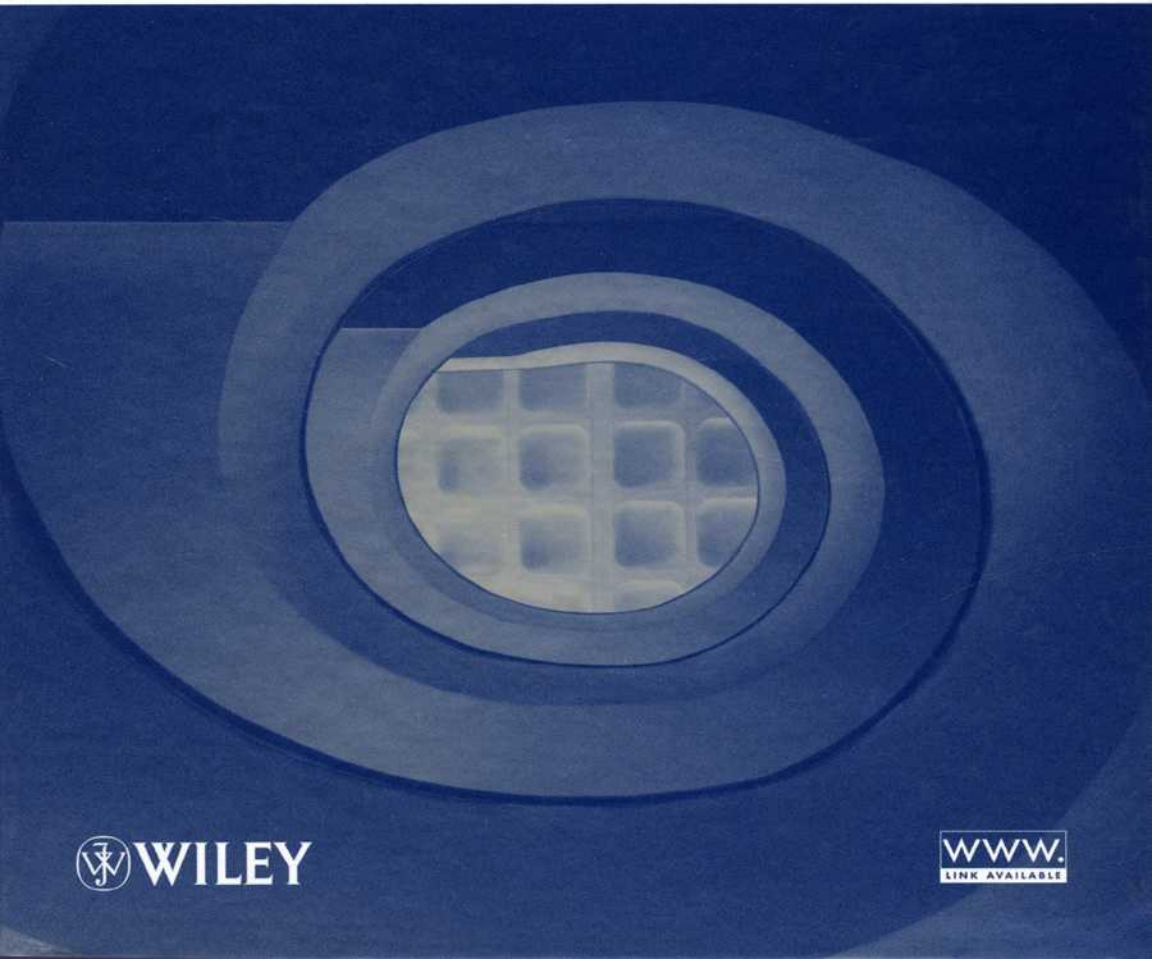
SERVICE SCIENCE

Mark S. Daskin



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To

My parents, Walter ז"ל and Betty,

My daughters, Tamar and Keren,

And my wife, Babette

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Appendixes and a full list of References are posted online.

All referenced files may be found at http://umich.edu/~msdaskin/servicescience/

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PREFACE

We depend on services and service providers for many of our day-to-day activities, from the news we wake up to on our clock radio to the e-mail we check before breakfast, from the dry cleaner we stop at on our way to work to the express mail delivery service that dropped off our latest holiday gifts, from the cute corner bistro we patronize daily for lunch to the movie theater at which we unwind on the weekends. Many services are implicit in our lives including banking, investments, insurance, police and fire services, and (hopefully) our heath care providers. Without service providers, our lives would simply not be what they are today.

The service sector in the United States is rapidly growing as a percentage of the economy. Sixty years ago, the service sector represented only 20 percent of the gross domestic product; today, services account for over 40 percent of the gross domestic product. The percentage of the GDP accounted for by the production of non-durable goods (e.g., food, clothing, and energy) has seen a commensurate decline. In 1960, slightly less than one out of every two people employed in the United States was employed in the service sector; today, more than two out of every three employees work in some form of service industry.

Given our daily dependence on services and the enormous role that the service sector plays in the economy—not only of the United States, but also of every developed country around the world—it is important that we understand the operation of this sector and that services be provided in an efficient and effective manner. Much of the current debate in the United States over health care reform—and health care is part of the service sector—focuses on ways of increasing access, reducing inequities, and containing costs.

This book will provide students with the tools and background needed to analyze and improve the provision of services in our economy.

Following a brief introduction to the service sector, Part I of the text deals with the methodological background needed to analyze service systems. Two core methodologies are introduced: optimization and queueing modeling. For students who have not had a course on one or both of these topics, these chapters provide the background necessary to master the material in the remainder of the text. In addition, the online Appendix B summarizes probability theory at a level that will allow students who have limited backgrounds to understand the chapter on queueing models.

While many students may have a background in optimization and queueing, topics covered near the end of each chapter are typically not included in

introductory courses. Section 2.8 deals with multi-objective optimization. This is critical in the analysis of many services because service providers must often balance conflicting objectives. A local government operating an emergency medical service department (ambulances) must carefully balance the need for rapid response against the demands for fiscal responsibility. Similarly, a cell phone company must balance the demands for expanded and enhanced service area coverage against the need to show a profit at the end of the year. Section 2.9 addresses a number of common mistakes that students (and professionals) make in formulating optimization problems. Section 3.5 summarizes key queueing results that extend beyond those included in many introductory stochastic processes books. Section 3.6 outlines how to solve queueing models numerically using Excel and section 3.7 discusses queueing problems in which the input or operating conditions change over time. Such problems are critical in the analysis of services. For example, there is typically a three or four to one ratio between the peak and off-peak call rates for emergency medical service. Planning for the average daily arrival rate of calls would lead to serious delays during the peak and excess capacity during the off-peak periods. Many other services experience daily, monthly, or annual spikes in demand. Even students with good backgrounds in optimization and queueing might find these sections useful.

The remainder of the text is devoted to the application of optimization and queueing to the analysis and design of service systems. Chapter 4 deals with strategic decisions regarding the number and location of service facilities. Cell phone service providers must, for example, determine the number and location of their cell phone towers to provide cost-effective coverage to a service region. Fast food restaurants must also determine how many stores to have and where they should be to balance easy access against the possibility of self-cannibalizing the market. Many service providers partition the service region into districts that are then served by individual customer service agents. The chapter concludes with a discussion of districting problems.

Many authors argue that the inability to store services in inventory is a key differentiator between the service sector and the manufacturing sector. A car that is not sold today can be stored in inventory for sale tomorrow or next week. On the other hand, a surgeon who takes an afternoon off from work to watch his son star in a school play cannot place the missed operating room hours in inventory for use later in the week. While the service itself cannot be stored in inventory for future use, many service providers depend critically on the ready availability of inventory to assist in the provision of the services they deliver. The same surgeon relies on the availability of sterile instruments in the operating theater at the beginning of each procedure. The local shoe store must stock shoes in numerous styles and sizes for its customers. Thus, an understanding of inventory problems and decisions is critical for students of the service industries. Furthermore, in contracting for services, individuals and firms must often make commitments before the demand for the services is realized. For example, many of us can place pre-tax funds in special accounts to pay for qualified medical expenses. We must decide in the Fall of one year how much money to set aside

during the following year before knowing what our medical expenses will be during the coming year. Any unused funds at the end of a year are lost. Such problems are known as newsvendor problems and are discussed at the end of Chapter 5 on inventory modeling.

At its core, many decisions in the provision of services boil down to resource allocation decisions. A college or university must allocate classroom space to courses. Colleges and universities must also allocate limited dormitory space to students and must also assign students to courses based on the students' preferences and requirements and the availability of space in the courses. Airlines must allocate gates to aircraft. Chapter 6 deals with resource allocation decisions.

Chapters 7 and 8 address short-term and long-term workforce management decisions and problems. In the short-term, service providers must determine how many staff to employ during each period of the day. For example, a hospital must decide how many full-time nurses to hire during each shift. It must also determine how it will staff each unit in the event that the number of patients on the unit exceeds the expected number. Typically, nurses are asked to perform overtime duty or more expensive temporary nurses are hired to fill in for the permanent staff.

In the long-term, providers must determine how many employees to hire, to promote, to release, and to retrain. A consulting firm, for example, needs to determine how many college seniors to hire each year in each of the specialty areas of the firm. Some of the more senior analysts at the firm may be targeted for management training. When the firm's business base changes, the firm may need to either retrain some of its employees or release the less productive members of its staff to make room for newer, better-trained employees in the growth areas. Chapter 8 addresses these problems.

Chapter 9 extends the discussion of queueing models to three particular topics that arise in many service providers. Not all customers are equal. An elderly woman presenting in an emergency room in active cardiac arrest is likely to be served long before a six-year-old boy who fell of his bicycle and who may have a broken leg or twisted ankle. Frequent customers may be flagged for improved service in many industries. Thus, priority service systems comprise the first part of this chapter. Nearly every major company and government service provider operates a call center to provide service to its customers. When it comes to call centers, bigger really is better. The second section of this chapter addresses the design and operation of call centers. Finally, in many services, customers can be scheduled for service. A dermatologist can schedule most of her patients. Issues in customer scheduling are outlined in the final portion of the chapter.

Finally, many services entail the delivery or pickup of customers or goods. A local public school must provide bussing to its students to pick them up from their homes in the morning and to return them home at the end of the school day. Large white goods (refrigerators, freezers, dish washers, washing machines, and dryers) must be delivered to customer homes in a timely manner following the purchase of the items. The mail must be delivered daily and streets must be

cleaned during the summer and plowed during the winter. Chapter 10 introduces vehicle routing problems and models as they arise in the delivery of services.

In addition to the mathematical derivation and formulation of the models outlined in the text, the book includes numerous sections summarizing how to implement the models using Microsoft® Office Excel®. These sections are highlighted in the text, just as this paragraph is highlighted. The example spreadsheets are available from the author's website. Equations or formulae in Excel are enclosed in single quotes such as 'IF(C1<0,1,0)'. This discussion and the spreadsheets should make the models accessible to a broader audience.

All referenced files may be found at http://umich.edu/~msdaskin/servicescience/

The course that I taught at Northwestern University, which operates on a 10-week quarter system, had prerequisites of (a) deterministic optimization, (b) probability, (c) statistics, and (d) stochastic modeling, including an introduction to queueing theory. Thus, students were largely well-prepared in terms of methodological backgrounds. Because of their background in optimization, after a quick summary of the first chapter, I was able to cover only sections 2.8 and 2.9 of Chapter 2. I usually did a one- or two-day review of queueing theory including a quick introduction to time-dependent problems covered in section 3.7. I typically would spend two weeks on location models (Chapter 4). My coverage of inventory theory focused on the newsvendor problem (section 5.6). Resource allocation problems (Chapter 6) were typically introduced during the review of optimization. I would often spend a week each on Chapters 7 and 8 on short-term and long-term workforce management. Topics from Chapter 9 on priority queueing systems, call centers, and customer scheduling typically rounded out the course. Routing and inventory were, with the exception of the newsvendor problem, not covered in the course as there was a separate supply chain management course as well as a production scheduling course that covered routing and inventory. Although students had to take only one of the three courses—supply chain management, production scheduling, or service operations management—many students took two or even all three of the courses. Excessive duplication of material was deemed inappropriate by those of us teaching these three courses.

In short, I encourage faculty and students using the text to pick and choose those topics that are of most interest to them. For students with a strong methodological background in optimization and stochastic modeling, Chapters 4 through 10 should generally stand on their own and can, to a large extent, be covered in any order and in a level of detail that suits the instructor and the class.

I hope you enjoy using the text as much as I enjoyed writing it and teaching the course, which was the genesis of the book.

Mark S. Daskin