Operations Management

Cachon • Terwiesch

Operations Management

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Operations Management

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OPERATIONS MANAGEMENT

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DEDICATION

To my core: Beth, Xavier, Quentin, Annick, and Isaac.

—Gérard

To the Terwiesch family—in Germany, Switzerland, and the United States.

—Christian

About the Authors

Gérard Cachon

Gérard Cachon is the Fred R. Sullivan Professor of Operations, Information, and Decisions and a professor of marketing at The Wharton School at the University of Pennsylvania.

Professor Cachon studies operations strategy with a focus on how new technologies transform competitive dynamics through novel business models.

He is the chair of the Operations, Information, and Decisions department; an INFORMS Fellow; a Fellow of the Manufacturing and Service Operations Management (MSOM) Society; a former president of MSOM; and a former editor-in-chief of *Management Science* and *Manufacturing & Service Operations Management.*

His articles have appeared in *Harvard Business Review, Management Science, Manufacturing & Service Operations Management, Operations Research, Marketing Science,* and the *Quarterly Journal of Economics,* among others.

At Wharton, he teaches the undergraduate course in operations management, and an MBA and executive MBA elective on operations strategy.

Before joining the Wharton School in July 2000, Professor Cachon was on the faculty at the Fuqua School of Business, Duke University. He received a Ph.D. from The Wharton School in 1995.

He is a bike commuter (often alongside Christian) and enjoys photography, hiking, and scuba diving.

Christian Terwiesch

Christian Terwiesch is the Andrew M. Heller Professor at The Wharton School of the University of Pennsylvania. He is a professor in Wharton's Operations, Information, and Decisions department; is co-director of Penn's Mack Institute for Innovation Management; and also holds a faculty appointment in Penn's Perelman School of Medicine.

His research appears in many of the leading academic journals ranging from operations management journals such as *Management Science, Production and Operations Management, Operations Research,* and *The Journal of Operations Management* to medical journals such as *The Journal of General Internal Medicine, Medical Care, Annals of Emergency Medicine,* and *The New England Journal of Medicine.*

Most of Christian's current work relates to using operations management principles to improve health care. This includes the design of patient-centered care processes in the VA hospital system, studying the effects of emergency room crowding at Penn Medicine, and quantifying the benefits of patient portals and remote patient monitoring.

Beyond operations management, Christian is passionate about helping individuals and organizations to become more innovative. Christian's book *Innovation Tournaments* (Harvard Business School Press) proposes a novel, process-based approach to innovation that has led to innovation tournaments in organizations around the world.

Christian teaches MBA and executive classes at Wharton. In 2012, he launched the first massive open online course (MOOC) in business on Coursera. He also has been the host of a national radio show on Sirius XM's Business Radio channel.

Christian holds a doctoral degree from INSEAD (Fontainebleau, France) and a diploma from the University of Mannheim (Germany). He is a cyclist and bike commuter and so, because his commute significantly overlaps the commute of Gérard, many of the topics in this book grew out of discussions that started on the bike. After 15 years of Ironman racing, Christian is in the midst of a transition to the sport of rowing. Unfortunately, this transition is much harder than predicted.

Preface

This introductory-level operations management title provides the foundations of operations management. The book is inspired by our combined 30 years teaching undergraduate and MBA courses and our recent experience teaching thousands of students online via Coursera.

Seeing the need for a title different from our (highly successful) MBA textbook, we developed this new book for undergraduate students and the general public interested in operations. To engage this audience, we have focused our material on modern operations and big-picture operations.

Modern operations means teaching students the content they need in today's world, not the world of 30 or 40 years ago. As a result, "services" and "global" are incorporated throughout, rather than confined to dedicated chapters. Manufacturing, of course, cannot be ignored, but again, the emphasis is on contemporary issues that are relevant and accessible to students. For example, a Materials Requirement Planning (MRP) system is important for the functioning of a factory, but students no longer need to be able to replicate those calculations. Instead, students should learn how to identify the bottleneck in a process and use the ideas from the Toyota Production System to improve performance. And students should understand what contract manufacturing is and why it has grown so rapidly. In sum, we want students to see how operations influence and explain their own experiences, such as the security queue at an airport, the quality of their custom sandwich, or the delay they experience to receive a medical test at a hospital.

Big-picture operations mean teaching students much more than how to do math problems. Instead, the emphasis is on the explicit linkages between operations analytics and the strategies organizations use for success. For example, we want students to understand how to manage inventory, but, more importantly, they should understand why Amazon.com is able to provide an enormously broad assortment of products. Students should be able to evaluate the waiting time in a doctor's office, but also understand how assigning patients to specific physicians is likely to influence the service customers receive. In other words, big-picture operations provide students with a new, broader perspective into the organizations and markets they interact with every day.

We firmly believe that operations management is as relevant for a student's future career as any other topic taught in a business school. New companies and business models are created around concepts from operations management. Established organizations live or die based on their ability to manage their resources to match their supply to their demand. One cannot truly understand how business works today without understanding operations management. To be a bit colloquial, this is "neat stuff," and because students will immediately see the importance of operations management, we hope and expect they will be engaged and excited to learn. We have seen this happen with our own students and believe it can happen with any student.

Acknowledgments

This project is the culmination of our many years of learning and teaching operations management. As such, we are grateful for the many, many individuals who have contributed directly and indirectly, in small and large ways, to our exploration and discovery of this wonderful field.

We begin with the thousands of students who we have taught in person and online. It is through them that we see what inspires. Along with our students, we thank our co-teachers who have test piloted our material and provided valuable feedback: Morris Cohen, Marshall Fisher, Ruben Lobel, Simone Marinesi, Nicolas Reinecke, Sergei Savin, Bradley Staats, Xuanming Su, and Senthil Veeraraghavan.

We have benefited substantially from the following careful reviewers: Bernd Terwiesch took on the tedious job of proofreading early drafts of many chapters. Danielle Graham carefully read through all page proofs, still finding more mistakes than we would like to admit. We also thank Kohei Nakazato for double checking hundreds of test bank questions.

"Real operations" can only happen with "real" people. We thank the following who matched supply with demand in practice and were willing to share their experiences with us: Jeff Salomon and his team (Interventional Radiology unit of the Pennsylvania Hospital System), Karl Ulrich (Novacruz), Allan Fromm (Anser), Cherry Chu and John Pope (O'Neill), Frederic Marie and John Grossman (Medtronic), Michael Mayer (Johnson&Johnson), and Brennan Mulligan (Timbuk2).

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Finally, we thank our family members. Their contributions cannot be measured, but are deeply felt.

Gérard Cachon
Christian Terwiesch

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Guided Tour

Key Features

Structured with Learning Objectives

Great content is useless unless students are able to learn it. To make it **accessible** to students, it must be highly organized. So, all of the material is tagged by **learning objectives.** Each section has a learning objective, and all practice material is linked to a learning objective.

Process Analysis **3**

LEARNING OBJECTIVES

LO3-1 Draw a process flow diagram

LO3-2 Determine the capacity for a one-step process

LO3-3 Determine the flow rate, the utilization, and the cycle time of a process

LO3-4 Find the bottleneck of a multistep process and determine its capacity

LO3-5 Determine how long it takes to produce a certain order quantity

Check Your Understanding 3.2

Question: It takes a color printer 10 seconds to print a large poster. What is the capacity of the printer expressed in posters per hour?

Answer: The capacity of the printer is $\frac{1}{10}$ poster/second, which is 360 posters per hour.

Question: A call center has one operator who answers incoming calls. It takes the operator 6 minutes to answer one call. What is the capacity of the call center expressed in calls per hour?

Answer: The capacity of the call center is $\frac{1}{6}$ calls/minute = 10 calls/hour.

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Check Your Understanding

Given the learning objective structure, it is possible to present the material in **small chunks** that logically follow from each other. And each chunk ends with several straightforward **Check Your Understanding** questions so that students can feel confident that they have absorbed the content.

CONNECTIONS: Amazon

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When Jeff Bezos started his company in 1994, he wanted to create the world's largest bookstore in terms of selection. So he named it Amazon.com after the world's largest river system. His initial business model was simple. He would have a single warehouse in Seattle, near a large book distributor. The tech climate of Seattle allowed him to hire the coders

Big-Picture Connections

Each chapter includes several Connections that don't teach new concepts; rather, their role is to intrigue students, to raise their curiosity, and to give a broader understanding of the world around them. For example, we talk about policy issues (emergency room overcrowding), the people who have influenced operations (Agner Erlang), and the companies that have transformed industries (Walmart).

CASE Tesla

The Tesla Model S, one of the most sought-after luxury cars, is produced in Tesla's Freemont factory in California. The production process can be broken up into the following subprocesses.

Stamping: In the stamping process, coils of aluminum are unwound, cut into level pieces of sheet metal, and then inserted into stamping presses that shape the metal according to the geometry of the Model S. The presses can shape a sheet of metal in roughly 6 seconds.

Subassembly: The various pieces of metal are put together using a combination of joining techniques, including welding and adhesion. This creates the body of the vehicle.

Paint: The body of the vehicle is then moved to the paint shop. After painting is completed, the body moves through a 350° oven to cure the paint, followed by a sanding operation that ensures a clean surface.

General assembly: After painting, the vehicle body is moved to the final assembly area. Here, assembly workers and assembly robots insert the various subassemblies, such as the wiring, the dash board, the power train and the motor, the battery pack, and the seats.

Quality testing: Before being shipped to the customer, the now-assembled car is tested for its quality. It is driven on a rolling road, a test station that is basically a treadmill for cars that mimics driving on real streets.

Overall, the process is equipped with 160 robots and 3000 employees. The process produces some 500 vehicles each week. It takes a car about 3–5 days to move from the beginning of the process to the end.

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QUESTIONS

Imagine you could take a tour of the Tesla plant. To prepare for this tour, draw a simple process flow diagram of the operation.

1. What is the cycle time of the process (assume two shifts of eight hours each and five days a week of operation)?
2. What is the flow time?
3. Where in the process do you expect to encounter inventory?
4. How many cars are you likely to encounter as work in progress inventory?

SOURCES

http://www.wired.com/2013/07/tesla-plant-video/
http://www.forbes.com/sites/greatspeculations/2014/09/26/fremont-factory-delays-shouldnt-affect-teslas-sales-this-quarter/

Exercises and Cases

We have an extensive portfolio of exercises and cases. These exercises are entertaining but also illustrate key concepts from the text. Cases bring the "real world" into the classroom so that students appreciate that operations management is much more than just theory.

End-of-Chapter Content

The end of chapter provides students with the resources to reinforce their learning. Conceptual Questions explore their understanding of big-picture operations. Solved Example Problems give step-by-step illustrations into the chapter's analytical tools and Problems and Applications allow students to practice.

Conceptual Questions

LO6-1

1. A bank is underwriting loans for small businesses. Currently, about 5 percent of the underwriting decisions are found to be incorrect when audited by the bank's quality assurance department. The bank has a goal of reducing this number to 1 percent. What form of an improvement trajectory is most likely to occur?
   a. Exponential growth
   b. Exponential decay
   c. Diminishing return growth

Problems and Applications

LO6-1

1. Consider the trajectory showing the percentage of customer orders in a restaurant that were handled correctly. What shape would a learning curve have in this setting?
   a. Exponential growth
   b. Exponential decay
   c. Diminishing return growth

Solved Example Problems

LO6-1

1. Consider the trajectory showing the percentage of patients with depression that were not appropriately screened for suicide risk. A doctor's practice aims to reduce this percentage over time. What shape would a learning curve have in this setting?
   a. Exponential growth
   b. Exponential decay
   c. Diminishing return growth

   Answer: B.

Interactive Learning Resources

Students today don't learn by just reading. They expect to learn via multiple modalities. In particular, they like to learn (and in fact do learn) via video tutorials. Each tutorial is targeted to a single learning objective and provides a focused lesson in 1 to 5 minutes. These tutorials provide students with a "safety net" to ensure that they can master even the most challenging material.

Real Operations, Real Solutions, Real Simple

Our chapters are motivated by a diverse set of *real operations*—of companies that students can relate to. They include Subway, Capital One, Medtronic, O'Neill, LVMH, and many more. They are central to the core content of the chapters: We show students how to analyze and improve the operations of these actual companies, in many cases with actual data from the companies, that is, *real solutions.*

Next, *real simple* means that the material is written so that students can actually learn how to implement the techniques of operations management in practice. In particular, we write in a logical, step-by-step manner and include plenty of intuition. We want students to be able to replicate the details of a calculation and also understand how those calculations fit into the overall objectives of what an organization is trying to achieve.

Focus on Process Analysis

All operations management books talk a little bit about process analysis; we believe that not only is process analysis the starting point for operations management, it also is the heart of operations management. Process analysis is at the core of how an organization delivers supply. Hence, students need to understand the key metrics of process analysis (inventory, flow rate, flow time, utilization, labor content, etc.), how they are related, and, most importantly, what the organization can do to improve its processes. Most students will not work in a factory or be in charge of a global supply chain. But all students, no matter where they work or in what industry they work, will be involved in some organizational process. This is why process analysis deserves the prominence it is given in our product.

Written for the Connect Platform

Operations Management has been written specifically for the McGraw-Hill Connect platform. Rather than fitting a learning management system to a book, we designed the product and the learning management system jointly. This co-development has the advantage that the test questions map perfectly to the learning objectives. The questions are also concise and can be assessed objectively. It is our experience that open-ended discussion questions ("What are the strengths and weaknesses of the Toyota Production System?") are important in a course. But they make for great discussion questions in the classroom (and we mention such questions in the instructor support material). However, they are frustrating for students as homework assignments, they are difficult to grade, and it is hard to provide the student with feedback on mastery of the topic.

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Introduction to Operations Management

1

LEARNING OBJECTIVES

LO1-1 Identify the drivers of customer utility

LO1-2 Explain inefficiencies and determine if a firm is on the efficient frontier

LO1-3 Explain the three system inhibitors

LO1-4 Explain what work in operations management looks like

LO1-5 Articulate the key operational decisions a firm needs to make to match supply with demand

CHAPTER OUTLINE

Introduction
1.1 The Customer's View of the World
1.2 A Firm's Strategic Trade-Offs
1.3 Overcoming Inefficiencies: The Three System Inhibitors
1.4 Operations Management at Work
1.5 Operations Management: An Overview of the Book
Conclusion

Introduction

As a business (or nonprofit organization), we offer products or services to our customers. These products or services are called our **supply**. We provide rental cars, we sell clothes, or we perform medical procedures. Demand is created by our customers—**demand** is simply the set of products and services our customers want. Our customers may want a rental car to travel from A to B, or a black suit in size 34, or to get rid of an annoying cough.

To be successful in business, we have to offer our customers what they want. If Mr. Jamison wants a midsize sedan from Tuesday to Friday to be picked up at Chicago O'Hare International Airport (demand), our job is to supply Mr. Jamison exactly that—we need to make sure we have a midsize sedan (not a minivan) ready on Tuesday (not on Wednesday) at O'Hare (not in New York) and we need to hand it over to Mr. Jamison (not another traveler).

If on Saturday Sandy wants a green dress in size M in our retail outlet in Los Angeles, our job is to get her exactly that—we need to make sure we have a green dress in size M (not in red or in size L) in the Los Angeles store (not in San Francisco) on Saturday (not on Friday of last week).

And if Terrance injures his left knee in a soccer game and now needs to have a 45-minute meniscus surgery in Philadelphia tomorrow, our job is to supply Terrance exactly that—we need to make sure we reserve 45 minutes in the operating room (not 30 minutes), we need to have an orthopedic surgeon and an anesthesiologist (not a dentist and a cardiologist) ready tomorrow (not in six weeks), and the surgeon definitely must operate on the left knee (not the right one).

Another way of saying "we offer customers what they want" is to say, "we match supply with demand"! Matching supply with demand means providing customers what they want, while also making a profit. Matching supply with demand is the goal of operations management.

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Supply Products or services a business offers to its customers.

Demand Simply, the set of products and services our customers want.

This book is about how to design operations to better match supply with demand. It thus is a book about getting customers what they want. Our motivation is simply stated: By better matching supply with demand, a firm is able to gain a significant competitive advantage over its rivals. A firm can achieve this better match through the implementation of the rigorous models and the operational strategies we outline in this book.

In this introductory chapter, we outline the basic challenges of matching supply with demand. This first requires us to think about demand—what do customers want? Once we understand demand, we then take the perspective of a firm attempting to serve the demand—we look at the supply process. We then discuss the operational decisions a firm has to make to provide customers with what they want at a low cost. Now, typically, customers want better products for lower prices. But, in reality, this might not always be simple to achieve. So, a subsequent section in this chapter talks about overcoming three inhibitors that keep the operation from delivering great products at low prices. Beyond overcoming these inhibitors, the operation also needs to make trade-offs and balance multiple, potentially conflicting objectives. We conclude this chapter by explaining what jobs related to operations management look like and by providing a brief overview of operations management in the remainder of the book.

1.1 The Customer's View of the World

You are hungry. You have nothing left in the fridge and so you decide to go out and grab a bite to eat. Where will you go? The McDonald's down the street from you is cheap and you know you can be in and out within a matter of minutes. There is a Subway restaurant at the other end of town as well—they make an array of sandwiches and they make them to your order—they even let you have an Italian sausage on a vegetarian sandwich. And then there is a new organic restaurant with great food, though somewhat expensive, and the last time you ate there you had to wait 15 minutes before being served your food. So where would you go?

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LO1-1 Identify the drivers of customer utility.

Economic theory suggests that you make this choice based on where you expect to obtain the highest **utility**. Your utility associated with each of the eating options measures the strength of your preferences for the restaurant choices available. The utility measures your desire for a product or service.

Now, why would your utility associated with the various restaurant options vary across restaurants? We can think about your utility being composed of three components: consumption utility, price, and inconvenience.

Consider each of these three components in further detail. Let us start with **consumption utility**. Your consumption utility measures how much you like a product or service, ignoring the effects of price (imagine somebody would invite you to the restaurant) and ignoring the inconvenience of obtaining the product or service (imagine you would get the food right away and the restaurant would be just across the street from you). Consumption utility comes from various attributes of a product or service; for example, "saltiness" (for food), "funniness" (for movies), "weight" (for bicycles), "pixel count" (for cameras), "softness" (for clothing), and "empathy" (for physicians). There are clearly many attributes and the relevant attributes depend on the particular product or service we consider. However, we can take the set of all possible attributes and divide them into two sets: performance and fit. These sets allow us to divide consumption utility into two subcomponents:

- **Performance**. Performance attributes are features of the product or service that most (if not all) people agree are more desirable. For example, consumers prefer roasted salmon cooked to perfection by a world-class chef over a previously frozen salmon steak cooked in a microwave. In the same way, consumers tend to prefer the latest iPhone over an old iPod, and they are likely to prefer a flight in first class over a flight in economy class. In other words, in terms of performance, consumers have the same ranking of products—we all prefer "cleaner," "more durable," "friendlier," "more memory," "roomier," and "more efficient."
- **Fit**. With some attributes, customers do not all agree on what is best. Roasted salmon sounds good to us, but that is because we are not vegetarian. Customers vary widely in the utility derived from products and services (we say that they have **heterogeneous preferences**), which is the reason why you see 20 different flavors of cereals in the supermarket aisles, hundreds of ties in apparel stores, and millions of songs on iTunes. Typically, heterogeneous preferences come from differences across customers in taste, color, or size, though there are many other sources for them.

The second component of the customer's utility is **price**. Price is meant to include the total cost of owning the product or receiving the service. Thus, price has to include expenses such as shipping or financing and other price-related variables such as discounts. To state the obvious, holding everything else constant, customers prefer to pay less rather than paying more.

The third and final component of the customer's utility function is the **inconvenience** of obtaining the product or receiving the service. Economists often refer to this component as **transaction costs**. Everything else being equal, you prefer your food here (as opposed to three miles away) and now (as opposed to enduring a 30-minute wait). The following are the two major subcomponents of inconvenience:

- **Location**. There are 12,800 McDonald's restaurants in the United States (but only 326 in China), so no matter where you live in the United States, chances are that there is one near you. McDonald's (and many other restaurants for that matter) wants to be near you to make it easy for you to get its food. The further you have to drive, bike, or walk, the more inconvenient it is for you.
- **Timing**. Once you are at the restaurant, you have to wait for your food. And even if you want fast-food, you still have to wait for it. A recent study of drive-through restaurants in the United States found that the average customer waits for 2 minutes and 9 seconds at Wendy's, 3 minutes and 8 seconds at McDonald's, and 3 minutes and 20 seconds at Burger King. All three of those restaurants are much faster than the 20 minutes you have to wait for the previously mentioned roasted salmon (though the authors think that this is well worth the wait).

Utility A measure of the strength of customer preferences for a given product or service. Customers buy the product or service that maximizes their utility.

Consumption utility A measure of how much you like a product or service, ignoring the effects of price and of the inconvenience of obtaining the product or service.

Performance A subcomponent of the consumption utility that captures how much an average consumer desires a product or service.

Fit A subcomponent of the consumption utility that captures how well the product or service matches with the unique characteristics of a given consumer.

Heterogeneous preferences The fact that not all consumers have the same utility function.

Price The total cost of owning the product or receiving the service.

Inconvenience The reduction in utility that results from the effort of obtaining the product or service.

Transaction costs Another term for the inconvenience of obtaining a product or service.

Location The place where a consumer can obtain a product or service.

Timing The amount of time that passes between the consumer ordering a product or service and the consumer obtaining the product or service.

Figure 1.1
Consumer utility and its components and subcomponents

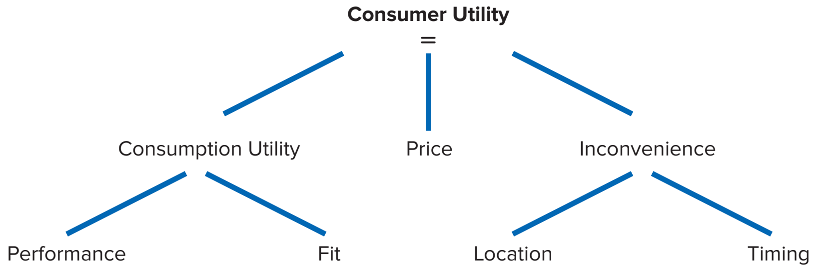

Figure 1.1 summarizes the three components of a consumer's utility for a product or service along with their subcomponents.

Customers buy the products or services that maximize their utility. They look at the set of options available to them, including the option of doing nothing (make their own lunch or stay hungry). We can define the demand of a business as the products or services that customers want; that is, those products that are maximizing their utility. So, our demand is driven by the consumption utility of our product or service, its price, and the associated inconvenience for our customers. In the case of a McDonald's restaurant, on any given day the demand for that restaurant corresponds to those customers who, after considering their consumption utility, the price, and the inconvenience, find that McDonald's restaurant is their best choice. Because we most likely have multiple customers, our demand corresponds to a total quantity: 190 cheeseburgers are demanded in Miami on Tuesday at lunch.

Marketing The academic discipline that is about understanding and influencing how customers derive utility from products or services.

Understanding how customers derive utility from products or services is at the heart of **marketing**. Marketers typically think of products or services similar to our previous discussion in conjunction with Figure 1.1. As a business, however, it is not enough to just understand our customers; we also have to provide them the goods and services they want.

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Check Your Understanding 1.1

Question: What drives your utility in terms of choosing a hotel room in San Francisco?

Answer: Consider each of these items:

- Performance attributes of consumption include the number of amenities and the size of the room (think two-star versus five-star hotel). Fit attributes are driven by personal preferences. For example, some like classic décor, while others like modern styling, and some like a noisy, busy atmosphere, while others prefer a subdued, quiet ambience.
- Price is simply the price you have to pay to the hotel.
- Inconvenience is driven by the availability of the hotel relative to your travel plans. You might be off from work or study in July, but the hotel might only have rooms available in March. This is the timing piece of inconvenience. Inconvenience can also relate to location. If you want to go sightseeing, chances are you would prefer a hotel in the Fisherman's Wharf area of San Francisco over one next to the airport.

Therefore, the utility is driven by the utility of consumption, price, and inconvenience.

1.2 A Firm's Strategic Trade-Offs

In a perfect world, we would provide outstanding products and services to all our customers, we would tailor them to the heterogeneous needs of every single one of our customers, we would deliver them consistently where and when the customer wants, and we would offer all of that at very little cost.

Unfortunately, this rarely works in practice. In sports, it is unlikely that you will excel in swimming, gymnastics, running, fencing, golf, and horse jumping. The same applies to companies—they cannot be good at everything. Companies have **capabilities** that allow them to do well on some but not all of the subcomponents making up the customer utility function. We define a firm's capabilities as the dimensions of the customer's utility function it is able to satisfy.

Consider the following examples from the food and hospitality industry:

- McDonald's is able to serve customers in a matter of three minutes (see the previous section). One reason for this is that they make the burgers before customers ask for them. This keeps costs low (you can make many burgers at once) and waiting times short. But because McDonald's makes the burger before you ask for it, you cannot have the food your way.
- Subway, in contrast, is able to charge a small premium and has customers willing to wait a little longer because they appreciate having sandwiches made to their order. This approach works well with ingredients that can be prepared ahead of time (precut vegetables, cheeses, meats, etc.) but would not work as well for grilled meat such as a hamburger.
- Starbucks provides a fancy ambiance in its outlets, making it a preferred place for many students to study. It also provides a wide array of coffee-related choices that can be further customized to individual preferences. It does, however, charge a very substantial price premium compared to a coffee at McDonald's.

So companies cannot be good at everything; they face **trade-offs** in their business. For example, they trade off consumption utility and the costs of providing the products or services. Similarly, they trade off the inconvenience of obtaining their products or services with the costs of providing them; and, as the McDonald's versus Subway example illustrated, they even face trade-offs among non-cost-related subcomponents of the utility function (fit—the sandwich made for you—versus wait times).

Such trade-offs can be illustrated graphically, as shown in Figure 1.2. Figure 1.2 shows two fast-food restaurants and compares them along two dimensions that are important to us as potential customers hunting for food. The *y*-axis shows how responsive the restaurant is to our food order—high responsiveness (short wait time) is at the top, while low responsiveness (long wait time) is at the bottom. Another dimension that customers care about is the price of the food. High prices are, of course, undesirable for customers. We assume for now that the restaurants have the same profit per unit. For the sake of argument, assume they charge customers a price of $2 above costs, leaving them with $2 of profit per customer. So, instead of showing price, the *x*-axis in Figure 1.2 shows cost efficiency—how much it costs a restaurant to serve one customer. Cost performance increases along the *x*-axis.

Consider restaurant A first. It costs the restaurant an average of $4 for a meal. Customers have to wait for 10 minutes to get their food at restaurant A, and restaurant A charges $6 to its customers for an average meal ($4 cost plus $2 profit).

Restaurant B, in contrast, is able to serve customers during a 5-minute wait time. To be able to respond to customers that quickly, the restaurant has invested in additional resources—they always have extra staff in case things get busy and they have very powerful cooking equipment. Because staffing the kitchen with extra workers and obtaining the expensive equipment creates extra expenses, restaurant B has higher average costs per customer (a lower cost performance). Say their average costs are $5 per customer. Because they have the same $2 profit as restaurant A, they would charge their customers $7.

Capabilities The dimensions of the customer's utility function a firm is able to satisfy.

Trade-offs The need to sacrifice one capability in order to increase another one.

Figure 1.2
The strategic trade-off between responsiveness and productivity

Assuming the restaurants are identical on all other dimensions of your utility function (e.g., cooking skills, food selection, location, ambience of the restaurant, etc.), which restaurant would you prefer as a customer? This clearly depends on how much money you have available and how desperate you are for food at the moment. The important thing is that both restaurants will attract some customers.

Figure 1.2 illustrates a key trade-off that our two restaurants face. Better responsiveness to the needs of hungry customers requires more resources (extra staff and special equipment), which is associated with higher costs. Most likely, restaurant B is occasionally considering cutting costs by reducing the number of staff in the kitchen, but this would make them less responsive. Similarly, restaurant A is likely to also investigate if it should staff extra workers in the kitchen and invest in better equipment, because that would allow it to charge higher prices. We refer to trade-offs such as the one between responsiveness and costs as a **strategic trade-off**—when selecting inputs and resources, the firm must choose between a set that excels in one dimension of customer utility or another, but no single set of inputs and resources can excel in all dimensions.

Considering restaurants A and B, which one will be more successful? Low cost (and low price) with poor responsiveness or higher costs (higher prices) with good responsiveness? Again, assuming the two restaurants are identical in all other aspects of their business, we first observe that neither restaurant is better on both dimensions of performance. From the customer's perspective, there exists no dominant choice. As discussed earlier, some customers prefer the fast service and are willing to pay a premium for that. Other customers cannot afford or do not want to pay that premium and so they wait. As a result of this, we have two different **market segments** of consumers in the industry. Which restaurant does better financially? The answer to that question strongly depends on the size and dynamics of these market segments. In some areas, the segment served by restaurant A is very attractive (maybe in an area with many budget-conscious students). In other regions (maybe in an office building with highly paid bankers or lawyers), the segment served by restaurant B is more attractive.

Now, consider restaurant C, shown in Figure 1.3. Restaurant C has its customers wait for 15 minutes for a meal and its costs are $6 for the average customer (so the meals are priced at $8). The restaurant seems to be slower (lower responsiveness; i.e., longer waits) and have higher costs. We don't know why restaurant C performs as it does, but (again, assuming everything else is held constant) most of us would refer to the restaurant as underperforming and go to either restaurant A or B when we are hungry.

As we look at restaurant C, we don't see a rosy future simply because restaurants A and B can provide a better customer experience (faster responsiveness) for a lower price. Why would any customer want to go to restaurant C? Restaurant C is **Pareto dominated** by

Market segment A set of customers who have similar utility functions.

Pareto dominated Pareto dominated means that a firm's product or service is inferior to one or multiple competitors on all dimensions of the customer utility function.

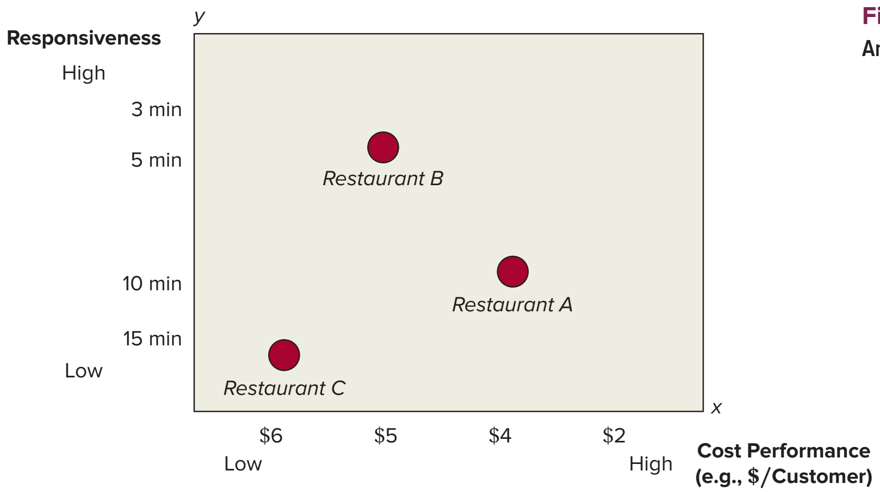


Figure 1.3
An underperforming operation (restaurant C)

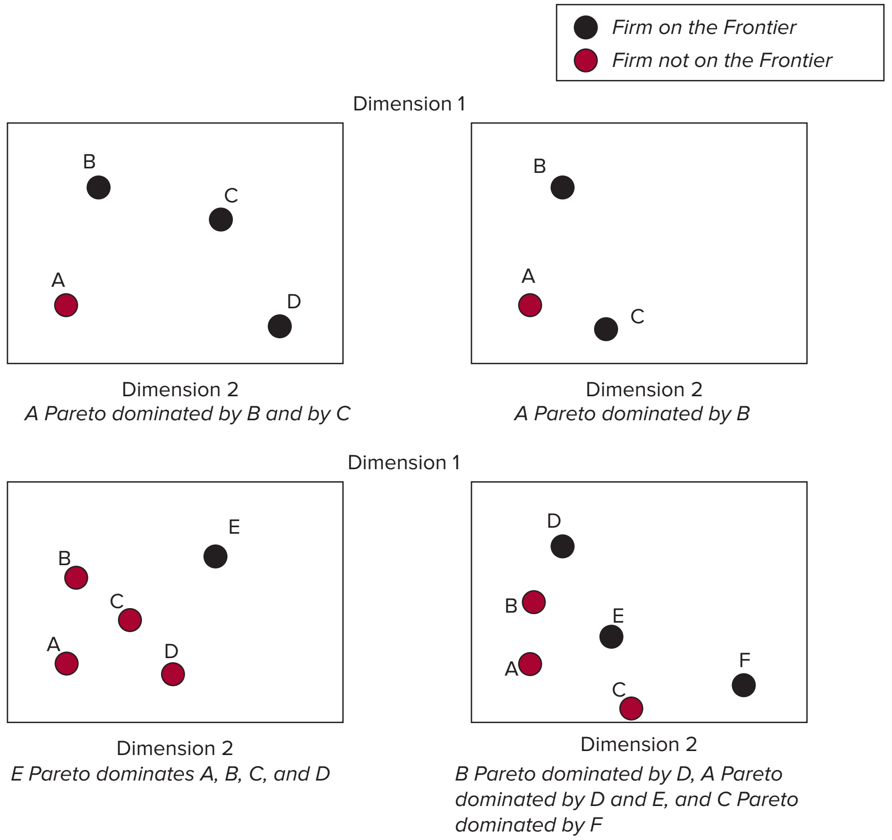


Figure 1.4
The definition of the efficient frontier

restaurants A and B. They perform equally or better on all attributes of the customer's utility function. Or, put casually, they are simply *better.*

We define the **efficient frontier** in an industry as the set of firms in the industry that are not Pareto dominated. In other words, firms that are on the efficient frontier have no firms in the industry to their upper right (i.e., are better on all dimensions). In Figure 1.3, the efficient frontier consists of restaurants A and B. Restaurants on the frontier have made different strategic trade-offs and thus focus on different market segments, but no single firm on the frontier Pareto dominates another.

Efficient frontier The set of firms that are not Pareto dominated.

LO1-2 Explain inefficiencies and determine if a firm is on the efficient frontier.

Some firms, in our case restaurant C, are not on the frontier. The fact that others can provide better (equal) customer utility at equal (lower) costs suggests that restaurant C is **inefficient**. We can visualize inefficiency as the gap between the firm's current position and the efficient frontier. Figure 1.4 helps illustrate this definition of the efficient frontier.

Figures 1.2 and 1.3 illustrate two ways operations management achieves the goal of "matching supply with demand." First, operations management designs the operations that match the demand of a market segment with the supply of products and services appropriate for that segment. The management of the restaurant achieves this by making a strategic trade-off—does it want to be like restaurant A or like restaurant B? Operations management helps to execute on that strategy by building an operation appropriate for that market segment.

Second, operations management seeks to utilize inputs and resources to their fullest potential. Restaurant C is not doing this simply because restaurants A and B can provide a better customer experience (fast responsiveness) for a lower price. Applying operations management to restaurant C means figuring out how to eliminate inefficiencies (and thereby move the firm to the efficient frontier). This might mean changing the inputs and resources it currently has, or it might mean managing those inputs and resources more effectively.

But there is a third, and very crucial, way that operations management achieves the goal of "matching supply with demand." To explain, consider restaurant D, as shown in Figure 1.5. Restaurant D offers a meal within three minutes and operates with an average cost of $3 per customer (so the price is $5). The restaurant is faster (higher responsiveness) and has lower costs! It is able to get more out of its resources along all dimensions relative to the other firms in the industry. It must be doing something smarter. For example, restaurant D might have found a way to make the same food with fewer worker hours. One of the first innovations at McDonald's on its journey from a small restaurant to a multibillion-dollar company was the invention of a sauce dispenser that allowed for consistent portion sizing even when operated by an unskilled worker at high speed—one of many innovations that led it to continuously increase the output it was able to achieve with its resources.

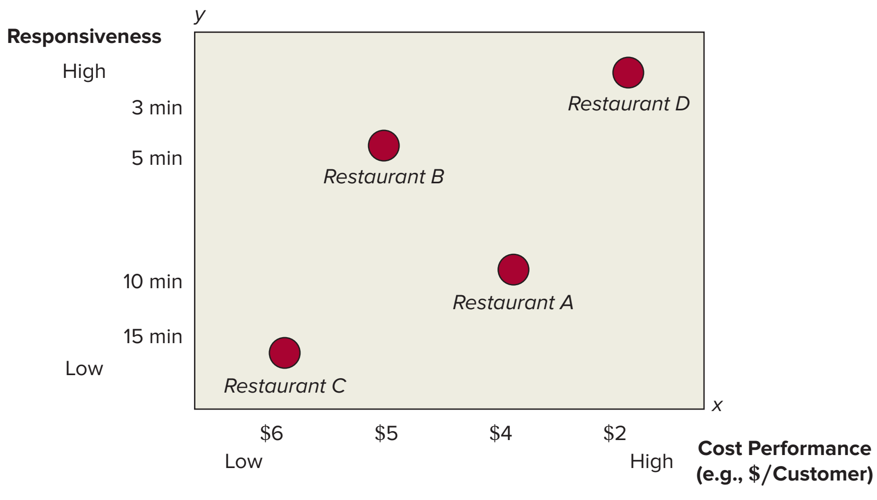
Assuming everything else is constant across the restaurants, most of us would make restaurant D our preferred choice when hunting for food. And that bodes well for its future and profits. So the third way operations management achieves the goal of "matching supply with demand" is to keep innovating to shift the efficient frontier. Restaurant D must have gone beyond just eliminating inefficiencies and moving toward the frontier. Instead, it broke the existing cost–responsiveness trade-off.

inefficient The gap between a firm and the efficient frontier.

So, great operations never rest on their laurels. Operations management is not just about executing the current way of doing things but about constantly improving and looking for new ways of doing business. Such innovations might be incremental, such as McDonald's sauce

Figure 1.5

A high-performing operation (restaurant D) enters the market



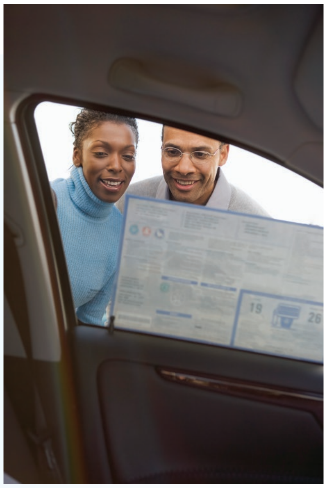
Check Your Understanding 1.2

Question: **There are four automotive companies competing with otherwise very similar products on the dimensions of fuel economy (measured in miles per gallon, mpg) and price.**

- Company A: price = $40,000; mpg = 50
- Company B: price = $50,000; mpg = 60
- Company C: price = $30,000; mpg = 40
- Company D: price = $45,000; mpg = 45

Which of these companies are on the efficient frontier?

Answer: The only company that is Pareto dominated is company D; all others are on the efficient frontier. Company D is Pareto dominated by company A, because A is both cheaper ($40,000 instead of $45,000) and more fuel efficient (50 instead of 45 mpg).



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CONNECTIONS: Airlines

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The airline industry is a difficult industry to succeed in. Many companies have gone bankrupt. Some (Delta and United) have reemerged from bankruptcy; others have disappeared forever even though they were once big players in the industry (TWA and PanAm). Consider the data shown in Figure 1.6(a). The figure shows how much U.S. air carriers can charge for each mile they transport a passenger (*y*-axis) as a function of what costs they incur to provide that mile (*x*-axis).

For example, we see that **American Airlines** is able to charge a little less than 20 cents ($0.20) per passenger mile. We also see that American Airlines is able to fly a little more than 5 miles (5.1 miles to be exact) for every dollar of expense. The figure illustrates the concept of the efficient frontier. In the year 2012, no carrier Pareto dominated another carrier. Firms faced the trade-off between customer service, which arguably leads to higher prices, and efficiency (which allows you to get more miles per dollar of expense).

Continued