

# **SOME STUDIES IN FACILITIES LOCATION PLANNING IN THE PRESENCE OF FORBIDDEN REGIONS**

by

**K. Ravindranath**

Department of Mechanical Engineering

Thesis submitted in fulfilment  
of the requirements for the degree of  
**DOCTOR OF PHILOSOPHY**



to the

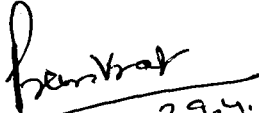
**INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

April, 1985

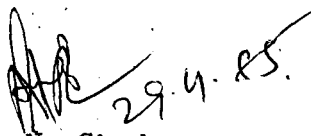
In fond memory of my Mother

CERTIFICATE

The thesis entitled "Some Studies in Facilities Location Planning in the presence of Forbidden Regions" being submitted by Mr. K. Ravindranath to the Indian Institute of Technology, Delhi, for the award of the Degree of Doctor of Philosophy, is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree of this Institute. This work has not been submitted elsewhere for the award of any degree or diploma.

  
Dr. Prem Vrat  
Professor

29.4.85

  
Dr. N. Singh  
Assistant Professor

Department of Mechanical Engineering  
Indian Institute of Technology, Delhi  
New Delhi 110 016

## ACKNOWLEDGEMENTS

It is with a deep sense of gratitude that the author records his sincere thanks to Prof. Prem Vrat and Dr. N. Singh of the Department of Mechanical Engineering, Indian Institute of Technology, Delhi, for their able guidance, encouragement and suggestions throughout the period of research work reported in this thesis.

The author wishes to thank the authorities of Sri Venkateswara University, Tirupati, for sponsoring him under Q.I.P. for the Ph.D. programme.

Thanks are also due to his colleagues and friends, Mr. M.M. Naidu, Dr. D.K. Banwet, Mr. C. Adishesu, Mr. S.V.M. Ratnakumar and Mr. Krishna Moorthy for their help and cooperation.

The author is thankful to his family members, Smt. Rama Mani, Nithu and Hari for their patience, understanding and cooperation, but for which this work would not have been completed in time.

Finally, the author wishes to thank Mr. P.M. Padmanabhan Nambiar for his meticulous typing.

*K. Ravindra Nath*  
29.4.85  
K. Ravindra Nath

## ABSTRACT

Sound location planning is necessary for any organization/ establishment as locational decisions are of strategic importance. Facility location problems have been the subject of mathematical analysis for quite some time. With the birth of operations research, the subject started drawing the attention of researchers from various disciplines. Consequently, research on location problems has proceeded in three non-mutually exclusive directions of planar, network and discrete models.

The interest in the present research study is on a class of deterministic, planar, static and non-discrete models. Unfortunately, planar location problems are formulated with some what stringent assumptions. For example, it is assumed that any point in the plane is a valid location to consider. As a result, sometimes the location site may turn out to be the centre of lake or mountain which is infeasible. However, in the present study, the assumption is relaxed to some extent incorporating forbidden region of a pre-specified configuration, into the mathematical model; neither transportation nor location is permitted within the forbidden region. Because of its practical importance, location problems in the presence of forbidden regions have attracted the attention of location analysts recently.

Since the emphasis is on normative models, appropriate criterion must be selected to formulate any facility location problem.

Both minisum and minimax criteria are considered in the present research while modelling the location problems in the presence of a forbidden region. Moreover, the decision making becomes still complex when both minisum and minimax criteria are important. Since the minisum and minimax locations are usually different, a compromise solution is required when both the criteria are considered simultaneously. Hence, much of the work in the present research study deal with bicriteria formulations of the facility location problems considered.

One of the factors, apart from the criterion chosen, that affects any locational decision, is the distance norm employed. Hence, the present study deals with location problem involving different distance norms and in some cases, also mixed norms.

In some situations, the optimal location point may not be available as a location site as the point may coincide with any permanent structure or it may not be accessible. In that case, it may be required to carry out sensitivity analysis by constructing iso-cost lines. Iso-cost lines, as the name implies, are the lines of constant cost in the plane. They provide considerable insight into the shape of the surface of the total cost function and aid in evaluating alternative locations for the new facility. A direct linear search procedure is developed to obtain iso-cost lines for any single facility location problem irrespective of the distance norm and criterion considered. The method is found to give accurate and reliable results.

In location theory, there may exist a class of problems known as location-allocation problems in which the interest is not only to find optimal locations of sources but also to find the optimal allocations of destinations to sources. The location-allocation problems, both constrained and unconstrained are modelled using different criteria.

Since most of the present study is concerned with modelling of constrained location problems (problems with forbidden regions) the objective function loses one of the important properties, i.e., convexity thus making the problems complex. Hence, a pattern search procedure based on Hooke and Jeeves algorithm has been successfully employed to solve all the location problems and location-allocation problems considered.

The generalized search algorithm has been found to be very reliable and accurate and this is substantiated with extensive computational experience. Finally, it is hoped that the mathematical models developed in this thesis along with the simple solution procedure, would aid the decision maker operating in complex environment to take effective and constructive decisions.

## C O N T E N T S

	Page
ABSTRACT	i
NOMENCLATURE	iv
CHAPTER I	
INTRODUCTION TO THE FACILITIES LOCATION PROBLEM	
1.1 Facilities Planning	1
1.1.1 The Concept of Facility	1
1.1.2 Facility Location Problem (FLP)	2
1.1.3 Facility Design Problem	3
1.2 Growth of Location Theory	5
1.3 Taxonomy of FLP	6
1.4 Classification of FLP on the Basis of Solution Space Characteristics	9
1.4.1 Planar Location Models	10
1.4.2 Network Location Models	11
1.4.3 Discrete Location Models	12
1.5 Location Problems with Mixed Norms	13
1.6 Location Problems in the presence of Forbidden Regions	14
1.7 Location-Allocation Problems	16
1.8 The Statement of Research Problem	17
1.9 An Overview of the Thesis	19

	Page
CHAPTER II LITERATURE REVIEW	
2.1 Introduction	22
2.2 Earlier Review Approaches	24
2.3 Present Review Procedure	25
2.4 Deterministic Location Models	26
2.4.1 Planar Location Models	26
2.4.1.1 Problems with Euclidean Norm	27
2.4.1.2 Problems with Rectilinear Norm	41
2.4.1.3 Problems with Constraints in the form of Forbidden Regions	50
2.4.2 Discrete Location Models	53
2.4.2.1 Covering Problems	59
2.4.3 Network Location Models	61
2.4.3.1 Single Objective Deterministic Network Location Models	62
2.4.3.2 Covering Problems	62
2.4.3.3 Minimax Location Problems	63
2.4.3.4 Minisum Location Problems	65
2.4.3.5 Maximax (Anti-Center) and Maxsum (Anti-Median or Maxian) Location Problems	66
2.4.3.6 Multiobjective Network Location Problems	67
2.5 Stochastic Location Models	71
2.5.1 Problems with Euclidean Norm	72
2.5.2 Problems with Rectilinear Norm	75
2.6 Limitations of the Present Models	76
2.7 Conclusions	79

	Page
CHAPTER III SINGLE AND MULTIPLE LOCATION PROBLEMS WITH MIXED NORMS	
3.1 Introduction	81
3.2 Development of Modified HAP for Minisum Problems	83
3.2.1 Single Facility Location Problems	83
3.2.2 Multifacility Minisum Location Problem	87
3.2.3 Computational Experience	90
3.3 Application of Search Method for Facility Location Problems	93
3.3.1 Methodology of the Search Algorithm	93
3.3.2 Program Description	96
3.4 Single Facility Location Problems Using Proposed Direct Search Technique	98
3.4.1 Single Facility Minisum Location Problem with Mixed Norms	99
3.4.2 Single Facility Minimax Location Problem with Mixed Norms	99
3.4.3 Bicriteria Location Problems	100
3.4.3.1 Mathematical characterization of Bicriteria Problems	101
3.5 Multifacility Location Problems using the Direct Search Technique	104
3.6 Computational Experience	105
3.7 Conclusions	119

	Page
CHAPTER IV	
SINGLE FACILITY EUCLIDEAN LOCATION PROBLEM IN THE PRESENCE OF FORBIDDEN REGIONS	
4.1 Introduction	120
4.2 The Model	122
4.3 Computation of Geodesic Distances	124
4.3.1 A Circular Forbidden Region	124
4.3.2 A Rectangular Forbidden Region	128
4.4 Solution Methodology	141
4.5 Computational Experience	143
4.6 Conclusions	163
CHAPTER V	
SINGLE FACILITY RECTILINEAR LOCATION PROBLEMS IN THE PRESENCE OF FORBIDDEN REGIONS	
5.1 Introduction	164
5.2 The Model	166
5.3 Computation of Constrained Rectilinear Distances	167
5.3.1 Case of a Rectangular Forbidden Region	168
5.3.2 Case of a Circular Forbidden Region	170
5.4 Solution Methodology	173
5.5 Computational Experience	174
5.6 Conclusions	202

	Page
CHAPTER VI DEVELOPMENT OF SEARCH ALGORITHM FOR CONSTRUCTING ISO-COST LINES FOR SINGLE FACILITY LOCATION PROBLEMS	
6.1 Introduction	203
6.2 Review of Relevant Studies on Iso-Cost Lines	205
6.3 The Problem	207
6.4 Search Algorithm	208
6.5 Computational Experience	216
6.6 Conclusions	230
CHAPTER VII MULTIFACILITY EUCLIDEAN LOCATION PROBLEMS IN THE PRESENCE OF FORBIDDEN REGIONS	
7.1 Introduction	232
7.2 The Problem	233
7.3 Computation of Geodesic Distances	235
7.3.1 Case of a Circular Forbidden Region	235
7.3.2 Case of a Rectangular Forbidden Region	238
7.4 Solution Methodology	246
7.5 Computational Experience	247
7.6 Conclusions	267

	Page
CHAPTER VIII A DIRECT SEARCH PROCEDURE FOR LOCATION-ALLOCATION PROBLEMS	
8.1 Introduction	269
8.2 The Mathematical Representation and Existing Solution Approaches of LAP	270
8.3 The Problem	274
8.4 Computation of Geodesic Distances	276
8.5 Solution Methodology	276
8.6 Computational Experience	279
8.7 Conclusions	292
CHAPTER IX SUMMARY OF MAJOR CONTRIBUTIONS AND CONCLUDING REMARKS	
9.1 Introduction	294
9.2 Summary of Research Study	294
9.3 Significant Contributions of the Research	297
9.4 Limitations of the Present Study	299
9.5 Scope for Further Work	301
9.6 Concluding Remarks	302
REFERENCES	303
APPENDICES	
BIOGRAPHICALNOTE	