it does not influence the optimization calculations.

However, it is important to note that if the total demand or supplier pricing varies or quantity discounts are available, the total acquisition cost may become a variable component that must be incorporated into the optimization models.

By carefully analyzing the demand patterns, supplier pricing strategies, and the availability of quantity discounts, organizations can determine whether the total purchasing or acquisition cost should be treated as a fixed or variable component in their inventory management models. This approach ensures accurate cost considerations and facilitates the determination of optimal order quantities, ultimately contributing to operational efficiency and cost minimization.

Inventory Holding Costs

Inventory holding costs aim to capture all the actual and opportunity costs incurred by an organization due to maintaining inventory. The main components of holding costs include:

Financing Costs

Inventory represents a significant portion of a firm's assets and working capital. This holding cost component is often estimated as the cost of borrowing or the opportunity cost of deploying funds for alternative uses. The most accurate estimate is the weighted average cost of capital used in capital budgeting decisions. This cost component is directly proportional to the value of the firm's inventory.

Storage and Handling Costs

These costs are incurred due to the physical storage of inventory and are typically a function of the item's size rather than its value. Storage costs may include expenses related to the physical space required for inventory storage. However, these costs are irrelevant when calculating pipeline inventory (inventory in transit).

Inventory Risk Costs

This component accounts for the costs associated with deterioration, obsolescence, shrinkage, theft, or damage to inventory. The level of risk and associated costs depend on the nature of the item. For instance, fashion goods, perishable products, and high-technology items will likely have higher inventory risk costs due to their shorter shelf life or rapid obsolescence.

Insurances

Since we always need to have insurance for our warehouses, the insurance cost can be calculated as a percentage for each item. This cost will, in turn, be used as another part of the holding cost percentage.

By carefully considering and quantifying these components, organizations can accurately estimate their inventory holding costs and make informed decisions regarding inventory levels, storage strategies, and risk mitigation measures. Managing inventory holding costs effectively can contribute to overall operational efficiency and profitability.

Insight:

"If the price or the value of the item is higher, the holding cost will be higher. That is one of the main reasons why companies tend to keep as few units as possible for those items when dealing with more expensive items. Sometimes, they keep only one unit just for showing at their store, and they get the customers' orders to deliver the item to them later or to bring it to the store for customers' pick up later. They could not afford to keep several of those very expensive items in the store because otherwise, the cost of holding them would be very high."

Calculating Inventory Holding Costs

In operations management, inventory holding costs are typically calculated as a percentage of the item's value. This approach allows organizations to estimate the cost of holding a particular item in stock for a specific period.

Example Scenario

Consider an item valued at $1,000, and the organization's inventory holding cost is 20% per annum.

Annual Holding Cost per Unit

If the organization holds one unit of this item for an entire year, the annual holding cost would be:

Annual Holding Cost per Unit = Item Value × Inventory Holding Cost Percentage
Annual Holding Cost per Unit = $1,000 × 0.2 = $200

Holding Cost for a Partial Year

If the same item is held in inventory for only a quarter of the year (3 months), the holding cost per unit would be:

Quarterly Holding Cost per Unit = (¼) × Annual Holding Cost per Unit.
Quarterly Holding Cost per Unit = (¼) × $200 = $50

Total Annual Holding Cost for Multiple Units

If the organization holds 10 units of this item for an entire year, the total annual inventory holding cost would be:

Total Annual Holding Cost = Number of Units × Annual Holding Cost per Unit
Total Annual Holding Cost = 10 × $200 = $2,000

Organizations can accurately estimate the expenses associated with maintaining inventory levels by calculating inventory holding costs as a percentage of the item's value. This approach allows for effective inventory management, cost optimization, and informed decision-making regarding order quantities and inventory levels.

Ordering Costs

Ordering costs refer to the expenses incurred by an organization when placing an order for inventory replenishment. These costs comprise several components:

Administrative Costs

Placing an order involves administrative tasks such as preparing purchase orders, obtaining necessary approvals, and completing other formalities. The administrative cost component includes all fixed costs associated with these activities, regardless of the order size. Electronic ordering systems can help reduce the time and effort required, thereby minimizing this cost component.

Transportation Costs

A fixed transportation cost is often incurred when transporting ordered goods, regardless of the order size. This cost component accounts for the logistics expenses associated with the delivery of inventory.

Receiving Costs

Upon receiving an order, administrative work is required, such as preparing goods receipt notes, updating inventory records, and verifying the order against the respective purchase order. The receiving cost component accounts for the expenses associated with these receiving activities.

It is important to note that all fixed costs, which do not vary with the order quantity, should be included in the ordering costs. Conversely, costs that vary with the order size should be included in the cost of the item itself.

In a purchasing environment, a significant portion of the ordering cost is information-intensive. Implementing electronic ordering systems can substantially reduce these costs. In a production environment, the ordering cost is referred to as the setup cost, which is the fixed cost associated with preparing machinery or equipment for production, also called Economic Production Quantity (EPQ). Unlike purchasing environments, setup costs are less information-intensive and are primarily influenced by the time lost during the setup activity. Consequently, in production environments, the focus is reducing setup time to minimize these costs.

By carefully considering and quantifying these components, organizations can accurately estimate their ordering costs and make informed decisions regarding order quantities, inventory levels, and potential cost-saving measures, such as implementing electronic ordering systems or optimizing setup processes.

Stock-Out Costs

Stock-out costs refer to the economic consequences an organization faces when it runs out of stock for a particular item. There are two possible scenarios in this situation: either the customer is willing to wait for the item to be restocked (backorder), or the customer's order cannot be fulfilled from the current inventory (lost sale). Stock-out costs can be categorized into two types (Singla, 2018):

Lost Sales Costs

When a company cannot fulfill a customer's order due to a lack of finished goods inventory, it results in a lost sale. The associated cost is the opportunity cost of the potential profit from that transaction. Additionally, lost sales can negatively impact the company's goodwill and future sales prospects.

Backorder Costs

Backorder costs are incurred when a customer is willing to wait for their order to be fulfilled after the item is restocked. In such cases, the organization incurs additional administrative costs and potential additional transportation and handling costs if the material needs to be rushed through to meet the backorder. While some of these costs are tangible, backorder costs also include intangible costs related to the firm's goodwill and potential impact on future sales.

It is important to note that stock-out costs are often intangible and difficult to measure precisely. However, organizations must consider these costs when making inventory management decisions, as they can significantly impact customer satisfaction, profitability, and long-term business performance.

By implementing effective inventory management strategies and maintaining appropriate stock levels, organizations can minimize the occurrence of stock-outs and the associated costs, thereby enhancing customer satisfaction, operational efficiency, and overall profitability.

8.5 INVENTORY MODELS FOR CERTAIN DEMAND: ECONOMIC ORDER QUANTITY (EOQ) MODEL

The Economic Order Quantity (EOQ) model is a fundamental inventory management model used when the following assumptions hold:

Assumptions

- The item is ordered from an external supplier (no internal production)
- Demand is fixed or steady over time (known with certainty)
- Lead time (the duration between order placement and receipt) is constant
- A fixed order quantity is placed each time
- The ordering cost is fixed per order, regardless of order size

Inventory Control Cycles

Each order placement initiates an inventory control cycle or order cycle. Upon receiving an order, the inventory level increases, and as demand is satisfied, the inventory level decreases over time. When the inventory level reaches a predetermined reorder point, a new order is placed, and the cycle repeats.

The inventory level fluctuates, as shown in the following diagram:

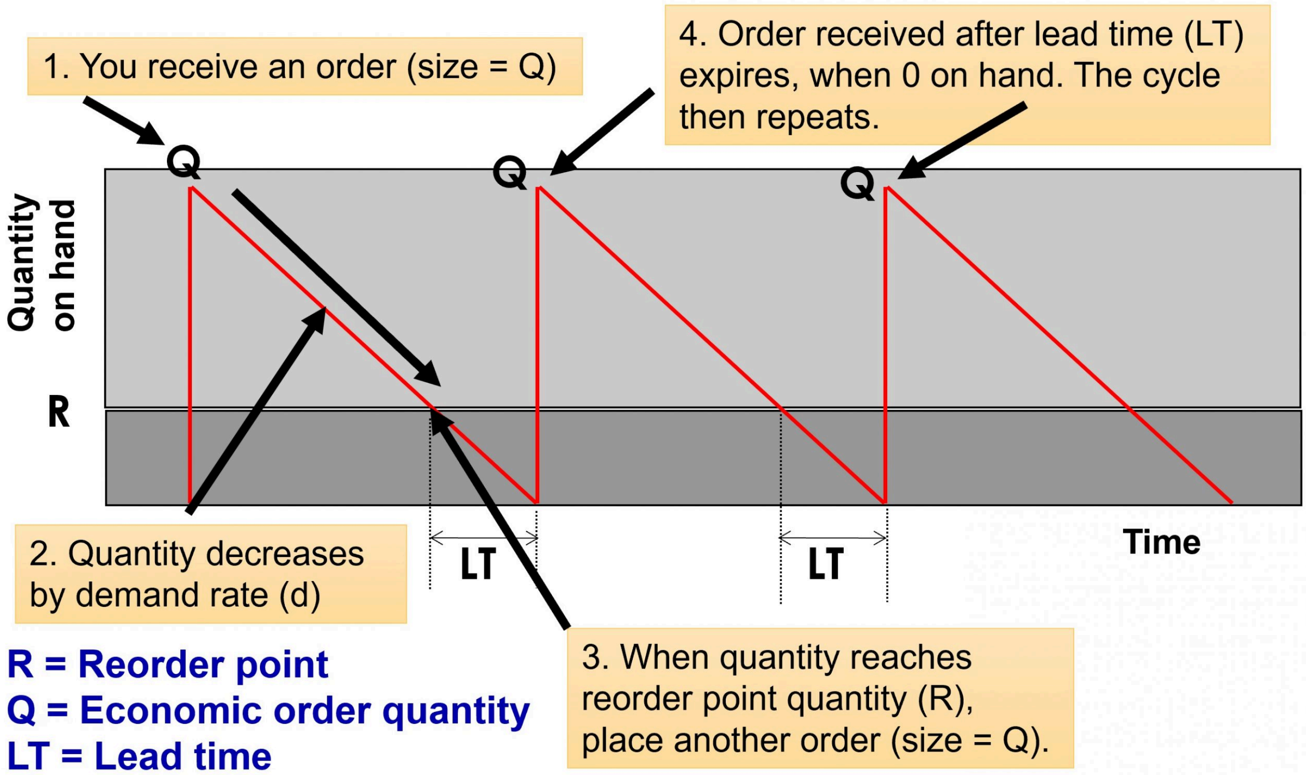


Figure 8.5.1: A diagram showing how the inventory level change over time

At point 1, an order of quantity Q is received, increasing the inventory level from zero to Q units. As time progresses, the inventory level decreases due to demand. When the inventory level reaches the reorder point R, a new order is placed to ensure that the order is received just as the inventory level reaches zero, preventing stock-outs.

Objective and Cost Components

The objective of the EOQ model is to determine the optimal order quantity *(Q*)* that minimizes the total relevant costs, which include:

1. Total Ordering Costs
2. Total Inventory Holding (Carrying) Costs

Other costs, such as total acquisition (purchasing) costs and shortage costs, are excluded from the model due to the assumptions of fixed demand and no stock-outs.

Notation and Calculations

Let:

D = demand (units/year)

Q = order quantity

S = order cost ($/order)

H = carrying cost ($/item/year)

I_{avg} = Average inventory

N = number of orders per year

TC = Total Cost

Total Cost = Ordering cost + Carrying cost

TC = (S × N) + (H × I_{avg})

TC(Q) = (S × D ÷ Q) + (H × Q ÷ 2)

The number of orders per year (N) can be calculated as N = D÷Q.
The average inventory level is Q÷2, assuming a constant demand rate.

The total relevant cost function, *TC(Q)*, is given by:

$$TC(Q) \;=\; (D \div Q) \;\times\; S \;+\; (Q \div 2) \;\times\; H$$

By setting the derivative of *TC(Q)* with respect to *Q* equal to zero and solving for *Q*, the optimal order quantity *Q** is obtained:

$$Q^* = \sqrt{\frac{2DS}{H}}$$

This optimal order quantity minimizes the total relevant costs for the given demand, ordering cost, and holding cost parameters.

The EOQ model provides a straightforward approach to determining the optimal order quantity when demand is certain, and other assumptions are met, enabling organizations to optimize their inventory management strategies and minimize associated costs.

The * on top of Q shows that it is a special value of the Q, which, in this case, is the optimal value. Let's have a look at some examples.

Video: "Inventory Management: Economic Order Quantity (EOQ) Model Video 1" by Excel@Analytics – Dr. Canbolat [15:25] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Examples

Example 1

Assume that Apple Canada has an annual demand of 250,000 for one of its tablets. A component has annual holding cost of $12 per unit, and ordering cost of $150. Calculate EOQ, total cost of ordering and inventory holding, number of orders per year and the order cycle time for this item. Assume 250 working days in a year.

Solution

H = $12 per unit

S = $150

D = 250,000 units

$$EOQ = Q^* = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \times 250,000 \times 150}{12}} = 2500$$

$$TC(Q^*) = S \times \frac{D}{Q^*} + H \times \frac{Q*}{2} = 150 \times \frac{250,000}{2500} + 12 \times \frac{2500}{2} = 15000 + 15000 = \$30,000$$

$$\text{Optimal number of orders per year } = \frac{D}{Q^*} = \frac{250,000}{2500} = 100$$

$$\text{Length of order cycle time } = \frac{\text{250 days in a year}}{\text{100 orders}} = 2.5 \text{ days}$$

Example 2

Assume that it costs BestBuy $625 each time it places an order with a manufacturer for a specific model of laptop. The cost of carrying one laptop in inventory for a year is $130. The store manager estimates that total annual demand for the laptops will be 1500 units, with a constant demand rate throughout the year. The store policy is never to have stockouts of the laptops. The store is open for business every day of the year except Christmas Day.

Determine the following:

a. Optimal order quantity per order
b. Minimum total annual inventory costs
c. The optimal number of orders per year
d. The time between orders (in working days)

Solution

D = 1500

S = $625

H = $130

a. $Q* = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(1500)(625)}{130}} = 120.1$

b. $TC(Q) = \frac{SD}{Q} + \frac{HQ}{2} = \frac{625 \times 1500}{120.1} + \frac{130 \times 120.1}{2} = \$15,612.49$

c. $\frac{D}{Q} = \frac{1500}{120.1} = 12.49 \text{ orders}$

d. $\frac{364}{12.49} = 29.14 \text{ days}$

Example 3

The Modern Furniture Company purchases upholstery material from textile supplier in Halifax, Canada. The company uses 45,000 yards of material per year to make sofas. The cost of ordering material from the textile company is $1500 per order. It costs Modern Furniture $0.70 per yard annually to hold a yard of material in inventory. Determine:

a. The optimal number of yards of material Modern Furniture should order
b. The minimum total inventory cost
c. The optimal number of orders per year, and
d. The optimal time between orders

Solution

D = 45,000

S = $1500

H = $0.70

a. $Q* = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(45000)(1500)}{0.70}} = 13,887.3 \text{ yd}$

b. $TC(Q) = \frac{SD}{Q} + \frac{HQ}{2} = \frac{1500 \times 45000}{13887.3} + \frac{0.7 \times 13887.3}{2} = \$9721.11$

c. $\frac{D}{Q} = \frac{45000}{13887.3} = 3.24 \text{ orders per year}$

d. $\frac{365}{3.24} = 112.6 \text{ days}$

8.6 INVENTORY MODELS FOR CERTAIN DEMAND: ECONOMIC PRODUCTION QUANTITY (EPQ)

The Economic Production Quantity (EPQ) model is applicable when an organization has its own internal production capabilities rather than ordering from an external supplier. Unlike the Economic Order Quantity (EOQ) model, where inventory is received in a single batch, the EPQ model accounts for a gradual replenishment of inventory through production.

Key Differences from EOQ

1. Production Setup Cost: In the EPQ model, there is a production setup cost associated with preparing the machines or production area before commencing each production run or cycle.
2. Gradual Inventory Replenishment: Instead of receiving the entire order quantity (Q) at once, as in the EOQ model, the inventory level increases gradually during the production uptime or run time.

Inventory Level Behaviour

The inventory level fluctuates in a distinct pattern under the EPQ model, as illustrated in the following diagram

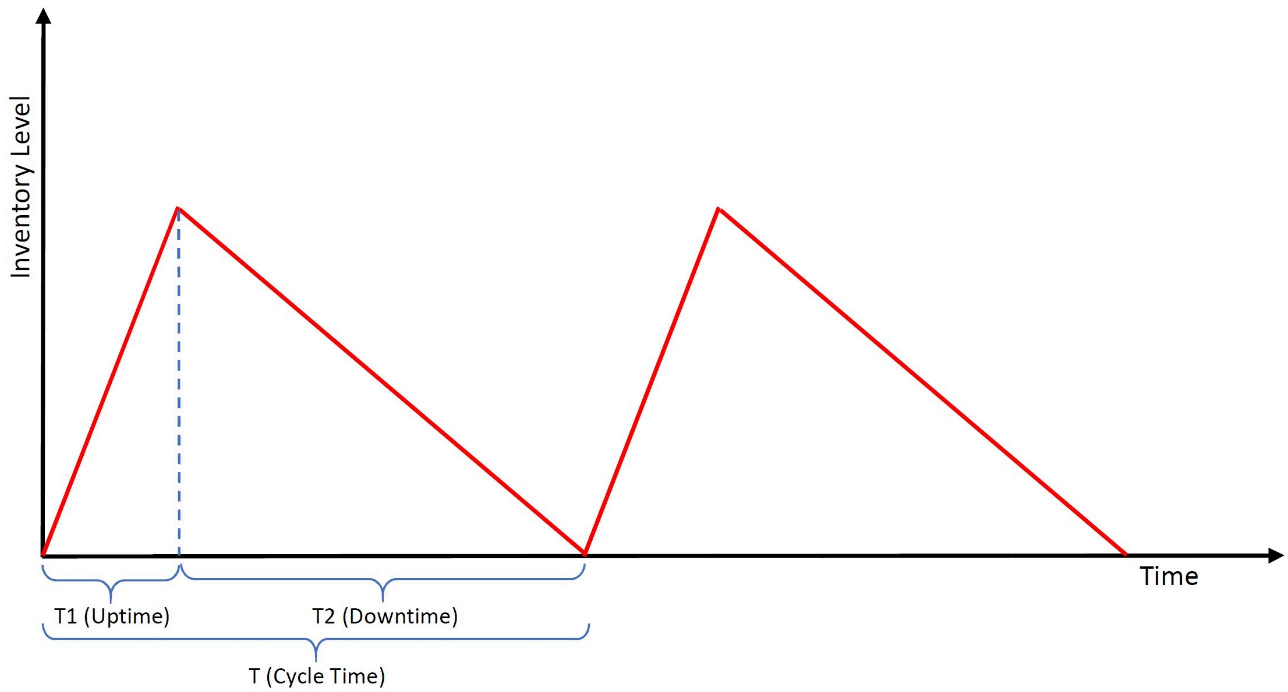


Figure 8.6.1: A chart showing how the inventory level changes over time

The red line in the diagram represents the fluctuating inventory level over time. During the uptime or run time *(T1)*, production is ongoing at a rate of p units per day, while customer demand is occurring simultaneously at a rate of d units per day. Consequently, the inventory level increases at a rate of $(p - d)$ units per day, reflecting the net accumulation of inventory.

Production continues until the inventory level reaches a predetermined maximum level. At this point, production is halted, and the accumulated inventory is utilized solely to satisfy customer demand during the downtime period *(T2)*. During the downtime, the inventory level gradually decreases as the piled-up stock is depleted to meet demand.

A fundamental assumption of the EPQ model is that the production rate (p) exceeds the demand rate (d). If this assumption is violated, and the demand rate surpasses the production rate, the organization will inevitably face stock-outs, as the production capacity would be insufficient to replenish the inventory at the required rate.

By adhering to the condition of $p > d$, the EPQ model ensures that the production process can consistently replenish inventory levels, enabling the organization to meet customer demand without experiencing stock-outs during the downtime period. This assumption is crucial for maintaining a stable inventory management system and ensuring uninterrupted operations.

In terms of calculations, if we use the following notation and replace the H (i.e., the holding cost per unit of item per year) by it, we can use the same formulations from the EOQ model for the optimal lot size (run size) and the total cost. Here are the calculations:

$$H' = H\left(1 - \frac{d}{p}\right)$$

$$EPQ = Q^* = \text{The optimal production lot (run) size in each cycle}$$

$$EPQ = Q^* = \sqrt{\frac{2DS}{H'}} = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

$$T_1 = \text{Uptime or production time} = \frac{Q*}{P}$$

$$T = \text{Cycle time} = \frac{Q*}{d}$$

$$T_2 = \text{Downtime} = T - T_1$$

$\mathrm{TC(Q)}$ = Total cost of production setup and inventory holding associated with a production lot size of Q

$$TC\left(Q\right) = S \times \frac{D}{Q} + \frac{Q}{2} \times H' = S \times \frac{D}{Q} + \frac{Q}{2} H\left(1 - \frac{d}{p}\right)$$

$$\text{Maximum Inventory} = Q^*\left(1 - \frac{d}{p}\right)$$

Note that *"D"* is defined as the demand per year, while "*d*" is the demand per day. In addition, Q^* is a specific value for Q, which is associated with the optimal quantity. If we need to find the optimal total cost, we will need to use the value of Q^* as the Q in the formula for *TC(Q)*. Let's have a look at an example.

Example

An automotive manufacturer uses 48,000 M1 gearboxes per year for its X1 SUV series. The firm makes its own M1 gearboxes, which it can produce at a rate of 800 per day. The carrying cost is $1 per gearbox per year. Setup cost for a production run of M1 gearboxes is $45. The firm operates 240 days per year. Determine:

a. The optimal run size
b. The minimum total annual cost for carrying and setup
c. Cycle time for the optimal run size
d. The production run time (uptime)
e. Maximum inventory

Solution

Demand per year = *D* = 48000

Production rate per day = *p* = 800

Demand rate per day = *d* = 48000 ÷ 240 = 200

Ordering cost per unit = *S* = $45

Unit inventory holding cost = *H* = $1

$$H' = H\left(1 - \frac{d}{p}\right) = 1 \times \left(1 - \frac{200}{800}\right) = 0.75$$

a. The optimal run size

$$Q^* = \sqrt{\frac{2SD}{H'}} = \sqrt{\frac{2 \times 45 \times 48000}{0.75}} = 2400$$

b. The minimum total annual cost for carrying and setup

$$TC\left(Q^*\right) = S \times \frac{D}{Q^*} + H' \times \frac{Q^*}{2} = 45 \times \frac{48000}{2400} + 0.75 \times \frac{2400}{2} = 1800$$

c. Cycle time for the optimal run size

$$T = \frac{Q^*}{D} = \frac{2400}{48000} = 0.05 \text{ year} = 0.05 \times 240 = 12 \text{ days}$$

d. The production run time (uptime)

$$T_1 = \frac{Q^*}{p} = \frac{2400}{800} = 3 \text{ days}$$

e. Maximum inventory

$$I_{max} = Q^* \left(1 - \frac{d}{p}\right) = 2400 \times \left(1 - \frac{200}{800}\right) = 1800$$

8.7 INVENTORY MODELS FOR UNCERTAIN DEMAND

The previous models are valid on the assumption that the market demand is known and stays unchanged. However, sometimes, the market demand could change unexpectedly. This could lead to an inventory shortage, which would change the reorder point. To keep pace with the market, it would be prudent to consider the oscillation in demand during lead time and add in a safety stock. The demand oscillation is commonly measured in terms of the standard deviation *(∂)* from the average demand during the total time for an order as calculated below:

$$\delta_L = \delta_t \sqrt{L}$$

Knowing the demand variation, the safety stock should be considered to avoid stock out. However, the level of certainty for not facing stock out must also be considered. For example, if we choose to have 95% certainty that stock out and backorder does not happen (also known as Cycle Service Level), then we are reducing the risk of stock out to 5% (100%-95%). Assuming that the demand during lead time is normally distributed, the Z value (Z table) for the selected certainty level would be multiplied to the calculated ∂_L to determine the Safety stock as shown below:

$$SS = Z\delta_L$$

The incorporation of safety stock, based on the cycle service level, would move the reordering point to:

$$ROP = d_L + SS$$

Example

A cell phone kiosk has an average demand of 20 phones per week with a variation of 4 phones. The lead time for this kiosk is always 1 week. The Kiosk wishes to maintain a 90% cycle service level. What would be the safety stock and reorder point for this kiosk?

Solution

$$\delta_L = \delta_t \left(\sqrt{L}\right) = 4\left(\sqrt{1}\right) = 4$$

$$SS = Z\delta_L = 1.28\ (4) = \mathbf{5.12\ or\ 5}$$

Note: *Z value for 90% in Z table is 1.28*

$$ROP = \delta_L + SS = 4 + 5 = 9$$

8.8 CHAPTER SUMMARY & REVIEW

Summary

Inventory management is a critical function in industrial operations, focusing on the oversight of material resources to ensure future revenue. This chapter explores inventory management models that address the fundamental questions of how many units to order and when to place these orders, with the objective of balancing customer service levels and inventory costs. Various types of inventory are discussed, including raw materials, work in process, finished goods, and spare parts. The reasons for maintaining inventory range from preventing stock-outs and leveraging quantity discounts to smoothing production requirements and mitigating operational disruptions.

The chapter delves into relevant inventory costs, such as purchasing, holding, and ordering costs. Holding costs include financing, storage, handling, risk costs, and insurance, which can be significant for high-value items. Ordering costs encompass administrative, transportation, and receiving expenses. The Economic Order Quantity (EOQ) model is highlighted as a method to determine the optimal order quantity that minimizes total relevant costs by balancing ordering and holding costs; that is, an order quantity at which these two costs are equal. The chapter also covers the Economic Production Quantity (EPQ) model, which is applicable for internal production, and inventory models for uncertain demand, emphasizing the importance of safety stock and cycle service levels to prevent stock-outs.

Overall, this chapter provides comprehensive insights into inventory management strategies, including the calculation of relevant costs and the application of various inventory models. By understanding and implementing these models, organizations can optimize their inventory levels, reduce costs, and improve customer service, ultimately enhancing operational efficiency and profitability.

OpenAI. (2024, June 18). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than three paragraphs. Reviewed by authors.*

Review Questions

1. Explain the role of inventory management in industrial operations. Why is it important for Operations Managers to oversee inventory?
2. Identify and describe the different types of inventory managed by organizations. Provide examples of each type in a specific industry.
3. Discuss the various reasons organizations maintain inventory. How do these reasons impact the overall inventory strategy?
4. What are the key components of inventory holding costs? How do these costs influence inventory management decisions?
5. Describe the EOQ model and its assumptions. How does this model help in determining the optimal order quantity?
6. Compare and contrast the EOQ and EPQ models. In what situations would an organization use the EPQ model instead of the EOQ model?
7. Explain the concept of stock-out costs. How do lost sales and backorder costs affect a company's inventory management policies?
8. How do inventory models for uncertain demand differ from those for certain demand? Discuss the role of safety stock in managing uncertain demand.
9. How are inventory holding costs typically calculated in operations management? Provide an example calculation to illustrate this process.
10. Define lead time and review time in the context of inventory management. How do these factors influence the choice of inventory model and order quantities?

OpenAI. (2024, June 18). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

8.9 KEY TERMS

Key Terms

- **Backorder costs** are incurred when a customer is willing to wait for their order to be fulfilled after the item is restocked.
- **Finished goods or merchandise:** These are the final products ready for sale and distribution to customers, commonly found in retail stores and warehouses.
- **Inventory holding costs** aim to capture all the actual and opportunity costs incurred by an organization due to maintaining inventory.
- **Ordering costs** refer to the expenses incurred by an organization when placing an order for inventory replenishment.
- **Raw materials or purchased parts:** These are the basic components or materials required for production or assembly processes.
- **Spare parts, tools, and supplies:** These are additional inventory items required for maintenance, repair, and operational purposes within the organization.
- **Stock-out costs** refer to the economic consequences an organization faces when it runs out of stock for a particular item.
- **Total purchasing or acquisition costs** refer to the total expenditure incurred by an organization in procuring an item over a specific period, such as a year, quarter, or month.
- **Total Cost of Optimal Order size (TC(Q)** is the sum of ordering cost (S) and holding cost (H). At its minimal level, ordering cost and holding cost are equal.
- **Work in process (WIP) or work in progress:** These are semi-finished or partially completed items found in the middle of assembly lines and manufacturing facilities.

CHAPTER 9: JUST-IN-TIME AND LEAN SYSTEMS

Chapter Overview

9.0 LEARNING OUTCOMES

Learning Objectives

At the end of this chapter, students will be able to:

- Explain the fundamental principles of Just-In-Time (JIT) and lean manufacturing, identifying how these approaches aim to eliminate waste and improve efficiency in production processes.
- Describe the core objectives and principles of lean manufacturing, including the five core principles identified by James Womack and Daniel Jones, and apply these principles to analyze and improve manufacturing processes.
- Outline the key components and benefits of Just-In-Time (JIT) systems, including inventory reduction, pull production systems, quick setups, and flexible resources, and evaluate how these components contribute to operational efficiency and waste reduction.
- Learn the commonly observed types of waste (transportation, Excessive inventory, excessive motion, waiting, overproduction, over processing, defects).
- Examine the process of Value Stream Mapping, to remove or reduce non-value adding activities through Kaizen and convert push production system to pull system using Kanban and supermarket.

9.1 JUST-IN-TIME AND LEAN MANUFACTURING CONCEPTS

Imagine ordering a pizza for dinner from a restaurant that advertises a delivery time of six hours. Clearly, such a prolonged wait would be unacceptable, as the pizza would arrive cold and stale, failing to meet the customer's expectations. Conversely, a restaurant that promises to deliver a cold, stale pizza within five minutes would also be unsatisfactory. To truly satisfy consumer needs, a pizza shop must be capable of providing customers with the desired number of fresh pizzas at the precise time they are wanted.

Preparing pizzas in advance would be wasteful, as most consumers are unlikely to purchase a stale product. Conversely, an excessively long delivery time would result in the loss of customers to more responsive competitors. The concept of **just-in-time (JIT)** focuses on producing goods or services to meet customer demand only when they are needed. For a pizza delivery shop, this translates to delivering a fresh pizza to the customer's doorstep within approximately 30 minutes.

This philosophy can be applied to a wide range of operations, from simple tasks like washing a car to the complex manufacturing of aircraft. Similarly, the concept of **lean manufacturing** refers to the elimination of waste in the manufacturing process. The Toyota Production System serves as a model for modern manufacturers seeking to control and minimize waste.

The core focus of Lean system is to tackle waste. By definition, any activity in a process that does not have any value for the customer is waste. As a result, the customer will not pay for these activities, yet resources have been allocated to those activities at a cost. In this unit, we will explore seven types of waste as shown in the following video and later we will look at the processes for controlling them.

Video: "7 wastes in garments factory | Live form Factory" by Garments Learner [3:56] is licensed under the Standard YouTube License.

Additionally, we will delve into the origins of the Just-in-Time (JIT) philosophy and the use of pull systems to control inventory effectively. By embracing the principles of just-in-time and lean manufacturing, organizations can streamline their operations, minimize waste, and enhance their ability to meet customer demands promptly and efficiently, ultimately improving customer satisfaction and operational performance.

9.2 LEAN MANUFACTURING AND CONTROL

Lean control, or simply lean, has seen a surge in popularity in recent years as businesses strive to improve operational efficiencies and product quality through lean methodologies. **Lean control** is a refined example of nonfinancial controls in action aimed at enhancing product and service quality while reducing waste. Originally focused on improving manufacturing operations, lean concepts have now expanded to encompass product development, order processing, and various other nonmanufacturing processes, sometimes referred to as "lean in the office."

The widespread adoption of lean control methodologies is driven by the quest for streamlining processes, eliminating waste, and maximizing productivity. Lean control techniques involve analyzing processes, identifying value-adding activities, and eliminating non-value-adding activities or waste. This process is called Value Steam Mapping (VSM) and is done in three steps:

1. Drawing the current state map (how the operation is currently carried out in an attempt to identify the non-value adding activities (waste) that need to be improved or eliminated)
2. Coming up with ideas of how the non-value added activities can be improved or eliminated (Kaizen) , to outline the future plan (how the operation should be carried out without waste or with less waste (hence with more value-adding activities)
3. Prepare the future plan (how the operation should be carried out without waste or with less waste (hence with more value-adding activities)

This approach is based on the premise that by eliminating waste, whether in the form of excess inventory, overproduction, waiting times, or unnecessary transportation, businesses can enhance their operational efficiencies and product quality. Value Stream Mapping will be further illustrated in details in a video in section 9.4 where we learn about Pull Production System.

Lean control is a multifaceted approach to process improvement and resource optimization. According to James Womack, it involves measuring and reducing inventory, streamlining production, changing performance measurement, and implementing a knowledge-based continuous improvement system. Lean control requires long-term commitment and top management support.

The term "lean" gained popularity after the 1990 book *The Machine That Changed the World* by Womack, Jones, and Roos. The core principle is using fewer resources like space, inventory, and labour while maintaining or improving output levels. This is achieved by identifying and eliminating non-value-adding activities and waste from processes to increase productivity and quality and reduce costs, ultimately enhancing competitiveness (Womack et al., 1990).

Toyota's Pioneering Role in Lean Manufacturing

Video: "How Toyota Changed The Way We Make Things" by Bloomberg Originals [4:52] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

The Toyota Production System (TPS), developed by Toyota Motor Corporation in Japan after World War II, serves as the cornerstone of lean manufacturing principles. This period presented significant challenges for Toyota's leadership, who aspired to establish the company as a full-fledged car and truck manufacturer. The nascent Japanese automotive market, characterized by a demand for diverse vehicle types despite its small size, necessitated a production strategy that balanced profitability with low-volume, high-variety output. Capital scarcity further compounded these challenges, precluding investments in advanced production equipment. To ensure survival and success, Toyota required a resource-efficient vehicle production system. This critical need led Eiji Toyoda and Taiichi Ohno to spearhead developing and implementing the now-renowned lean production techniques and tools.

To maximize the benefits of lean, managers must determine which specific lean tools and techniques will be effective for their business. This requires a clear understanding of Lean's primary objectives and core principles. With this understanding, managers can decide which lean tools will work well, which need adaptation, and which are inappropriate.

By aligning lean implementation with lean's objectives and principles, managers can strategically select and tailor the right lean tools for their business. This targeted approach ensures lean initiatives are tailored to their unique needs, maximizing successful implementation and desired outcomes like improved efficiency, reduced waste, and enhanced quality and productivity. Discerning the suitability of various lean tools is crucial for managers to integrate lean principles and derive maximum benefits effectively.

9.3 CORE OBJECTIVES AND PRINCIPLES OF LEAN MANUFACTURING

To fully understand and effectively implement lean methodologies, it is crucial to grasp the major objectives and core principles that underpin the lean philosophy.

7 – Wastes

Despite ongoing debates and arguments surrounding the precise definition and description of lean, it is clear that the ultimate objective of lean is the avoidance of muda, or wasteful activity, in all business operations. Muda comprises seven deadly wastes, and in the lean world, waste is defined as any activity or condition that consumes resources but creates no value for customers. These seven deadly wastes include:

1. **Defects:** Products that fail to meet customer requirements, rendering the effort to create them wasted and necessitating additional waste management processes.
2. **Overproduction:** Producing or acquiring items before they are actually required, leading to excess inventory that must be stored, managed, and protected, often masking underlying production problems.
3. **Transportation:** Moving products without adding value, incurring costs, and risking damage, loss, or delays.
4. **Waiting:** Idle time spent by workers or capital tied up in goods and services not yet delivered to customers, often requiring additional processes to manage.
5. **Inventory:** Raw materials, work-in-progress, or finished goods representing capital outlay that has not yet generated income, with any non-value-adding inventory considered waste.
6. **Motion:** Unnecessary movements by workers or equipment that can lead to damage, wear, and safety issues, as well as incurring fixed assets and expenses.
7. **Over-processing:** Using more expensive or valuable resources than necessary or adding features that are unneeded by customers, potentially leading to waste, particularly in

terms of overqualified personnel performing tasks below their competency level.

By identifying and eliminating these seven deadly wastes, lean methodologies aim to streamline operations, reduce costs, and enhance value creation for customers, ultimately driving business success and competitiveness.

Video: "The 7 Wastes of Lean for Frontline Kaizen – Lean Manufacturing Training" by Lean Smarts [6:05] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

The Five Core Principles of Lean

Lean methodologies enable organizations to achieve more with fewer resources. A lean organization utilizes less human effort, equipment, facility space, time, and capital while continually striving to meet customers' exact needs. Lean is not merely a cost-cutting program; it is a philosophy centred on conserving valuable resources.

In their seminal book, *Lean Thinking*, James Womack and Daniel Jones identified five core principles that underpin the lean approach:

Define Value from the Customer's Perspective

The first principle emphasizes that value must be defined and specified from the customer's perspective. This requires a deep understanding of how each specific product or service meets the needs of specific customers at a specific price and time. Generic statements are insufficient; value must be defined in terms of tangible products or services.

Describe the Value Stream for Each Product or Service

The second principle involves describing the value stream for each product or service (or groups of similar products). The value stream encompasses all activities, both direct and indirect, performed to bring a finished product or service to the customer. This includes manufacturing activities, order processing, purchasing, and materials management. Mapping the value stream reveals waste, enabling managers to identify value-adding activities, non-value-adding but necessary activities, and non-value-adding activities that can be eliminated or reduced.

Create Flow in Each Value Stream

The third principle is embodied in the concept of flow. Once non-value-adding activities have been eliminated, the remaining activities should be arranged sequentially to enable smooth and continuous product or service flow. Flow challenges the traditional "batch-and-queue" model, where products are manufactured in large batches based on functional organization. Lean organizations strive to improve flow by reducing batch sizes, increasing flexibility, and lowering costs.

Video: "Lean Manufacturing One Piece Flow vs. Mass Production Paper Airplane Simulation (Lean Tip 005)" by Lean Smarts [7:46] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Produce at the Pace (Pull) of Actual Customer Demand

The fourth principle is producing at the pace or pull of actual customer demand. Continuous flow production dramatically reduces lead times, enabling lean organizations to respond to actual customer demand rather than relying on demand forecasts. This allows for substantial reductions in finished goods and work-in-process inventories.

Strive for Continuous Improvement (Kaizen)

The fifth principle is continuous improvement, expressed in Japanese as "kaizen." Lean organizations adopt the mindset that any business activity can be improved and regularly conduct kaizen events to enhance specific processes or operations. Even the leanest organizations, like Toyota, continuously strive for improvement, recognizing that pursuing perfection is an ongoing journey.

By adhering to these five core principles, organizations can effectively implement lean methodologies, eliminate waste, enhance value creation for customers, and drive continuous improvement, ultimately achieving operational excellence and sustainable competitive advantage.

9.4 JUST-IN-TIME (JIT) SYSTEMS

Just-In-Time (JIT) is a management philosophy that emerged in the 1970s, pioneered by Taiichi Ohno and perfected for Toyota's manufacturing plants in Japan. The primary objective of JIT is to eliminate any activity that does not add value from the customer's perspective. Activities that do not contribute value are referred to as "waste" within the JIT framework.

The JIT philosophy aims to eliminate these forms of waste by producing only what is needed when it is needed and in the exact quantity required. This approach minimizes inventory levels, reduces lead times, and enhances overall operational efficiency.

By adopting JIT principles, organizations can streamline their processes, reduce waste, and improve responsiveness to customer demand. JIT systems emphasize continuous improvement, flexibility, and the involvement of all employees in identifying and eliminating non-value-added activities.

Successful implementation of JIT requires a cultural shift within the organization, fostering a mindset of continuous improvement, waste elimination, and a relentless pursuit of perfection in meeting customer needs. By embracing the JIT philosophy, companies can achieve significant improvements in quality, productivity, and competitiveness, ultimately driving long-term business success.

Three essential elements contribute to the successful practice of JIT:

- JIT manufacturing principles
- Total Quality Management (TQM)
- Employee empowerment

JIT manufacturing principles

There are several JIT principles that are applied in a manufacturing setting.

The following are some of these main principles:

- Inventory reduction to expose waste
- Use of a "demand-pull" production system
- Quick setups to reduce lot sizes
- Flexible resources
- Cellular layouts

Inventory Reduction to Expose Waste

Excess inventory can mask wasteful practices like poor equipment, weak vendors, bad quality, and long setup times. Gradually reducing inventory exposes these weaknesses, allowing organizations to address them systematically.

As inventory levels decrease, organizations can replace or maintain equipment, improve vendor quality and delivery, streamline setups, implement robust quality practices, and optimize labour/equipment layout.

Inventory reduction exposes waste, creates urgency for improvement, and fosters a continuous improvement mindset. Organizations can streamline processes, enhance efficiency, reduce costs, improve responsiveness, and deliver greater customer value by using it as a tool to identify and eliminate non-value-added activities.

Pull Production System

Traditional manufacturing management approaches emphasize maximizing machine and labour utilization, assuming that keeping workers and machines constantly busy will lead to productivity and efficiency. This approach is known as the "push" system, where raw materials and work-in-process are continuously pushed through the factory in pursuit of high utilization. However, this method often results in high inventory levels, long lead times, overtime costs, increased rework potential, and a competitive rather than cooperative workforce.

In contrast, Just-In-Time (JIT) employs a "pull" system, where workflows to a work centre only when that centre needs more work. If a work centre is already occupied, the upstream work centre should stop production until the downstream centre communicates a need for more material. The emphasis on maintaining high utilization is removed in a JIT environment. Instead, the focus shifts to addressing challenges that affect the factory's overall effectiveness in meeting its strategic goals, such as setup time reduction, quality improvement, enhanced production techniques, and waste elimination, rather than allowing excess inventory to cover up inefficiencies that reduce competitiveness.

Video: "[Toyota Production System] Just-in-Time: The Pull System" by Toyota Motor Corporation [1:14] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

One of the tools used in JIT systems to facilitate the pull system and coordinate activities (such as picking up new raw materials, work-in-process, or production itself) between different workstations is called Kanban. Kanban is a signal or ticket that is passed from one part of the process to another, indicating that they are allowed to start their next activity. This supports the concept of pull production and avoids waste by preventing activities from occurring when they are not needed. Kanban is also a visual signboard used to organize and display what needs to be done, what is in progress, and what is completed, a concept adopted in Agile workflow management systems.

In section 9.2 we learned that Value Stream Mapping is a process used for eliminating waste, and the most costly waste, inventory. Value stream mapping intends to turn a push production system into a pull system. Two key tools used in this process are Kanban, and Supermarket.

By implementing a demand-pull production system and leveraging tools like Kanban, organizations can streamline their operations, reduce waste, and enhance responsiveness to customer demand, ultimately improving overall efficiency and competitiveness.

Watch the following videos to get a better sense of how the Kanban system works:

Video: "[Toyota Production System] Just-in-Time: Collaboration with Parts Suppliers for Timely Production" by Toyota Motor Corporation [2:09] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

Video: "What is Kanban? – Agile Coach (2019)" by Atlassian [5:32] is licensed under the Standard YouTube License.*Transcript and closed captions available on YouTube.*

In section 9.2 we learned that Value Stream Mapping (VSM) is a process used for eliminating waste, and the costliest waste, inventory. Value stream mapping intends to turn a push production system into a pull system. Two key tools used in this process are Kanban, and Supermarket. Watch the following video to gain a better insight into how VSM uses these two tools to transition a traditional push production into a pull production system.

Video: "VSM .Value Stream Mapping" by Shrinivas Gondhalekar [8:35] is licensed under the Standard YouTube License. Transcript.

Quick Setups to Reduce Lot Sizes

Traditional production management philosophies promoted the notion that long production runs of the same item were key to driving down unit costs. However, the problem with this approach was that large production runs created excessive quantities of work-in-process (WIP) and finished goods inventory, far exceeding actual demand. Consequently, these excess inventories led to high inventory costs, long lead times, increased potential for rework, and low flexibility in responding to customer needs.

In a Just-In-Time (JIT) environment, reducing setup costs and setup times is crucial for dramatically improving factory competitiveness. In the 1980s, 3M transformed a factory that produced a few adhesive products in long production runs into a facility that manufactured over 500 adhesive products in small production runs. To maintain low unit production costs, 3M focused on optimizing the setups on its coating machines.

Since the cost of chemical waste disposal was a significant factor in the cost of changing over a coating machine to produce another product, 3M took several steps to shorten setup times:

1. Reducing the length of hoses that needed purging
2. Redesigning the shape of the adhesive solution holding pan on the coating machine to be shallower
3. Implementing quick-connect devices and disposable filters
4. Utilizing work teams to speed up setups

As a result of these efforts, 3M could maintain low unit costs on its coating machines while producing small lots of hundreds of products to meet market demand quickly and efficiently.

By embracing quick setup practices and reducing lot sizes, organizations can minimize excess inventory, shorten lead times, increase flexibility in responding to customer needs, and ultimately enhance their competitiveness in the market. Quick setups enable companies to produce the right products in the right quantities at the right time, aligning with the core principles of the Just-In-Time philosophy.

Flexible Resources

The enemy of Just-In-Time (JIT) is uncertainty. A JIT environment thrives on predictability in customer demand, production processes, supplier performance, and worker availability. However, complete elimination of uncertainty is often unrealistic in most organizational environments.

To defend against unavoidable uncertainty, implementing Flexible Resources that can adapt easily to changing circumstances is crucial. One way to improve flexibility is through the use of general-purpose, movable equipment that can fulfill a wide variety of production requirements. For example, drilling machines with quick-change bits that can be wheeled into position to form new work cells allow the factory to maximize efficiency while producing exactly what is needed to satisfy immediate demand. Another example is Toyota's use of paint canisters that attach to paint sprayers, enabling any car to be painted any colour without the need to purge hoses when switching from one colour to another.

Multifunctional workers are another way to bring flexibility to the work environment. At Honeywell's heating and cooling controls plant, workers are trained to operate all the machines on their work line. The flexibility that comes from multifunctional workers changes the nature of how work gets done. Instead of workers being trained on a single machine and working independently, multifunctional workers have a "big picture" view of the production line, understanding all aspects of the line and how to work together to meet quality and schedule goals regardless of the circumstances.

By implementing flexible resources, such as general-purpose equipment and multifunctional workers, organizations can better adapt to changing circumstances and mitigate the impact of uncertainty. This flexibility enables them to respond quickly to fluctuations in demand, production disruptions, or other unforeseen events, ensuring that they can continue to meet customer needs efficiently and effectively within the JIT.

Cellular Flow Layouts

Cellular flow layouts promote JIT goals through unidirectional product flows, high visibility, and fast throughput times. Multifunctional workers are assigned to cells and have responsibility over products from raw materials to finished goods.

This "big picture" view gives workers greater ownership and pride. Their deeper process understanding increases opportunities to contribute ideas for improvement.

Key benefits of cellular layouts for JIT:

- Streamlined flow, minimizing transportation
- High visibility aiding issue identification
- Reduced lead times and faster throughput
- Flexibility from cross-trained workers
- Continuous improvement from engaged workers

Cellular layouts create an environment supporting JIT principles like waste reduction, lead time reduction, and continuous improvement while empowering workers.

Total Quality Management

Total Quality Management (TQM) goes hand in hand with the Just-In-Time (JIT) philosophy. Poor quality is a major source of uncertainty and non-value-added activities that disrupt JIT flow.

TQM promotes continuous improvement, doing things right the first time, designing quality into products/processes, and focusing on prevention – aligning with JIT's waste elimination goals.

Key synergies between TQM and JIT:

- Continuous improvement mindset
- Waste reduction through defect prevention
- Process optimization for smooth flow
- Employee empowerment and involvement
- Customer-centric focus on quality

Integrating TQM principles into JIT environments mitigates quality-related disruptions, enabling more efficient JIT implementation. This synergistic approach enhances operational excellence and drives continuous improvement.

Employee Empowerment

Front-line employees play a pivotal role in the successful implementation of Just-In-Time (JIT) practices. They work in partnership with management and each other to continuously pursue excellence. Front-line employees contribute to JIT success in several ways:

1. *Problem-solving teams:* Employees work together in teams to gather data and build consensus on improving work processes, fostering a collaborative approach to continuous improvement.

2. *Quality responsibility:* Employees are responsible for understanding the quality measures of their work and what they need to do to meet the needs of internal and external customers, promoting accountability and customer focus.
3. *Empowerment to take action:* Each employee is empowered to take action to correct problems, enabling swift resolution of issues and minimizing disruptions to the flow of operations.
4. *Cross-functional skill sets:* Employees possess cross-functional skill sets that allow them to be assigned to areas that need support, helping them adopt a broader ("big picture") view of the production process.
5. *Interconnectedness through demand-pull:* Unlike traditional "push" environments where line workers operate independently, JIT employees are connected by the "demand-pull" discipline, where work is produced only when the downstream work centre needs it, promoting interconnectedness and collaboration.
6. *Basic maintenance responsibilities:* Front-line employees are responsible for the basic maintenance of their machines, fostering a better understanding of equipment conditions and their ability to meet quality and production requirements.
7. *Coaching and facilitation:* Management works with employees as coaches and facilitators rather than authoritative supervisors, creating an environment that encourages proactive teamwork and continuous improvement.

By empowering front-line employees and fostering a culture of collaboration, accountability, and continuous improvement, organizations can harness the full potential of their workforce in support of JIT principles. This approach not only enhances operational efficiency but also promotes employee engagement and ownership, driving sustained success in a JIT environment.

9.5 CHAPTER SUMMARY & REVIEW

Summary

Chapter 9, "Just-In-Time and Lean Systems," provides a comprehensive overview of the key principles and practices that underpin these methodologies. The chapter begins by explaining the concepts of JIT and lean manufacturing, which focus on producing goods or services to meet customer demand precisely when needed, thereby eliminating waste and enhancing efficiency. The Toyota Production System is highlighted as a pioneering model in lean manufacturing, showcasing how it transformed production processes to minimize waste and optimize resource use. Lean manufacturing aims to eliminate seven types of waste: defects, overproduction, transportation, waiting, inventory, motion, and over-processing.

The chapter further delves into the core principles of lean manufacturing, which include defining value from the customer's perspective, mapping the value stream, creating flow, producing at the pace of actual customer demand, and striving for continuous improvement (Kaizen). These principles guide organizations in identifying and eliminating non-value-adding activities, thereby improving overall efficiency and customer satisfaction. The importance of lean control methodologies is also emphasized, highlighting how businesses can enhance operational efficiencies and product quality through systematic waste elimination and process optimization.

Additionally, the document discusses JIT systems, which aim to reduce inventory levels and lead times by producing only what is needed when it is needed. Key elements of JIT include inventory reduction to expose waste, pull production systems facilitated by tools like Kanban, quick setups to reduce lot sizes, flexible resources, and cellular flow layouts. The integration of Total Quality Management (TQM) with JIT is also explored, emphasizing continuous improvement and employee empowerment as crucial factors in successful JIT implementation. By adopting these principles, organizations can achieve significant improvements in quality, productivity, and competitiveness.

OpenAI. (2024, June 21). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: *Please take the chapter content in this document attached and summarize the key concepts into no more than three paragraphs. Reviewed by authors.*

Review Questions

1. What is the core philosophy behind Just-In-Time (JIT) manufacturing, and how does it differ from traditional manufacturing approaches?
2. Explain the significance of the Toyota Production System (TPS) in the development of lean manufacturing principles.
3. Identify and explain the seven types of waste (muda) targeted by lean manufacturing.
4. What are the five core principles of lean as identified by James Womack and Daniel Jones in their book "Lean Thinking"?
5. Describe the role of a pull production system in JIT and how it contrasts with a push production system.
6. How does Total Quality Management (TQM) integrate with JIT principles to enhance operational efficiency?
7. Explain the concept of cellular flow layouts and their benefits in promoting JIT goals.
8. Discuss the importance of flexible resources in a JIT environment.
9. What steps did 3M take to optimize setups on its coating machines, and how did these steps align with JIT principles?
10. In what ways can empowering front-line employees contribute to the success of JIT practices?

OpenAI. (2024, June 21). *ChatGPT.* [Large language model]. https://chat.openai.com/chat

Prompt: Create ten discussion questions based on the attached chapter document that assesses the student's knowledge based on the learning outcomes for the chapter. *Reviewed by authors.*

9.6 KEY TERMS

Key Terms

- **Defects:** Products that fail to meet customer requirements, rendering the effort to create them wasted and necessitating additional waste management processes.
- **Inventory:** Raw materials, work-in-progress, or finished goods representing capital outlay that has not yet generated income, with any non-value-adding inventory considered waste.
- **Just-in-time (JIT)** focuses on producing goods or services to meet customer demand only when they are needed.
- **Kaizen :** a incremental improvements in process that might be small, but contribute to continuous improvement.
- **Kanban :** a tool used in different forms (card, bin, etc.) that prompts the flow of work at the time it is needed to increase efficiency and reduce work in progress.
- **Lean control** is a refined example of nonfinancial controls in action aimed at enhancing product and service quality while reducing waste.
- **Lean manufacturing** refers to the elimination of waste in the manufacturing process.
- **Motion:** Unnecessary movements by workers or equipment that can lead to damage, wear, and safety issues, as well as incurring fixed assets and expenses.
- **Over-processing:** Using more expensive or valuable resources than necessary or adding features that are unneeded by customers, potentially leading to waste, particularly in terms of overqualified personnel performing tasks below their competency level.
- **Overproduction:** Producing or acquiring items before they are actually required, leading to excess inventory that must be stored, managed, and protected, often masking underlying production problems.
- **Push System :** Traditional manufacturing system that emphasizes maximizing machine and labour utilization, assuming that keeping workers and machines constantly busy will lead to productivity and efficiency.**Pull System :** a production system where work flows to a work

centre only when that centre needs more work (Just-In-Time).

- **Transportation:** Moving products without adding value, incurring costs, and risking damage, loss, or delays.
- **Value Strem Mapping (VSM):** the process of analyzing processes, identifying value-adding activities, and eliminating non-value-adding activities or waste in order to increase productivity.
- **Waiting:** Idle time spent by workers or capital tied up in goods and services not yet delivered to customers, often requiring additional processes to manage.
- **Waste:** any activity that does not add value for the customer, but is associated with use of resources at a cost.

VIDEO TRANSCRIPTS

9.4 Just-In-Time (JIT) Systems

VSM .Value Stream Mapping

Hi everyone, today's video is to learn value stream mapping. There are three objectives.

The first objective is to draw the current state plan.

The second is to identify improvement opportunities.

And the third is to make a future state map.

But how do we do it?

I'll tell you. We will show this by simulating a physical supply chain corresponding to the map on the screen.

Now, let us introduce the supply chain. The supply chain is about producing 2 varieties of these wheels: one is with a green cap, and one is with a yellow cap.

I will be the customer. I will give the order to Amrsha.

I'm the planner and the heart of the company. I take the order, make changes to it, and give it to Aishwarya.

I'm the supplier. I take the order from her, and I send the material to the receiving warehouse. I may also introduce some changes to achieve full load capacity of the truck.

Since I'm the planner, I also give the instruction to the departments of the company.

I'm Rashmi, and I received my order from the planner in the shop. My department procured the material from the receiving warehouse and our job is to stick these wheel caps to the wheels and keep it in the intermediary warehouse.

I'm Sakshi, I'm department two. My work is to attach a screw in the wheel.

I'm Shubhangi, and the operation here is to put the logo on the wheel and put it in the finished goods section. I also get my plan from Amrsha.

Can you see the correspondence between the physical simulation and the map? We've even tried to color code it for you.

Now that we have the process going in place, what else is missing? these details, we need the cycle time and the changeover time of each of these operations. Rashmi what is yours?

I have a cycle time of 10 seconds and a changeover time of one hour.

Sakshi.

My cycle time is 20 seconds and changeover time of two hours.

Shubhangi.

Well, I have to work according to the speed of the bottleneck, so my only work is to put the same drive logo, and that is why I have no changeover and my cycle time is of 10 seconds.

Great, let's fill in the details now.

It is a combination of the information flow and the material flow. The dotted lines indicate the information, and the pink lines indicate the material's flow.

So, what is the biggest advantage of VSM?

Kashyap, it is showing up non valuating activities and valuating activities in proportion to each other, you know the biggest non valuating activity, it is waiting, here is the waiting, that is the WIP contributed by these two.

The next step is to calculate the value adding and nonvalue adding time. Let's start.

My value adding time is 10 seconds, but I have 15 inventory waiting.

So, how does it translate into time?

Each one would take 10 seconds, so 15 into 10, 150 seconds.

OK what about the next operation.

So, my value adding time is 20 seconds, and the inventory waiting is 7. So, total nonvalue adding time will come down to 140.

Alright so 20 seconds while waiting and 140 seconds of nonvalue adding. Great, Shubhangi.

So, my value adding time is just 10 seconds, and my inventory time is one, two, three. 3 into 10, 30 seconds.

So, now what I did was, I told you the time I put it up on the map. The triangle with an 'I' represents the inventory waiting, and this is the time that is waiting for, 4 into 10, 40 seconds for this process.

So, what will you do with this data?

Let me tell you. We will calculate the value adding ratio, where we will calculate the ratio, which is 40 above 370, which gives us 10.8% only.

That means almost 89% of the time is non value adding.

Yes.

Yeah, but it sleeps almost 90% of the time.

The current state map is now ready, it's now ready, it's on the diagram, and to understand it better, it's also physically demonstrated.

This planner, she gave me so many changeovers! Doesn't she realize I have a huge changeover time? I cannot finish this with a given plan, I'll stick to whatever best I can do.

Since I'm the bottleneck of the process, I cannot sit idle, and I have to keep working with whatever I have.

What I get from Sakshi does not meet the plan. So, to utilize the capacity I produce what I get.

All these problem areas are the improvement opportunities which we can work upon. These improvement opportunities are shown by the starburst on the map. But how to work upon them?

Firstly, the planner makes only one plan and interacts only with the last operator. This creates the pull system of material flow.

I'll be the happiest here.

Oh, and also we can add the supermarket and Kanban system here.

But what about the high changeover time?

We can use SMED.

And you can watch a video on SMED of us too on the same channel.

Now, this is our future state map and the change physical simulation. Amrsha will you tell us about it?

Sure, what I do according to this map is I give the order to the third operator. Here is your plan.

Thank you. So now, only I get the plan. So as soon as I start working on the piece, I take the Kanban card and put it in the Kanban order box.

So, now I will start working as per the common receipt. I will pull this much of material from the supermarket and start working on it, and I'll also put this Kanban card to my previous operator.

Based on the Kanban, I can procure the material from the supermarket and start working on it, so using SMED my changeover time has drastically disappeared. I can produce whatever comes to me. Now that I've finished my operation, I take the Kanban card and the material and replenish the supermarket and wait for the next order.

Here, we were able to achieve three things. The first, we could work with very less inventory. The second, is get down the non value adding time. And the third, that we were able to increase the value adding ratio.

I hope you understood by this physical simulation and diagram how to use the tool of value stream.

REFERENCES

American Society for Quality. (n.d.). The define measure analyze improve control (DMAIC) process. https://asq.org/quality-resources/dmaic

The Art and Science of Forecasting in Operations Management. (n.d.). Universal Class. https://www.universalclass.com/articles/business/the-art-and-science-of-forecasting-in-operations-management.htm

Cameron, J. (2024, February 6). A complete guide to forecasting in operations management. *GetApp.com*. https://www.getapp.com/resources/what-is-forecasting-in-operations-management/

Ciliberti, F., Pontrandolfo, P., & Scozzi, B. (2008, May). Logistics social responsibility: Standard adoption and practices in Italian companies. *International Journal of Production Economics*, 113(1), 88-106. https://doi.org/10.1016/j.ijpe.2007.02.049.

Competition (companies). (2019, October 7). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Competition_(companies)&oldid=920132676

Diesing, G. (2023, August 25). The essential benefits of ISO standards for manufacturers. *Quality Magazine*. https://www.qualitymag.com/articles/97509-the-essential-benefits-of-iso-standards-for-manufacturers

EDI Resource Center. (n.d.). What Is EDI? The complete guide to electronic data interchange. *CData Software*. https://arc.cdata.com/resources/edi/?ref=rssbu

FasterCapital. (n.d.). .com/content/Control-Chart--Using-Control-Charts-for-Quality-Improvement--Best-Practices.html" data-url="https://fastercapital.com/content/Control-Chart--Using-Control-Charts-for-Quality-Improvement--Best-Practices.html">Control chart: Using control charts for quality improvement: Best practices. https://fastercapital.com/content/Control-Chart–Using-Control-Charts-for-Quality-Improvement–Best-Practices.html.

Forecasting. (2020, January 2). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Forecasting&oldid=933732816

Frenzel. (2023, October 3). The role of forecasting in operations management. *Medium*. https://prof-frenzel.medium.com/the-role-of-forecasting-in-operations-management-7429fba668f0

Garvin, D. (1987). Competing on the eight dimensions of quality. *Harvard Business Review*. https://hbr.org/1987/11/competing-on-the-eight-dimensions-of-quality%20accessed%20Dec%202019

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

Kenton, W. (2019). Distribution management. *Investopedia*.

Kettering University. (2016, September 21). 10 critical decisions of operation management. *Kettering Global*. https://online.kettering.edu/news/2018/05/11/10-critical-decisions-operations-management

McKinsey & Company. (2022, August 17). What are industry 4.0, the fourth industrial revolution, and 4IR. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir#

Onspring. (n.d.). .com/blog/benefits-of-being-iso-certified/" data-url="https://onspring.com/blog/benefits-of-being-iso-certified/">Benefits of being ISO certified. https://onspring.com/blog/benefits-of-being-iso-certified/.

Parkhani, P. (2019, April 3). Full circle for vertical integration: Ford to Tesla. *Linkedin*. https://www.linkedin.com/pulse/full-circle-vertical-integration-ford-tesla-parth-parkhani

Quain, S. (2018, November 26). Examples of vertically integrated companies. *Chron*. https://smallbusiness.chron.com/examples-vertically-integrated-companies-12868.html

Singla, V. (2018). *Operations Management*. INFLIBNET Centre.

Standford, S. C. (n.d.). Henry Ford – An impact felt. *Henry Ford Heritage Association*. https://hfha.org/the-ford-story/henry-ford-an-impact-felt/

The St. Lawrence Seaway Management Corporation. (n.d.).The St. Lawrence Seaway: A vital waterway. *Great Lakes St. Lawrence Seaway System*. https://greatlakes-seaway.com/en/the-seaway/.

Twin, A. (2023, August 30). Core competencies in business: Finding a competitive advantage. *Investopedia*. https://www.investopedia.com/terms/c/core_competencies.asp

What do you need to know about naïve forecasting? (n.d.). TransImpact. https://transimpact.in/nextsights/what-do-you-need-to-know-about-naive-forecasting/

Womack, J. P., & Jones, D. T. (2003). *Lean thinking*. New York: Simon & Schuster.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world*. New York: Rawson Associates.

VERSION HISTORY

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.1. If the edits involve a number of changes, the version number increases to the next full number.

The files posted alongside this book always reflect the most recent version.

Version	Date	Change	Affected Web Page
1.0	August 13, 2024	First publication	N/A