Preface

Wouldn't it be nice to have a book on location analysis which

- contains most of the main stream topics,
- could be used for teaching purposes,
- could be used for self study or reference,
- would motivate the material not only by reviewing the theoretical results, but also by giving some of the practical success stories using location theory as model for problems in industry and management science?

As the reader may guess, this question is a rhetoric one – sure it would be nice to have such a book, and many who want to learn about the subject or teach corresponding courses in university departments of mathematics, management science, computer science, geography, civil engineering, etc. would be likely users of such a book. Practitioners who want to find out, whether one of their problems can be solved with one of the location tools would love to get a quick overview of what is available in this area. Researchers could use the book to check whether there is any new literature on a location subject they would want to work on.

This book is an attempt to satisfy this wish list. We were lucky enough to find many of the most prominent researchers and practitioners in the world, who contributed 14 chapters to a book in which the largest part of the location area is covered. A most up-to-date collection of references is provided at the end of each chapter.

In the first chapter **"The Weber Problem"**, Zvi Drezner, Kathrin Klamroth, Anita Schöbel, and George O. Wesolowsky introduce the classic of location theory, the Weber problem in the plane. Many historical notes show, how location theory has evolved over time, and that the idea of this book – to show the power of models from location theory to solve real-world problems – is well-founded by the positive experience over the last century. The authors discuss the single facility Weber problem with Euclidean distance in some details and introduce the reader to modifications of this basic model by changing the distance to ℓ_p-norms or gauges, and by finding more than one new facility.

In situations, where certain regions are not allowed to be used for siting new facilities, or may not even be used for trespassing more advanced models are required. These situations occur obviously very often, if geographic characteristics have to be taken into account in regional planning problem, machines or conveyer belts have to be considered in production environments, etc. The authors introduce restricted and barrier location problems as corresponding models.

The last topic which is discussed in this chapter is devoted to line locations or locations of objects. Planning of railway lines of highways and plant layout are examples where the algorithms sketched by the authors can be used.

A point is covered by a facility when its distance to the facility is within some threshold radius. Obviously, many locational questions in practice deal with this problem, in particular in the social area, where "good" covering may mean the difference between life and death (for instance in a good covering of neighborhoods by health services, see Chapter 4). Frank Plastria reviews in Chapter 2 many classical, but also very recent **"Continuous Covering Location Problems"**. When locating a useful and desirable facility one may seek full covering, i.e. a covering of all points of a given set using a smallest possible radius, or maximal covering, when one wants to cover as many points as possible within a fixed radius. When locating a necessary, but undesirable facility, one will rather look for empty or minimal covering, i.e. try to cover none or the smallest number of possible points within the largest possible or given radius. Frank describes in Chapter 2 applications of such questions occurring within a given geographical region, their models and corresponding solution methods. In the plane, distance is traditionally measured the Euclidean way, and covering problems then amount to placing circular disks. This seems easy, since it uses traditional geometric objects only. But, from an algorithmic point of view, various difficulties need to be overcome using a number of ideas and constructs from computational geometry.

As in Chapter 1, need arises to use other distances than the Euclidean one to model real-world problems. While some theoretical properties nicely carry over, solution methods must be adapted to the new geometric objects involved. Further topics which are discussed by Frank include other environments than the plane, the need to locate several facilities simultaneously, and line and dimensional facilities.

The third chapter by John Current, Mark Daskin and David Schilling presents several classic **"Discrete Network Location Models"**. Here, a "discrete" problem is one for which there are a fixed number of candidate facility sites and the locations of these are known with certainty. Consequently - in contrast to the first two chapters - "continuous" problems in which the facilities can be located anywhere in the feasible region are not addressed. A "network" problem is one in which the set of potential facility sites is located at the nodes of some underlying network. In general, it is assumed that demand also exists at some known set of nodes on the underlying network.

As basic models, the set covering, maximal covering, p-center, p-dispersion, p-median, fixed charge hub and maxisum problem are introduced. While these basic models assume direct delivery from a facility, many facilities such as solid waste collections substations and distribution centers provide collection and/or distribution functions in which demand is served by multiple drop off and/or pickup routes. In order to efficiently plan this services, location- routing models can be used. Obviously, the design of the network is in all models of crucial importance. Corresponding models are reviewed. In all models, multiple criteria, time dependency and stochasticity can be important to mirror reality as well as possible. Several classes solution techniques are presented to solve all of these problems. The chapter concludes with a discussion of recent directions in modifying and extending these classic problems.

The chapter **"Location Problems in the Public Sector"** written by Vladimir Marianov and Daniel Serra deals with the location of facilities or services in discrete space or networks, that are related to the public sector, such as emergency services (ambulances, fire stations, and police units), school systems and postal facilities. The main difference between this class of problems and the location of private facilities is in the objective function. Profit maximization and capture of larger market shares from competitors are the main criteria in private applications, while social cost minimization, universality of service, efficiency and equity are the goals in the public sector. Since these objectives are in general difficult to measure, they are frequently surrogated by the minimization of locational and operational costs needed for full coverage by the service, or the search for maximal coverage given an amount of available resources.

Vladimir and Daniel first focus on public facility location models that use some type of coverage criterion, with special emphasis on emergency services. The second section examines models based on the p-median problem and some of the issues faced by planners when implementing this formulation in real-world locational decisions. The last section examines new trends in public sector facility location modeling

In the fifth chapter **"Consumers in Competitive Location Models"** Tammy Drezner and H.A. Eiselt extend previous models in a decisive way. Instead of assuming that the customers are allocated by certain rules to the facilities, customers are in this type of models considered free to choose their facility. Assuming some knowledge about the customers attributes (disposable income, age, level of education, etc.), complete market and distance information and a "rational" behavior of all customers, each of them will evaluate potential facilities by a utility function. Consequently, they will choose the facility which has for them the highest utility.

After introducing the main elements of service-oriented competitive location models, Tammy and H.A. show, how the major decisions made by consumers to arrive at their purchasing decision are structured. The paper then demonstrates ways to incorporate facility features in the decision-making process. A discussion concerning the lack of rationality on the part of consumers as well as more complex behavioral patterns conclude the paper.

The p-median problem has been introduced in Chapter 3. Burcin Bozkaya, Jianjun Zhang, and Erhan Erkut show in the sixth chapter **"An Efficient Genetic Algorithm for the p-Median Problem"** how to tackle this difficult problem using a genetic algorithm (GA): GA is a modern heuristic method that has been applied to a number of combinatorial optimization problems with success. However, there are very few applications of GAs to location-allocation problems. In this chapter, the authors provide an overview of GA concepts, review related previous studies, and develop a GA considering three different crossover operators as well as mutation and invasion features. They report the results of their computational experiments with medium-sized random instances of the p-median problem. It turns out, that the GA produces solutions are of comparable quality to those produced by a well-known and widely used heuristic for this problem. The obvious conclusion is that GA has the potential to provide very good solutions for the p-median problem.

Because location problems with many demand points are difficult to solve, most large-scale location problems are solved by first grouping the demand points into representative aggregate points, and then locating servers with respect to these aggregate points. In Chapter 7 entitled **"Demand Point Aggregation for Location Problems"** Richard L. Francis, Timothy J. Lowe, and Arie Tamir study the resulting error. They provide a useful upper bound on this error which leads to algorithms to determine, where aggregate demand points should be placed with the objective of minimizing the value of this error bound. They give an example of one such algorithm when the objective of the original location problem is the p-median problem. They also report on some computational experimentation with the algorithm. Finally, they generalize their approach to obtain error bounds for an entire class of location problems.

The objective of Chapter 8 **"Location Software and Interface with GIS and Supply Chain Management"**, co-authored by Thorsten Bender, Holger Hennes, Jörg Kalcsics, M. Teresa Melo, and Stefan Nickel, is to bridge the gap between location theory and practice by focussing on the development of software capable of addressing the different needs of a wide group of users. For those interested in non-commercial applications (e.g. students and researchers), the library of location algorithms (LoLA) can be of considerable assistance. LoLA contains a collection of efficient algorithms for solving planar, network and discrete facility location problems. These algorithms are available as callable library and therefore can be incorporated into other applications. To address the specific needs of users working with large amounts of demographic data (e.g. urban planners), LoLA was linked to a geographical information system (GIS), thus taking advantage of the additional functionality that such a tool offers. Finally, there is a wide group of practitioners who need to solve large problems and require special purpose software with a good data interface. For these users, a commercial location software tool in the area of supply chain management (SCM) was developed. The tool is embedded in the Advanced Planner and Optimizer SCM software developed by SAP AG, Germany.

The interrelation between **"Telecommunication and Location"** is the subject of Chapter 9. The authors, Eric Gourdin, Martine Labbé, and Hande Yaman review models for telecommunication network design where location problems are involved. The key observation here is, that telecommunication networks are naturally structured in a multi-layer hierarchical architecture.

At a lower level of such an architecture, collectors are used to collect the traffic and to sent it to a higher level. The network design is then done in an iterative way by deciding on the number and location of concentrators, and the assignment of the terminals to these concentrators, the design of the access network and then the design of the backbone network. The location of the collectors is therefore of crucial importance for the network design problem.

The authors consider three classes of models, namely uncapacitated, capacitated and dynamic ones. For each class, they discuss the core problem, its generalizations and the solution methods in the literature.

In the chapter **"Reserve Design and Facility Siting"**, Charles ReVelle and Justin C. Williams compare five classes of discrete siting models as to form and solution method against parallel parcel selection models for species protection. The location set covering model is compared to the species set covering problem, and the maximal covering location problem is viewed alongside the maximal covering species problem. As well, location covering models seeking backup and redundant coverage are seen to have distinct analogs in parcel selection models. In addition, the maximum expected covering problem has a mirror image in a model that seeks the maximum expected number of species protected through appropriate parcel choice. Finally, the maximum availability location problem, which maximizes calls covered with alpha reliability given a resource or facilities limit, has parallels in a parcel selection model which seeks to maximize the number of species protected with the stated reliability.

Oded Berman and Dmitry Krass consider in Chapter 11 **"Facility Location Problems with Stochastic Demands and Congestion"** a location problem under two sources of uncertainty: the exact timing of customer demands, and the potential congestion at the service facilities. These problems, referred to as "Location Problems with Stochastic demands and Congestion" (LPSDC), arise in location of emergency service facilities, as well as certain non-emergency (e.g., retail or health service) facilities. The goal of this chapter is to review the main approaches for LPSDC models on networks, identify the assumption structures implicit in these approaches, and discuss potential avenues for future work in this area.

After formulating a general LPSDC model, Oded and Dmitry point out the inherent complexities of the model related to describing the stochastic behavior of the underlying system. They provide a classification of the available approaches into cover-type and median-type models, with a further sub-division into fixed and mobile service models. Cover-type models attempt to assure specified standards of coverage (e.g., how many minutes a call for service is allowed to wait in the queue) through the use of service level constraints. By using strong assumptions about the underlying system, these constraints can be linearized, leading to solvable integer programming formulations. However, the effect of the assumptions on the quality of the underlying solutions is not clear – in particular, there is often no guarantee that the resulting solutions in fact satisfies the service level constraints. Median-type models attempt to minimize average response time to calls for service (they also contain a penalty term for calls that are rejected by the system). These models generally contain a much more accurate representation of the stochastics of the underlying system than the cover-type models. As a result, the formulation is often not available in closed form, leading t o a variety of location-allocation heuristic approaches. Some important questions for future research are outlined, and strengths and weaknesses of different approaches are discussed.

Chapter 12 deals with **"Hub Location Problems"**. The importance of this topic is, in particular, motivated by the fact, that hub networks play a very important role in modern transportation and telecommunication systems. In transportation, this includes air passenger and freight travel, express shipments (e.g. overnight delivery), large truck systems, postal operations and rapid transit systems. In the telecommunication area, computer communication, telephone networks, video conferences, distributed computer processing, etc. all rely on a smart installation of hubs. Rather than serving every origin-destination demand with a direct link, a hub network provides service via a smaller set of links between origins/destinations and hubs, and between pairs of hubs. The authors concentrate on new discrete or network hub location models in which location of the hubs is a key decision. Research that addresses hub network design, without determining hub locations is not considered. Since there have been previous survey articles on hub location, emphasis is on new work in this area.

Oliver Karch, Hartmut Noltemeier and Thomas Wahl consider in Chapter 13 the interrelation between **"Location and Robotics"**. An autonomous mobile robot, that has to navigate in its environment must be able to answer the following three questions: "Where am I?", "Where am I going?", and "How should I get there?", which are summarized under notion of *localizing a robot*. The authors give an overview of the localization problem and then consider the sensors with which the robots are equipped, the different types of localization (relative and absolute), and the corresponding localization methods. Variants of the localization problem, where some restrictive assumptions about the robot and its environment allow a formulation as a pure geometric problem are introduced. The latter problem is solved using methods from Computational Geometry. Due to the restrictive assumption, the resulting solution is, in general not directly applicable in practice, where the data is noisy. Therefore, the authors introduce distance functions of model the resemblance between the noisy sensor data and structures of the original method.

The last chapter is written by Franz Rendl, who discusses various aspects of **"The Quadratic Assignment Problem"** (QAP). This problem can be used to model various real- life problems including the design of a university campus or a hospital, the layout of a factory, wiring problems, the assignment of letters to typewriters, ranking or archaeological data, etc. On the other hand, notoriously difficult optimization problems such as the traveling salesman problem, the graph partition problem, or the max clique problem are special cases of QAP. Franz gives several equivalent formulations of QAP, describes various ways of relaxations, which can be used to solve it either exactly of by heuristics. He also discusses complexity issues and reports on computational experience with some of the methods described in his chapter.

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