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CHAPTER 1

INTRODUCTION

1.0 MOTIVATION

Did you ever wonder why a hospital, fire station, or shopping mall was built in a certain location? Identifying the best site for a particular facility is no easy task. Planners must consider economic and demographic factors, while addressing political realities. This task is as old as our world. From early prehistoric times man has had the task of determining the best location in which to site a place to dwell, for hunting food, harvesting natural resources, and so on. As civilizations evolved, cities developed, trade routes emerged, and roads were constructed. When observing the remains of aqueducts, roads and buildings of the Roman Empire, it is easy to wonder how such systems evolved and how critical siting decisions were made. One can conclude that location decisions have always been essential. For the hunter and gatherer, a good location decision might have meant survival. Today, such decisions might not be a life and death issue, but they are nonetheless very important.

When we look at our current urban systems, we can see specific types of order and systematic arrangement. For example, older cities were located along rivers, close to the fall line—a good place to generate mechanical power and, later on, electricity. Many major cities have port facilities, as they serve as gateways to hinterlands away from the coast or navigable waterways. Some cities have developed close to major natural resources, where, for example, they can convert coal and iron ore to steel. As one looks closely at vast areas of fertile soil and adequate rainfall, a spatial arrangement of villages, towns, and cities emerges that appears almost like a regular pattern of specific geometric shapes. Christaller (1932) reasoned, “Just as there are economic

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laws which determine the life of the economy, so are there special economic-geographic laws determining the arrangement of towns." A contrarian might suggest that poor choices in location will be punished economically. But no one disputes the importance of location in business, manufacturing, retail, and public services.

There are three ways in which we can study location. The first approach is to *map* what we see by positioning an object's location in space by its locational coordinates. We can use such positional coordinates to accomplish tasks like navigating across an ocean, mapping all land parcels in a county, or calculating the amount of deforestation. Collecting spatial data and capturing its geographical position is an important task. The major function of **geographical information systems (GIS)** is to provide a means to collect, store, retrieve, map, and analyze such spatial data. GIS allows us to store a number of different themes of data across space, including elements such as soil type, land cover, precipitation, elevation, and so on. It is with this richness of data types and the ability to manipulate, model, and analyze spatial data in complex ways that the real value of GIS becomes apparent. In fact, it is upon this seamless fabric of multiple layers of data that today's location decisions are made. The main theme of this book involves how to integrate spatial analysis and logic with GIS.

The second approach to location analysis is an attempt to describe arrangements that have emerged and try to explain why certain decisions were made. For example, we may look for spatial clusters of a specific industry, where an individual firm appears to have made a similar siting decision based on some agglomeration property like nearness to a uniquely qualified work force. We call this a **descriptive approach**. The descriptive approach attempts to explain what emerges over time, or where a certain animal is likely to be found, as an example.

The third approach to location analysis is to identify the best location for an activity, or maybe the best set of locations for a system of activities. We call this type of modeling **prescriptive** or *normative*, in that we are trying to determine which location is best, rather than why certain location patterns have emerged. That is, the inherent feature of normative modeling is to help make decisions for the present and future. Although many models have been developed from a purely theoretical viewpoint, many others have been developed with a definite bent towards the notion of supporting a specific application, such as locating a store, locating an alignment for a road, or siting a warehouse for a distribution system.

Both pure and applied location analysis have emerged into a field called **location science**. The growth of the field of location science has occurred somewhat independent of the development of GIS. This book arises from a need for addressing specific components of location conditioned with GIS. The integration of location modeling with GIS allows one to accomplish more, do it more efficiently, produce better data and model representations, develop better solution approaches, provide new insights, and aid in the visualization

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of location alternatives. Our central focus will be on how practical, real-life problems involving a "siting decision" can be supported through the use of this integrated approach.

You have probably heard that there are three important issues in real estate: "Location, location, location!" There is no denying that this is true to some extent in many areas such as commerce, natural resource management and conservation, resource extraction, manufacturing, and product distribution systems, but it is important to understand that every activity has a place or location, and often it impacts the function or role of that activity. Although it is not the only consideration in the planning process, the "location decision" is obviously important, and is the central focus of this book.

In the remainder of this chapter, we will introduce what we consider to be the theoretical roots of normative location modeling, along with a set of *first principles* of geographical location theory. We also will introduce several historical developments in which modeling and quantitative assessment have become the preferred approach to resolving siting decisions. We acknowledge that some siting decisions are made in an ad hoc fashion, and they will continue to be, but as our urban and commerce systems become more complex, the ad hoc and "back-of-the-envelope" approaches fail to capture all of the important problem complexities and are more likely to fail in identifying the best alternative. Worse yet, these simple approaches may highlight or suggest an inferior alternative to what actually exists.

Within the context of spatial planning, one may well think, "There are no easy problems left." It is important to recognize that *greenfield* problems, where we start from scratch, do not exist in most applications. Often, we have parts of a system that are already in operation and we need to locate one or more facilities in order to serve or operate in conjunction with the existing elements. This fact alone demands a greater concern for characterizing what exists, as well as locating within the context of the built-up or altered landscape. Consequently, the role of location scientists must include capturing and representing relevant landscape elements, from transport linkages to sources of raw materials, so that models of location activities include all relevant features such as barriers, connections, zones of demand, and so on. It is important to handle such complexities rather than ignore them or assume they are unimportant. In fact, the merger of location science with GIS will be a necessity in order to handle the complexities of the real world.

1.1 HISTORY

Location science deals with siting one or more activities or facilities in such a manner so as to optimize one or more objectives. One of the first problems of location science was proposed by Pierre de Fermet in the early 1600s. Fermet suggested the following problem: Given three points on the plane, find the fourth point such that the sums of the distances to the three given points is a

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minimum. This simple, geometrically inspired problem dealt with finding a central *median* location.

Weber (1909) described a three-point problem associated with an industrial setting as follows: Find a location for a manufacturing facility that receives raw material from two point sources and ships its final product to a point-specified market. Thus, Weber's problem suggests finding a fourth point (the factory) among three points (two raw-material points and one market) in order to minimize weighted distance (see Figure 1.1). Weights here represent per-unit product amounts (i.e., the amount of raw material 1 per unit product, the weight of raw material 2 per unit product, and the weight of the final product).

The objective of the classic Weber problem is to locate the most efficient site for the factory, assuming that transport costs are a function of Euclidean (straight-line) distances. Fermet defined an unweighted problem, whereas Weber defined a weighted point location problem that represented the best location of an industrial activity. This problem is usually called the **Weber problem**, given the realistic application orientation, rather than a problem of geometrical curiosity. Weber's analysis was the first to pose a problem of industrial activity in terms of optimal placement. Weber's original work has been expanded over time in two problem domains: networks and surfaces (planar, spherical, inclined planes, etc.).

In 1826, Johann H. von Thünen proposed a model for analyzing agricultural patterns. In his explanation, he assumed that there was an isolated city surrounded by a hinterland that was uniform and unbounded in any direction. The city receives agricultural products from the surrounding hinterland only and nothing from other areas. The hinterland is occupied by farmers who wish to maximize their profits, and who adjust automatically to the market's demands. There is only one mode of transport: horse and wagon (hey, it was 1826!). It is assumed that transportation costs are borne solely by the farmers

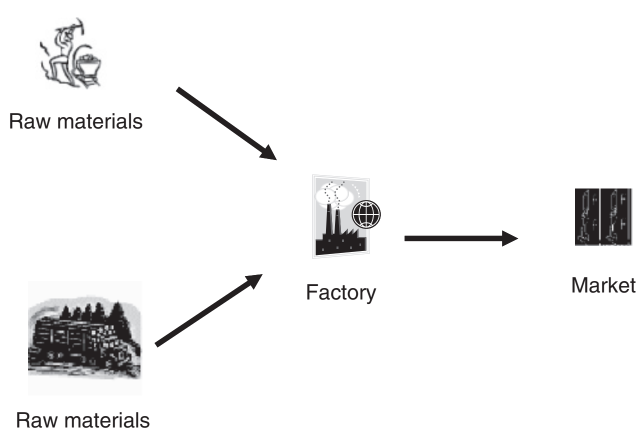

Figure 1.1 Weber's problem of locating a factory to minimize costs.

and are proportional to the distance to the market. Within this framework, von Thünen considered three interrelated factors: the distance farms are from the market (i.e., city), the prices received by the farmers for their goods, and economic rent of the land.

Land rent represents the difference between revenues obtained from the land and the costs of working that unit of land, and is the surplus left after all costs have been deducted.

Figure 1.2 depicts land rent as a function of distance from the city for two commodities. Each function is linear and decreases as a function of transport distance to the city. Notice that the cost of shipping commodity 2 is higher per unit distance than that of commodity 1. But at the market, commodity 2 commands a higher price than commodity 1. Thus, farmers near the market should plant commodity 2 instead of commodity 1. Beyond distance X, commodity 1 provides a greater net land rent than commodity 2. Thus, von Thünen reasoned that there were effectively rings around the city corresponding to different crops, reflecting the different values of uses for land. Thus, a given farmer would select those crops that would generate the greatest land rent, depending on the distance to the market and whether the demand for a given commodity has been met by farmers who are closer to the market. The von Thünen model is a simple economic construct that describes the process of land use allocation. This was the first attempt to systematically address land use allocation.

Hotelling (1929) wrote about pricing stability between two vendors of water. In his initial description, Hotelling fixed the vendors at sites of artesian wells along a linear market (see Figure 1.3). These two vendors paid nothing for the water, including pumping costs, as they were artesian sources. Hotelling's analysis showed how these two vendors would engage in **competition** for market share by setting prices, given that each attempted to maximize profit. Hotelling demonstrated that the two vendors acted like a two-person game, each responding, in turn, to the competitor's price until an equilibrium was reached. In his discussion of this model, Hotelling allowed competitors to

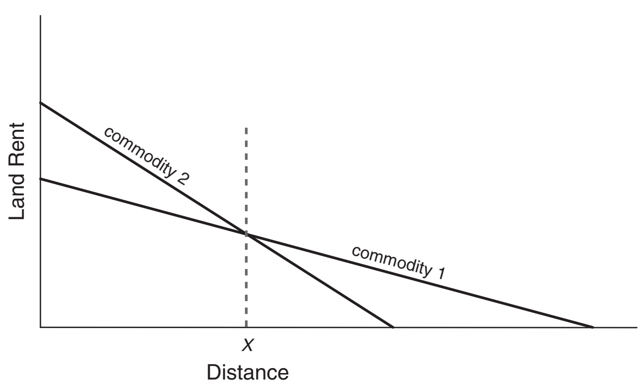

Figure 1.2 von Thünen's analysis of land rent for agricultural commodities.

Figure 1.3 Hotelling's competitive location problem.

move positions along the linear market. He reasoned that the two competitors would, in attempting to maximize profit over a series of moves, end up co-locating at the center of the market, sharing the market equally between them. Hotelling's analysis demonstrated the notion of competing retail strategies, gaming, and resulting location decisions.

In 1933, Walter Christaller attempted to describe the arrangements of the villages, towns, and cities of southern Germany. His work became the foundation of **central place theory**. Christaller's premise was that there are natural laws that could explain a systematic arrangement of towns. Christaller assumed that, given an unbounded fertile farming region, certain systematic and geometrical arrangements of retail centers would occur. He viewed the purchase of goods from retail centers based on several properties. First, all goods have a **range**, which is the furthest distance that consumers are willing to travel to buy the good. If the good is a refrigerator, for example, people are willing to travel a fairly long distance to make a purchase, because refrigerators are not purchased very often. In contrast, if the good is something like bread, which is purchased frequently, then a consumer will not be willing to travel far.

Goods with low distance ranges are classified as *low-ordered goods*, and goods with high distance ranges are *higher-ordered goods*. Christaller reasoned that centers offering low-ordered goods would be more plentiful and spread out, whereas centers offering higher-ordered goods would be less numerous.

Christaller also introduced the notion of **threshold**. The threshold is the distance from a center at which the demand for the good is large enough to satisfy the requirements for a vendor to remain in business. It is simple to see that if the threshold of a good exceeds the range of the good, at a given location, then that location is not profitable for offering that good.

Christaller assumed that each customer would travel to the closest retail center offering the good of interest, as retailers of a given type were considered to be equal in all ways. He reasoned that excess profits occurred when the market range exceeded the threshold. He further stated that entrepreneurs would attempt to compete so that excess profits would be kept to a minimum. He postulated that the ideal arrangements of centers offering the lowest ordered goods would be points on a triangular lattice, carving out hexagonal market

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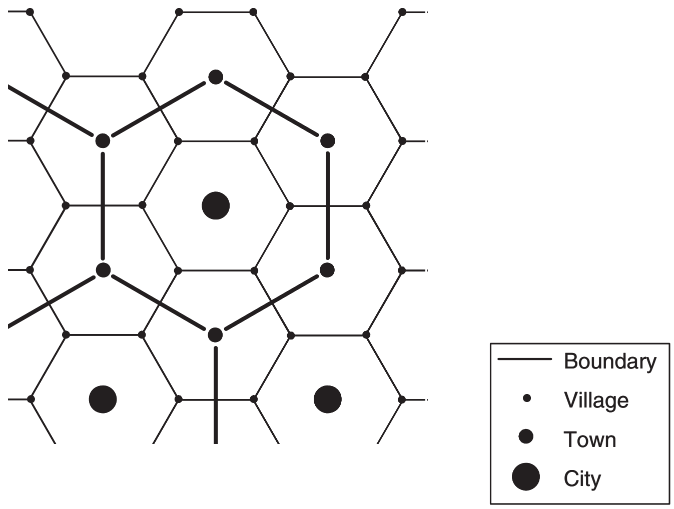

Figure 1.4 Christaller's central place hierarchy.

areas, where each customer assigns to his or her closest center. The next higher-ordered center would be located among a subset of the lowest-ordered centers. Thus, he argued that a hierarchical arrangement existed where high-ordered centers offer all goods that are offered by lower-ordered centers. Each set of higher-ordered centers, therefore, formed hexagonal-shaped market areas. A set of arrangements representing Christaller's marketing principle is given in Figure 1.4.

Geographers have had a long-term interest in Christaller's work. In the 1960s and early 1970s research focused on the geometrical arrangements reminiscent of that postulated by Christaller (Berry, 1967). Altogether, Weber, von Thünen, Hotelling, and Christaller represent founding fathers of location science, where each work laid the foundation for different areas of location research, retail competition, spatial layout, and industrial location. Much of the early work took place before computers were available. With the availability of computers, location science took a decided bent toward the use of computation and the solution of more complex location problems. Some of the leaders in the beginning of the computational modeling era of this field are Walter Isard, Leon Cooper, Charles ReVelle, Michael Teitz, and Louis Hakimi. The contributions of many of these individuals will be described at greater length in different chapters of this book.

1.2 FIRST PRINCIPLES

Some time ago, Tobler (1970) examined urban growth in an urban region. In the development of a model of population distribution, he discusses the nature

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of population from a global perspective. After identifying difficulties involved in specifying a model of global scale relative to impacts on a particular urban area, Tobler invoked what he termed the *first law of geography*:

> "Everything is related to everything else, but near things are more related than distant things."

With this principle, Tobler crafted a model for the urban area he was working with, Detroit, that ignored most of the world. It is important to understand that each field of science is based on a set of principles or laws, under which elements are analyzed, new laws are identified, and the field is advanced. It is natural to ask just what are the first principles of location science, and how would such principles guide us toward further study and scientific advancement?

In this spirit, we identify three **laws of location science (LLS)**. The first law of location science can be stated as follows:

LLS1—*Some locations are better than others for a given purpose.*

Even though this statement may seem obvious, the impact of this law is significant. If some locations are better than others for a stated purpose, then given a stated purpose, what is the best location at which to site a given activity? As an example, if we wish to place a fire station in order to serve a given area, it would be unlikely that the station would be located outside of the service area. Thus, one can begin the process of identifying a region, zone, or polygon within which a station should be located. The bottom line, of course, is that location matters.

A corollary to LLS1 is the following: *Efficient system locations tend to beat inefficient ones.* Holding all other factors constant, an efficient location pattern will tend to persist longer for a given use than inefficient ones. For example, if two stores are competing in a market that can support only one store, assuming that both offer the same goods and services at the same price, customers will go to the closest store. The store in the least efficient location, therefore, will have fewer customers and thus go out of business first. As a result, without other compelling factors, one should seek the best location(s) for an activity.

The second law of location science is this:

LLS2—*Spatial context can alter site efficiencies.*

Suppose you are going to locate a dry-cleaning business and you have identified an area to open a store in. The site that is the closest to your estimated customer base may not be as good as a site next to the local grocery

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store, as an example. That is, people can drop off their dry cleaning on their way to the grocery store, as it would be convenient and they visit the grocery store often. Even though the customer base of the grocery store may include a number of people that do not use dry-cleaning services, and that a better place to serve just those in need of dry cleaning might exist, locating next to the grocery store may be more efficient as the spatial context of other goods and services have altered travel patterns and behavior, thereby altering the landscape of efficient locations. Therefore, spatial context is important.

Often, sites where goods and services are provided tend to concentrate and build up around a given place, providing economies of agglomeration. For example, law offices are often selected close to courthouses, so that lawyers can minimize time traveling to and from the courthouse in the process of doing their business. Even though a customer base for a given legal group could be quite some distance from the courthouse, the cost of doing business may still be minimized by locating near the courthouse and ignoring the distances traveled by the clients. If a legal office is located at a great distance from a courthouse, then you will find that it tends to work in a specialty area in which the location of the local courthouse is not as important. Another example is the location of parts manufacturing in relation to assembly points for automobiles. If a given parts manufacturer only supplies parts to a single assembly plant, then the best location may well be close to the assembly plant itself. It is easy to see that the second law of location science is important in that there are dependencies between the location of other services that can be important determinants in finding the best location for a given activity.

The third law of location science is associated with investment in multiple facilities. Such problems are often termed *multifacility location problems*. Here is the third law:

> **LLS3** *Sites of an optimal multisite pattern must be selected simultaneously rather than independently, one at a time.*

Up to this point, virtually all of our examples have dealt with the location of a single store, office, or manufacturing location. But suppose that several locations are needed. For example, consider a simple problem of locating several pizza stores. Assume that only pizza delivery is provided, and there is guaranteed delivery of pizza in 30 minutes or less to any place in town or the pizza is free. If 15 minutes will be taken up by making and baking each pizza, this means that each area of the town needs to be within 15 minutes of at least one pizza store, or a lot of customers will be getting a free pizza.

Thus, we need to locate our pizza stores so that each neighborhood in town is within 15 minutes of at least one pizza store. Doing this means that the delivery areas of each store must be no greater in size than 15 minutes' driving

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time from a store, and that together the delivery areas of all stores must cover the town. Suppose that this can be achieved by the location of four pizzerias. The solution for this cannot be determined without locating the stores as a system (i.e., in concert with one another); otherwise, we risk leaving a neighborhood outside the necessary 15-minute delivery time. The third law highlights the fact that multiple facilities cannot be sited efficiently without taking into account service provided by each facility as an integrated whole. The best location of one facility is dependent on the location of others, and the best system can be found only when all facilities are located simultaneously.

The first law of location science (LLS1) easily leads us to the notion that a search for the optimal or near-optimal locations should be made. Otherwise, we risk locating in inferior places, which may lose out to a competitor's site. The second law (LLS2) means that spatial context is not only important, but that it is necessary to collect and analyze appropriate data for the purposes of making a site selection. Finally, the third law (LLS3) suggests that the search for the best pattern or configuration of sites cannot be achieved by solving a series of one-facility location problems. The impact of LLS3 is enormous, as the complexity of modeling location problems increases as the number of entities being located increases. Except in unusual circumstances, such problems cannot be decomposed into a series of simple independent problems. Thus, it is important to develop relevant multifacility location models to address complex spatial problems.

1.3 PLANNING CONTEXT

The process of planning as done by county and state public agencies and most private companies has evolved over time. For example, most public agencies now have a planning process that involves public participation. For example, in developing an *environmental impact statement* (EIS), the process starts at the outset with an invitation for the public to comment on what it considers to be elements or criteria that must be considered or addressed. Before an EIS is finally approved, the process includes a period of public review and comment, unlike master planning in the 1960s by engineers and planners with little or no public input. Planning by public agencies now includes significant public input. Such an open process requires that decisions be made with a focus on improvement, while mitigating impact as measured by metrics that communicate in a quantitative manner exactly what a project or plan is expected to produce. For example, building a county park may require a traffic study to measure the impact on local traffic levels and their impact on nearby residents, a forecast of expected attendance, a cost–benefit analysis to determine if it is economically viable, and an environmental impact review. The *do-nothing* alternative must always be considered as one possibility for final selection. Comparing alternatives, performing an EIS, and performing a cost–benefit analysis all require a quantitative framework in which to calculate

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metrics such as forecasted attendance and traffic flow. Some elements are not easily measured, but such intangibles (e.g., the loss of three acres of native bunch grass) need to be listed and addressed as well. With the exception of such intangibles, measuring and comparing alternatives usually can be presented in a format where each element is reported in a quantitative manner (e.g., expected attendance is 200 people per day, or traffic flows will impact traffic at the intersection of Elm and Main Streets by decreasing level of service B to C in the evening rush hour, or an additional recreational worker will be required).

It is important to note that legislation introduced in the late 1960s and early 1970s associated with the environmental movement goaded and required public agencies to be more open, involve the public, and address issues such as environmental impacts. For example, the National Environmental Policy Act (P.L. 91-190) in 1969, the Endangered Species Act (P.L. 93-205) in 1973, the Clean Water Act of 1972 (P.L. 92-500), the Resource Conservation and Recovery Act of 1974 (P.L. 92-580) and the Forest Management Planning Act of 1976 (P.L. 94-588) promulgated regulations that virtually required a quantitative approach to planning and environmental impact analysis. For example, both the Clean Water Act and the Resource Conservation and Recovery Act require that planning not be isolated and local, but that it be expanded to basinwide water management planning and regional planning for the disposal of solid waste. The cradle-to-grave requirements for hazardous materials of the Superfund Act (P.L. 96-510) require systems of quantitification, modeling, and monitoring. Thus, the era of environmentalism brought about major changes in the planning process, with a resulting need to better quantify impacts, benefits, and costs.

Another trend that emerged was the use of large-scale models called the planning revolution. In the 1960s and early 1970s, it was thought that large-scale comprehensive modeling could support and help resolve the needs of the planning process and environmental impact analysis. Although this supposition was true, there were impediments to a reliance on such large-scale models at the outset. Even though research was supported to develop large and comprehensive planning, monitoring, and management models, something was missing. That major ingredient was the technology to support such models.

First, computers were very expensive and very limited in their capability to handle large, comprehensive planning data sets. As an example, computer memory in most applications was less than 250 kilobytes, and processors were *very* slow compared to today's standards. Overall, the cost of computer use was considerably higher than it is today. The IBM personal computer was not available until 1983. Second, software for data management was limited, and GIS did not exist beyond simple raster-based applications. Software for handling spatial data was very limited, and in most instances was not sold commercially but was often written to support a specific application. Computer-driven plotters for producing maps did not exist, because most maps were produced by hand. Computer-produced maps were limited to crude shaded maps produced by repeatedly striking character keys. Color monitors did not exist, and the media for writing programs was usually limited to punch cards and paper tape. Third, inexpensive software did not exist to solve models and optimization problems representative of planning problems. Software available in the late 1960s could solve problems with a few thousand variables and constraints, but required the complete use of an expensive computer for considerable computational time. This meant that only a few agencies, such as the Air Force or companies like AT&T and Exxon (then Standard Oil), could afford to buy and apply such technology. Finally, technology to collect spatial data and store it was limited. Laser distance measures, GPS units, and satellite imagery did not initially exist. Consequently, the planning process needed technology that did not exist. But the story obviously does not end there, as improvements were made on all fronts: hardware (like computers, storage devices, monitors, plotters, etc.), database software, GIS software, modeling software, statistical software, and so on. Even new algorithms and heuristics were developed to solve model sizes that dwarfed those solved in the past.

Now it is commonplace to talk about large-scale models, such as global climate change models or large-scale models to optimize treatments within a national forest. Even linear programming software is ubiquitous; it is now a component of Microsoft Excel. Computational costs have consistently decreased over time, and now most maps are not drawn by hand but are produced using computer software. Thus, the revolution in planning, technology, and modeling has evolved over the last 40 years. We must now consider how technology can be used to support the continued quantitative revolution, supporting the planning process, optimizing the design and operations of systems involving business, natural resource management, and public services. It is with this perspective that this book has been written. Now we must, as a matter of course, consider just how to approach problems such as location modeling in an integrated manner using GIS and incorporating available census data, satellite imagery, and so on, along with data especially collected for a location model application.

1.4 ROLE OF GIS

The fields of location science and GIS have developed almost independently. The reasons for this are fourfold. First, models structured in the early period of location science were simple and structured as geometric problems (like those of the Weber and/or Fermet). Second, many models in location science utilize elements of operations research (OR). This field involves modeling for decision making where techniques are equally applicable in spatial and nonspatial domains. The field of OR has evolved since the 1940's and many of the models discussed in this text are solved using OR-based techniques. Third, the field of GIS did not develop to support location science, but, rather,

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because of the need to support a variety of uses and services. Geographical information systems were developed to collect, store, manage, manipulate, display, and analyze spatial data. Such systems are designed to present spatial data in the form of a map (e.g., thematic map), and are designed to retrieve data in a form that can be useful for analysis. As such, GIS was not developed per se to solve location models but to support a variety of needs, from mapping to spatial queries, and from visualizing a terrain to supplying data to models and statistical tools. That is, the goals in developing GIS transcend specific needs of location science, because the application domain is much broader than location science. Finally, the number of professionals working in both fields has been relatively small, and until now work in one area has been somewhat independent of work in the other. We can depict these three fields with a Venn diagram, as shown in Figure 1.5. Each field is illustrated as an ellipse. Notice that the ellipses overlap, reflecting that they are interdependent in some ways.

It is important to recognize that certain issues addressed in location science are actually spatial planning problems that can be resolved in GIS without knowledge of **operations research** or location science. Also, certain issues in location science can be addressed within a theoretical framework that does not involve actual data or specific techniques in operations research. However, many problems of location, from retail store siting to biological reserve site design, involve the need to characterize an application domain complete with spatial data of considerable detail (e.g., road network, census tracts, population estimates, etc.), and rely on a combination of functionality, from GIS to models and algorithms based on operations research.

As problem applications become more sophisticated, the spatial data needed in their application must be supported in one form or another by GIS. Thus, the role of GIS in location modeling ranges from central to peripheral data support, recognizing that complex spatial manipulation, query, and computation may be necessary. As an example, locating cell-phone towers requires characterizing the terrain along with characterizing surface clutter, which are elements that tend to reflect, bend, or obscure cell-phone signals (e.g., buildings and vegetation).

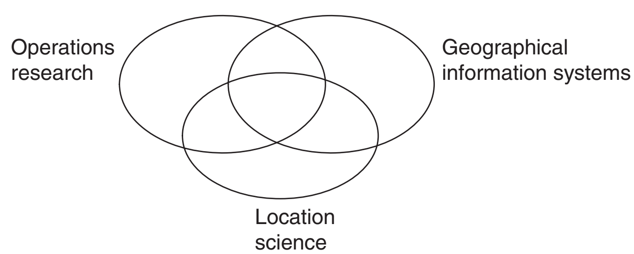

Figure 1.5 Overlapping fields of location science, operations research, and geographical information systems.

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Modeling terrain is a central element of many GIS packages, and keeping track of ground cover through data attributes helps to estimate clutter height. Thus, GIS keeps track of data needed to estimate the area coverage of a potential cell-phone site. Simply put, an antenna reception model can be easily integrated with a GIS data model in order to create map coverages of potential sites, whereas such a model would require significant database development and data collection without using a general purpose GIS.

What we have attempted to show is that as these three areas of modeling have matured (GIS, OR, and location science); there is a convergence and burgeoning overlap between these fields based upon the demand for better and more accurate spatial data, the demand for better models characterizing real-landscape problem domains, and the demand to map and visualize solutions in order to support decision making across a wide-ranging set of scales, from the warehouse floor to harvest areas in a large forest plantation to the infrastructure of pipes and pumps, reservoirs, and tanks of a water supply system. Whether a water tower or a retail shop is being located, future applications are likely to be intimately linked with GIS, relying on a wealth of spatial data and spatial operations and utilizing models that characterized the problem domain in a manner that is as close to ground truth as possible. This is not only the future of business location decision making, but location science applications in general. Looking beyond theoretical location constructs and focusing on the resolution of actual siting problems will result in the production of new models, data constructs, algorithms, and theoretical principles. Hopefully, this book will be the first of many that help lead the way in this multidisciplinary field.

1.5 SUMMARY

In this chapter, we have attempted to describe the evolving fields of location science and GIS. We have also attempted to demonstrate that the future of location science and GIS will evolve and overlap, whereby many new applications and models will be developed based on a fusion of these two fields of science. This book represents an attempt to show how this fusion and integration can be accomplished. This book is meant as a textbook as well as a reference. We recognize that many students, and experts, for that matter, will understand one field and not the other. We begin with two introductory chapters: one an introduction to GIS and the other an introduction to mathematical modeling. These two chapters will form the basis of different areas of location analysis and GIS presented in subsequent chapters. Many of our examples will utilize ArcGIS, along with an optimization package called LINGO. In subsequent chapters, our examples will build on the use of ArcGIS, LINGO, and special-purpose routines.

This is not a computer programming book, but a book that presents detailed models and applications, and demonstrates how such problems can be solved with a fusion of tools, relying on concepts that fall within location science and/or GIS.

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1.6 TERMS

descriptive approach
prescriptive approach
geographical information systems (GIS)
location science
Weber problem
efficiency
competition
central place theory
range
threshold
laws of location science (LLS)
operations research
planning revolution

1.7 REFERENCES

Berry, B. 1967. *Geography of market centers and retail distribution*. Englewood Cliffs, NJ: Prentice-Hall.

Christaller, W. 1966. *Central places in Southern Germany*. Trans. by C.W. Baskin. Englewood Cliffs, NJ: Prentice-Hall. Originally published in German in 1933.

Hotelling, H. 1929. Stability in competition. *Economic Journal* 39:41–57.

Isard, W. 1956. *Location and space economy*. Cambridge, MA: MIT Press.

Losch, A. 1954. *The economics of Location*. New Haven, CT: Yale University Press. Originally published in German in 1939.

Tobler, W. 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography* 46:234–240.

von Thünen, J. H. 1826. *Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie*. Hamburg: Frederich Perthes. Translated by Peter Hall as *Von Thünen's Isolated State* (Oxford: Pergamon Press, 1966).

Weber, A. 1909. *Uber den standort der Industrien* (Tubingen). Translated by C.J. Friedrichas as *Theory of the Location of Industries* (Chicago: University of Chicago Press, 1929).

1.8 EXERCISES

1.1. In your local town or region, can you list business locations that are struggling, strip malls or shopping centers that appear to have high vacancy rates, or offices with high tenant turnover? How is this explained by the first law of location science?

1.2. Give an example of how a service you rely on is well located. What about one that is poorly located?

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1.3. What is a good or service that you would prefer to be co-located, or near, an activity you regularly frequent? Why?

1.4. Many towns of 50,000 to 100,000+ people have experienced growth of retail concentrated at first in regional malls, and now in "big-box" retail shopping centers. Often, such centers have decimated the classic Main Street mercantiles of town.

(a) Has this happened in your area, or can you think of an area where this has happened?

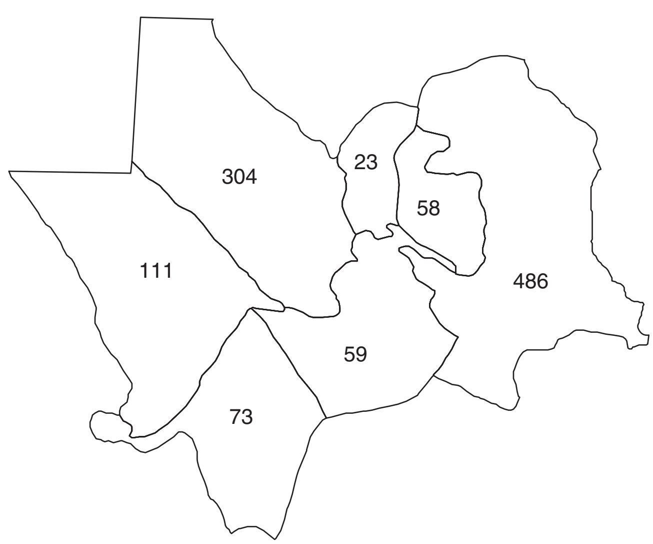
(b) What types of stores have moved onto Main Street after the traditional retail establishments relocated to the mall (e.g., antique stores)?

(c) Can you estimate the threshold for a mall by observing the sizes of cities that have malls?

1.5. Classify the following goods or services within the context of order: low, medium, or high:

(a) Plastic surgery
(b) Convenience store
(c) Home appliance and furniture store
(d) Dry-cleaning shop
(e) Videostore
(f) Ferrari dealership

1.6. The neighborhoods depicted in the following figure indicate the number of children under age 10 in a town. Identify the best locations for two day-care centers. Why are these good sites?



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1.7. During a time of budget crunch for the city of Los Angeles, the fire department considered closing up to 10 fire stations out of the city's 105 existing stations.

(a) Estimate how many different plans for closing 10 stations exist.

(b) Would you want to close all stations in a given neighborhood? Would this be equitable?

(c) Can you think of one or more metrics that can be used to measure how good one plan is, compared to another?

1.8. In making your decision in problem 1.6:

(a) Did you assume that there were no competitors?

(b) Did you assume that they could serve only those inhabitants within a neighborhood?

(c) Did you consider locating on a boundary between two or three neighborhoods?

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