Chapter 1
Matching Healthcare Resources to Patient Needs

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Abstract Healthcare scheduling entails matching health care resources (providers, rooms, equipment, supplies, organs, devices and instruments) to patient needs, when and where they need them. Effective scheduling reduces waste, reduces patient waiting and improves health outcomes. Scheduling methods rely on operations research techniques, including forecasting, mathematical modeling and optimization, queue models and stochastic processes. These techniques are used in many ways, including setting appointments, scheduling staff, planning surgeries and managing the flow of patients through health care systems.

1.1 Introduction

Most people have been frustrated by the experience of waiting to see a doctor. We have sat in crowded rooms surrounded by other frustrated patients; we have waited for appointments that had to be booked months in advance; we have lain on examination tables anticipating when the doctor will step through the door. And, as we have waited, we have undoubtedly wondered: why? Why is it that waiting is so pervasive when we seek health care, and why is it so much more common than when we receive other types of service?

Patient delay can be traced in part to economics. Societies believe that quality health care is important for all people—akin to a "right"—and therefore find ways to minimize costs charged to patients, whether through subsidized service,

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regulated prices or government-provided free care. But in doing so, we have removed the ability of markets to match supply and demand through competitive pricing. There may be insufficient health professionals, or insufficient professionals of particular specialties. Or patients may seek more care than they truly need because it is so inexpensive. Or providers may have no incentive to expand capacity to serve groups of patients who are unable to pay full costs.

Economics alone, however, does not fully explain patient waits. Culture also plays a part. In most nations, doctors are among the elite. They are highly educated, intelligent and well paid. Moreover, patients become attached to their own care providers and do not readily switch to others when they experience poor service. Put these factors together, and we see that patients often believe that they are the lucky ones when they are so privileged to see their own doctors (not the other way around, that the doctors are privileged to have patients as customers). Patients simply do not have high expectations for quality of service in many places because they are resigned to accept waiting for health care.

Economics and culture are two parts of the story. The third, and the focus of this book, is the efficiency by which health care is managed and delivered. Waiting is the consequence of a mismatch between the needs for service and the availability of resources to provide that service. This mismatch might be the result of having too little of needed resources, or perhaps because the needs themselves are excessive. But it is just as likely that resources and needs have not been adequately synchronized with each other. Perhaps there are sufficient doctors, but they are working in places where the demands are not so great, or at times of day when the needs are not as strong. Perhaps operating or procedure rooms are underutilized because of gaps in time created by patient, or doctor, cancelations. Or maybe in-patient rooms are left vacant while patients are left on gurneys in the emergency department, simply because cleaning crews have not been scheduled or patient transport is unavailable.

It is no simple task to match resources to needs in health care. Providing a medical procedure to a patient often entails sequences of tasks performed by different individuals in combination with equipment, supplies and specialized work spaces. Sometimes the patient must move from place to place within or among buildings to complete the care, and other times multiple specialists must come to the patient to provide needed services. At each stage of care, waiting may ensue; is a challenge to ensure that "patient flow" will be smooth from one step to the next.

Moreover, the time required to deliver a particular procedure tends to be more variable than in other systems, such as manufacturing, where each part may be processed in more or less the same time as the next. While health care can surely be more standardized than it is, patients are not all the same. Whether it is their genetic make-up, environment from which they come, demographic characteristics (such as age, language and mobility), particular symptoms that they exhibit or their own health behavior, patient care must always be individualized to some degree. Beyond this, the presentation of patients for service is inherently variable because health conditions can emerge at random due to injury or illness, and because

patients do not always show up on-time. Uncertainty, thus, creates a "wild card" for the best planned schedules.

Also, unlike manufacturing, health care usually requires the presence of the customer (i.e., the patient), often within a stressful or uncomfortable environment. It is not like dropping off shirts at the dry cleaner and waiting several days for them to come back. For health care, patients usually cannot leave until the job is done, making waiting that much more costly. But the consequences of waiting go beyond simple loss of time. The patient may experience pain, or conditions might worsen. For some diseases, death may result if not treated with sufficient speed. In emergency rooms, complications may occur when patients become frustrated with long waits and leave without being seen, or leave against medical advice.

Unfortunately, many care givers usually lack the skills to systematically improve service by creating schedules that better match resources to patient needs. health care today operates on the foundation of its historical roots, that of individual doctors serving patients from their private practices. The person in charge of the office is typically the doctor, someone with no managerial or engineering training. Even in larger clinics or health centers, it is uncommon to have someone with an advanced analytical education, such as operations research or industrial engineering, even though a large center may be a multi-billion dollar enterprise, much larger than a typical manufacturer. Looking at the national level, the industry of health care in America tends toward decentralization, rarely operating at a larger scale than regional networks. Only recently have organizations like Geisinger Health System developed ways to effectively standardize care and shown the benefits in improved efficiency, quality and outcomes.

1.2 Defining Patient Needs

The intent of this book is to offer a foundation from which skilled professionals can improve the delivery of health care through improved scheduling—that of matching health care resources with needs in time and place. Each chapter is written by an expert on a particular aspect of health care scheduling, and each chapter demonstrates how analytical methods arising from operations research can be used to produce schedules that reduce waiting, reduce idle time or improve health outcomes. From the patient perspective, we seek to ensure that their needs are met, such as:

Preferences to be served by particular individuals: These may be the people who have seen the patient in the past, or perhaps individuals who by recommendation or reputation are preferred by patients for their situation. A patient may also prefer providers who speak their own language, are the same gender, have comforting manners or understand his or her culture. One doctor does not easily substitute for the next given the close relationship that often develops with their patients.

Preferences to be Seen at a Particular Place: A location or provider may be preferred because of proximity to home or work; because it is a part of the patient's insurance network; because it offers a collection of integrated services; or because of good experiences in the past. Some centers are affiliated with the patient's own faith group. Others may provide an environment that reduces the stress of doctor visits.

Desire to be Seen at a Particular Time: A visit for care must fit within the complete set of activities (including work, school, childcare, etc.) in a patient's day, leading to preferences for visits at particular times. However, preferences are also driven by the urgency of the patient's condition, which may compel the patient to seek a same day appointment or drop in unscheduled for urgent or emergency care.

Medical Needs: Symptoms and diagnosed conditions motivate patients to seek particular types of care, sometimes from a primary care doctor, nurse practitioner or pharmacist, and other times from specialists. Preventive care—such as annual physicals, vaccinations or asymptomatic screenings—constitutes a modest portion of the demands for health care. Most care is driven by illness or injury, or symptoms thereof. However, the need for care is also affected by the availability and quality of prior care. Undiagnosed or untreated prior conditions, or the absence of preventive care, can lead to more severe future complications.

Medical Professional Opinion: Doctors, nurses and other medical professionals have the ability to create their own demand. This could be through routine scheduling of a follow-up visit. Or it could be the referral to another doctor for specialized care. It could be visits required for the management of chronic conditions. Or it could be scheduling a particular surgery at a particular hospital. In these and other examples, the demand for future care results, to a significant degree, from the professional opinion of the people who provide the care.

Coverage and Fees: Although health care is often subsidized by government or employer provided insurance, patients typically do pay a portion of their costs through varying "co-pays". Also, different providers charge different amounts, and different types of services bear different costs (e.g., care delivered in emergency departments is typically more expensive than care delivered in urgent clinics). These fees vary depending on whether the provider is inside or outside the patient's insurance network. And, the uninsured (or under insured) may only have access to care through particular providers.

1.3 Defining Healthcare Resources

All these factors—preferences for providers, place or time; medical need and professional opinion; and fees as well—affect the demands or needs for health care. Care is provided through the provision of resources that meet these needs, resources that include:

Doctors and other health professionals: Most aspects of care demand contact from health care professionals, and therefore availability of people drives most scheduling in health care. In some cases, the schedule represents appointments for specific patients to see specific doctors at specific times. In other cases, the schedule represents the assignment of particular people to work shifts with set start and end times. In other cases, the schedule represents the assignment of an operating room to a particular surgeon for a block of time. In all of these examples, the schedule focuses on the people providing care.

Rooms: The places where care is delivered are also scheduled and assigned, to both patients and providers. These include rooms for examinations, procedures, surgeries, diagnostics and tests and recuperation. Each of these types may be further specialized. For instance, hospital wards may be separated into intensive care, telemetry, isolation, recovery from anesthesia and so on. On the other hand, a hospital may opt to equip its rooms to accommodate virtually any type of condition. Rooms also reflect the needs of their facilities, anywhere from a private practice, to a specialized clinic, an academic health center or perhaps a rehabilitation hospital.

Equipment: Equipment is either permanently, or temporarily, assigned to each room to support the services that take place therein. When permanent, the room takes on the specialization offered by the equipment—for instance a place for conducting Magnetic Resonance Imaging (MRI) examinations or kidney dialysis. In other places, equipment may be portable (for instance a moveable x-ray machine), perhaps enabling the patient to stay put and allowing the equipment to move from room to room instead. Some equipment may reside in the homes of patients receiving care for a chronic condition, either temporarily or permanently.

Supplies: These are the expendable items that are consumed in the delivery of care. For instance, medications, bandages, protective garments, needles and blood are all expendable in the course of providing care. Supplies are stored in stock rooms or warehouses and made available as needed to serve medical needs. Scheduling is required for the transport of supplies and determination of stocking levels as well as planning their production.

Implantable devices and organs: Certain medical procedures require the implantation of an artificial device (e.g., a hip or knee replacement or a pacemaker) or a human organ (e.g., a kidney, liver or heart). The procedure cannot take place without the device or organ, and therefore surgery must be synchronized with their availability. In the case of transplants, scheduling includes matching particular organs (which become available at random) to particular patients, including the rapid transport of the organ to where it is needed.

Instruments: These items support medical procedures, diagnoses and other aspects of care, ranging from thermometers, to meters, and surgical instruments. Instruments are sometimes reusable, in which case they must be sterilized between patients, but are sometimes discarded after use.

For all of these examples of health care resources, the challenge is to synchronize availability with the needs for care, so that just the right amount and type are available when the patient needs them, thus minimizing both wastage and inconvenience (or harm) to patients.

1.4 Issues and Options for Scheduling Healthcare Resources

The keys to good scheduling in health care are data, analytics, systems, software, culture and management. **Data** combines with **analytics** to track historical trends, and forecast the future, answering questions like:

- How long will a particular procedure take for a given patient, with a given doctor, on a particular day?
- How many patients can we expect to present for care in an emergency department on a given day of the week, time of day and time of year?
- How will the demand for appointments depend on the prevalence of influenza, given the time of year and cases seen to date?
- What is the projected future need to care for a patient of a particular age, weight and blood glucose level, who has been diagnosed for type 2 diabetes?
- How likely is it that a particular patient will be a no-show for a scheduled appointment, made a set number of weeks in advance?
- What is the incidence of complications when care is delayed or foregone?

In all of these examples, the need is to maximize the precision by which health care is delivered to match demonstrated patterns of need.

Analytics, combined with **systems**, are also critical in the construction of schedules. Analytics provide the capability to optimize a schedule of a given type against defined objectives related to the cost of offering service, the quality of the service provided and health outcomes, while also meeting defined constraints. In surgery, the underlying system may be one of block scheduling, where particular times and rooms are reserved for specific doctors or specialties. Patients may then be assigned to dates based on the criteria defined by each surgeon. Within the context of such a system, computer algorithms may be used to optimally assign blocks to particular surgeons and to fill surgical appointment slots. As illustrated in this example, the analytics enable the schedule to be optimized within the context of the system created by the medical professionals or hospital administration. Analytics include algorithms for optimizing integer programs, stochastic process models representing patterns of patient and provider behavior and queueing models that predict the occurrence of delay as a function of supply and demand.

Data, **systems** and **analytics** come together within software, which is the enabling tool to support the implementation of a schedule and accompanying analytics. The software provides interfaces to: schedulers who set appointments and assign resources; doctors who may wish to input preferences and constraints; patients, who sometimes book their own appointments and management who

monitor and control performance as well as allocate resources. The software can also support the automated acquisition and recording of data. And software can provide a tool for communication among and between departments, so that the arrival of patients and resources can be anticipated with greater accuracy.

The **culture** represents the collective ethos of staff and patients participating in the healthcare environment, and particularly how they might respond to the scheduling system and interact with its software. Scheduling is only successful when those involved respect the outcomes—that it is important to follow the schedule, serve patients on-time, arrive on-time, show up to work when needed and so on. Good schedules cannot overcome a weak culture, but they can help a strong culture become even better.

Last, effective **management** is an important driver for successful scheduling. Those in a position of leadership need to convey the need for efficiency and service, and translate those needs into the reward structure: as a component of annual compensation, a factor in raises, and an element in hiring new employees. Relative Value Units (RVUs) are one tool that management can use to measure physician productivity (converting assignments into a uniform measure of work), and can help balance capacity with patient needs. Management must also be the role model for the entire organization. For instance, doctors cannot be expected to keep to their schedules if the leadership does not do the same.

Thus, data, analytics, systems, software, culture and management come together in successful scheduling. Yet there are still more options.

- Should an "open access" model be adopted, easing the process of scheduling same day appointments for urgent conditions with one's one primary care doctor?
- Can electronic health records be leveraged, making it easier for alternate doctors to step in when the primary doctor is unavailable?
- How much discretion should a surgeon have for setting surgical times, based on their own experience and understanding of the cases, rather than following a data-driven approach?
- To what degree should appointments be "over booked", and how should this be done, in expectation that some appointments will be canceled?

While the methods of operations research can be used to help answer these questions, there are no universal truths. Each situation (system, patient population, etc.) must be carefully analyzed to see what works best within the context of good scheduling methods.

1.5 Book Organization

The remaining 11 chapters of this book address separate aspects of health care scheduling, beginning with more strategic issues and moving toward more detailed operational questions.

1 **Capacity Planning**: Through queuing models, this chapter illustrates how randomness creates the need for surplus capacity to accommodate uncontrollable fluctuations, how that level of surplus capacity can be calculated, and how pooling resources can reduce the requirement for surplus capacity.
2 **Nurse Scheduling**: Presents the mathematical programing formulations for the creation of nurse schedules, both for wards and for operating rooms. The chapter shows how multiple objectives, representing such factors as cost of shift preferences, can be represented in scheduling models.
3 **Patient Appointments in Ambulatory Care**: Describes systems for setting outpatient appointments in two stages, first establishing the clinic profile (dividing days into appointment slots) and second booking patient appointments.
4 **Operating Theatre Planning and Scheduling**: Defines the operating theatre as a driver for hospital activity, developing planning models for scheduling elective procedures within a hierarchical structure.
5 **Appointment Planning and Scheduling in Outpatient Procedure Centers**: Provides systems for setting appointments for specialized procedure facilities, such as outpatient surgery or specialized diagnostics, for which cases are less complex than in inpatient surgery.
6 **Human and Artificial Scheduling System for Operating Rooms**: Focuses on scheduling cases within surgical rooms, and in particular the need for incorporating the knowledge of human schedulers within systems for setting surgical schedules, accounting for delays and cancelations while seeking to keep operating rooms from completing their delay schedules too early or too late.
7 **Bed Management and Control**: Examines the role of the inpatient bed as a key resource that defines the flow of patients through a hospital, and the relationship of bed management to intake and discharge.
8 **Queuing Networks in Healthcare Systems**: Provides an analytical queueing framework to represent the interaction between different stages of services within a complex network of care, identifying bottlenecks that inhibit patient flows through the system.
9 **Medical Supply Logistics**: Addresses scheduling of supplies and managing inventories to support the delivery of care and the needs to coordinate the flow of these items with patient demands. Management of blood supply is used as an illustration.
10 **Operations Research Applications in Home Health Care**: Provides models for managing the movement and timing of nurses and other health professionals, serving patients in their own homes, along with the provisioning of needed resources in patient homes.
11 **A Framework for Healthcare Planning and Control**: Concluding the book, the final chapter provides an integrative framework for health care system scheduling, based on four management areas (medical planning, resource capacity planning and financial planning) implemented within a four level hierarchy (strategic, offline operational, online operational and tactical).

Collectively, the book's 12 chapters provide a state-of-the-art review of models and methods for scheduling the delivery of patient care.

1.6 Closing Thoughts

Health and longevity are nearly universal aspirations. Despite dramatic improvements in health in the industrialized world, some countries have experienced little gain in life expectancy over the last century. Poor water quality, risky behaviors, infectious disease, violence and weak health care systems all contribute to shortened lives in third world countries, which sometime fall below half that of the industrialized world. Healthcare scheduling alone cannot correct disparities as huge as these, but can help make care accessible to more people.

Just as health outcomes vary from country to country, so does the cost of health care–without always producing concomitant improvements in health outcomes. America has suffered a terrible fate in that its cost of care is far larger than other countries, whereas its life expectancy is not. Many people simply lack access to basic preventive care. Improvements in the delivery of care, and in particular the application of analytic methods arising from operations research, can help correct this type of economic disparity.

We should strive for systems that ensure that our doctors are not just well trained and provide good individualized care. We should expect that our health care providers contribute to a well-coordinated system that delivers care with great efficiency and quality, at reasonable cost, matching the resources for care to where (and when) they are needed most. As is the focus of this book, striving for efficiency in care through good scheduling is good for health.