

**OR APPLICATIONS IN
STRATEGIC SECTOR CONSTRUCTIONS
WITH CAPITAL BUDGETING**

I.I.T. LIBRARY DELHI

by
KULDIP CHANDER

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



Department of Civil Engineering
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JULY, 1989

ACKNOWLEDGEMENT

I take this opportunity to thank Prof. P. Natarajan, Department of Civil Engineering, Indian Institute of Technology (Delhi), New Delhi, for the valuable guidance given to me from time to time.



(KULDIP CHANDER)

NEW DELHI

12TH JULY, 1990

CERTIFICATE

The thesis entitled "O R Applications in Strategic Sector Constructions with Capital Budgeting" submitted by Mr. Kuldip Chander 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 my 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. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

P. Natarajan,

(P. NATARAJAN)
PROFESSOR OF CIVIL ENGINEERING,
DEPARTMENT OF CIVIL ENGINEERING,
INDIAN INSTITUTE OF TECHNOLOGY (DELHI)
NEW DELHI - 110 016 (INDIA).

ABSTRACT

Specific characteristics distinguishing constructions in strategic sectors include: block allocations over a number of consecutive time-periods; releases of resources (and funds) in upper and lower bounds; finances earmarked suffering diminutions in their realisable worth due to transfers over time and space.

A certain category of problems refers to allocation of resources (and funds) to several projects at different sites with co-extensive headquarter control. The problem is to secure necessary funds for each project subject to the said diminution by transfers within the projects. Solution by LP formulation does not ensure allocations in consecutive years. Zero-One formulation can obtain allocations during consecutive periods allowing also for diminution of funds due to transfers but becomes too unwieldy for solution. A transportation algorithm has been developed alongwith a heuristic second stage of the algorithm to realise needful period-wise allocations for all projects at minimum cost in the needful transfers of funds.

A second category of problems deals with situations where available funds are generally inadequate unlike as above. Zero-One formulation could not provide for inter-project priority so as to eliminate non-subscribable project units. An LP formulation is usable though the solution process becomes almost enumerative.

Another category of problems involves sharing of multi-resources at multi-projects where the allocations beyond a floor level to each project are conditioned by the headquarter on specific goal realisations. A goal programming model proceeds with sequential decision-making with iteratively redefining the preferred levels of achievements in the several project components.

A last category of strategic sector construction pertains to allocation of resources to individual units within a single project site without obligation to headquarter. The iterative goal settings and obtaining of satisficing solutions with higher magnitudes of achievements of project components are realisable faster than in the last-said category of problems.

The applicability of the problem formulations and the solution methodologies have been demonstrated through case facts.

CONTENTS

CHAPTER I

CONSTRUCTION IN STRATEGIC SECTORS

1.1	GENESIS OF CONSTRUCTION	1
1.1.1	General Construction	1
1.1.2	Construction in Strategic Sector	2
1.2	HISTORY OF CONSTRUCTION IN INDIA	3
1.2.1	Construction Works in Ancient India and Formation of C.P.W.D.	3
1.2.2	Other Organisations Executing Construction Works	5
1.2.2.1	Public Undertakings Executing Construction Works	6
1.3	SOME FACTORS AFFECTING A CONSTRUCTION PROJECT	7
1.3.1	Preconstruction Planning	7
1.3.2	Management of Resources	8
1.3.2.1	Allocation of Funds	8
1.3.2.2	Allotment of Land	8
1.3.3	Distinctions in Strategic Sectors	9
1.3.4	Construction in Strategic Sectors : Recognition of Specifics Thereof	9
1.3.4.1	When the Terrain is Inaccessible	10
1.3.4.2	Effect of Inclement Weather	11
1.3.4.3	Role of Infrastructural Community Facilities	11

1.3.4.4	Effect of Displacement from place of Residence	12
1.4	ESTIMATING THE COST OF A PROJECT	12
1.4.1	Role and Effect of Inaccessibility in Strategic Sector	13
1.5	SYNTHESIS OF STRATEGIC SECTOR CONSTRUCTION PROBLEMS	15
1.6.	OBJECTIVE OF THE PRESENT STUDY	17

CHAPTER II

REVIEW OF ALLIED LITERATURE

2.1	INTRODUCTION	19
2.2	DIFFERENTIATION OF PROBLEM ENVIRONMENT SITUATIONS	22
2.3	LITERATURE ON CAPITAL BUDGETING WITH SINGLE OBJECTIVE	23
2.4	GOAL PROGRAMMING : HISTORY AND ITS APPLICATIONS	33
2.4.1	Historical Sketch of Goal Programming	33
2.4.2	Applications of Goal Programming	33
2.4.2.1	Accounting	34
2.4.2.2	Operations Management	35
2.4.2.3	Marketing	39

2.4.2.4	Manpower Planning	40
2.4.2.5	Social Economic Planning	40
2.4.2.6	Resource Allocation for Hospital Administration	42
2.4.3	Multiple Objective Formulation and Capital Budgeting	43
2.4.3.1	The Need for Multiple Objectives with Capital Budgeting	43
2.4.3.2	Goal Programming Applications With Capital Budgeting	45
2.5	LITERATURE REVIEW ON COMPREHENSIVE PLANNING	48
2.6	CAPITAL BUDGETING DECISION UNDER UNCERTAINTY	56
2.7	RISK ANALYSIS FOR CONSTRUCTION MANAGEMENT	61
2.7.1	Recognition of Risk in Execution of Construction	61
2.7.2	Schedules	63
2.7.3	Productivity	63
2.7.4	MUD, INCAD and DECAD	64
2.7.5	Work of Ahuja and Nand Kumar (and PRODUF)	66
2.7.6	Adaptation in this Study	66
2.8	CONCLUSION	67

CHAPTER III

PROBLEM MODELLING

3.1	GENERAL PROFILE	68
3.2	GENERALISED GOALS	68

3.2.1	Category I	68
3.2.2	Category II	69
3.2.3	Category III	69
3.2.4	Category IV	70
3.3	OPERATIONAL CONSTRAINTS	71
3.4	NOTATIONS	73
3.5	CONCEPTUAL MODEL FOR FUNDS ALLOCATION FOR PROBLEMS OF CATEGORY I	73
3.5.1	Limitations of the Model	75
3.5.2	Concept Adopted for the Zero-One Programming Formulations	76
3.5.2.1	Two Types of Formulations	77
3.5.2.2	Zero-One Non-Linear Programming	78
3.5.2.3	Zero-One Linear Programming	78
3.5.2.4	Limitation of Zero-One Formulations and Alternate Methodology Adopted	79
3.5.3	Adopting the Transportation Model	80
3.5.3.1	Expressing the Problem in Transportation Format	81
3.5.3.2	Balancing as Required	83
3.6	MODEL FORMULATION FOR ALLOCATION FOR PROBLEMS OF CATEGORY II	87
3.6.1	Zero-One Programming Model	88
3.7	CONCEPTUAL MODEL FOR MULTI-RESOURCE ALLOCATION FOR PROBLEMS OF CATEGORY III	89

3.7.1	Goals Constraints Relating to Projects	90
3.7.2	Goal Constraints Relating to Organisation	92
3.7.3	Objective Function	94
3.8	CONCEPTS OF MODEL FORMULATION FOR CATEGORY IV PROBLEMS	94
3.9	CONCLUSIONS	97

CHAPTER IV

CONTIGUOUS FUNDING FOR MULTIPLE PROJECTS

(i) WITH TIME SPACE TRANSFERS;AND

(ii) WITH PRIORITISATION UNDER POSSIBLE
WITHHOLDING OF FUNDS

4.1	INTRODUCTION	99
4.1.1	Independent, Mutually Exclusive and Competing Projects	99
4.1.2	Concept of Idealised Equivalent Cost	100
4.1.2.1	Partial Projects	101
4.1.3	Characteristics of the Problems and Categorisation	101
4.1.3.1	Category I Problem Situations	101
4.1.3.2	Category II Problem Situations	102
4.1.4	Funds for Competing Projects Under Category I	102
4.1.5	Prioritisation Among Projects Under Category II	102
4.2	SOLUTION OF CATEGORY I PROBLEMS	103

4.2.1	Data on Funds: Needs Vs. Availability	103
4.3	CONSTRUCTION OF THE COST MATRIX	105
4.4	SOLUTION BY LINEAR PROGRAMMING MODEL	107
4.4.1	Numerical Formulation	107
4.4.1.1	Objective Function	107
4.4.1.2	Availability of Funds Constraints	108
4.4.1.3	Requirement of Funds Constraints	109
4.5	SOLUTION OF THE LINEAR PROGRAMMING MODEL	110
4.5.1	Computing the Idealised Equivalents	111
4.5.2	Year-wise Allocations Indicated by the LP	111
4.6	ZERO-ONE FORMULATION	114
4.6.1	To Ensure Consecutive Allocations	114
4.6.2	To Preclude Allocations in all the n Periods ($r < n$)	119
4.6.3	Zero-One Non-Linear Programming	121
4.6.3.1	Objective Function	121
4.6.3.2	Availability of Funds Constraints (as equations)	123
4.6.3.3	Requirement of Funds Constraints (as equations)	124
4.6.4	Zero-One Linear Programming	126
4.6.4.1	Objective Function	126
4.6.4.2	Availability of Funds Constraints	127
4.6.4.3	Constraints Expressing the Limits of the Allocations	128

4.6.4.4	Requirement of Funds Constraints (as equations)	131
4.7	ADOPTING THE TRANSPORTATION MODEL	133
4.7.1	Determination of Starting Solution	133
4.7.2	Application of the VAM	134
4.7.3	Resultant Allocations from VAM	134
4.7.4	An Alternative Trial for Solution by LP	136
4.8	DISCUSSION ON RELATIVE MERITS OF THE ZERO-ONE PROGRAMMING (LINEAR AS WELL AS NON-LINEAR), GENERAL LINEAR PROGRAMMING AND TRANSPORTATION MODEL	137
4.9	NEED FOR THE SECOND STAGE ALGORITHM IN THE TRANSPORTATION MODEL	142
4.9.1	Application of the Second Stage of the Algorithm	142
4.9.2	Application of Transshipment Model (Stage 1)	143
4.9.2.1	Explanation of the Cost Matrix	144
4.9.3	Explanation of Elements in Cost Matrix	148
4.9.4	Discussion on Resultant Allocations	149
4.9.5	Making up the Deficits in the Summated Allocations by Transfers	151
4.10	RECAPITULATION	158
4.11	FUNDING OF PROJECTS WITH ADMINISTRATIVE PRIORITISATION - (CATEGORY II)	159
4.12	PROBLEM ENVIRONMENT	160
4.12.1	Classification of Projects	162

4.13	ZERO-ONE FORMULATION	163
4.13.1	Search for Methodology of Solution	165
4.14	SOLUTION METHODOLOGY DEVELOPED	167
4.15	RESULTS OF FIRST RUN	168
4.16	MANAGEMENT'S SEARCH TO IMPROVE ON THE SOLUTION	171
4.17	CONCLUSIONS	176

CHAPTER V

SELECTION OF PROJECTS AT MULTIPLE SITES UNDER UPPER AND LOWER BOUNDS OF RESOURCES (CATEGORY III)

5.1	INTRODUCTION	177
5.2	RECOGNITION OF PROBLEM ENVIRONMENT	177
5.3	GENERALISED PROBLEM STATEMENT	178
5.4	BOUNDS OF THE CASE STUDY	179
5.4.1	Availability of Funds	179
5.4.2	Land	181
5.4.3	Development Envisaged	182
5.4.4	Relative Costs and Construction Duration	184
5.4.5	Land-use Coefficients	185
5.4.6	Availability of Selected Resources	185

5.5	PROBLEM FORMULATION	188
5.5.1	Deviations and Their Minimisation	188
5.5.2	Assigning Priority Weightages	189
5.5.3	Preliminary Goals to be Programmed for the Case Study	189
5.5.4	First Search for Managerial Decisions	191
5.5.5	Objective Function	208
5.5.6	Results of First Run	209
5.6	REVIEWING THE ACHIEVEMENT OF GOALS	211
5.7	GOALS FOR THE SECOND RUN	212
5.7.1	Objective Function	213
5.7.2	Search for Improvement in Solution	214
5.7.3	Results of Second Run	214
5.7.4	Further Review of the Achievement of Goals	216
5.8	CONTINUING THE SEARCH FOR FURTHER IMPROVED SOLUTION(S)	217
5.8.1	Another Search to Improve the Management Decision	218
5.8.2	Objective Function	219
5.8.3	Results of Third Run	219
5.9	GOAL IMPROVEMENTS BETWEEN THE THREE RUNS	222
5.10	A CRITIQUE ON SUCCESSIVE ITERATIONS	223
5.11	CONCLUSION	224

CHAPTER VI

CHOICE OF PROJECT FACILITIES UNDER DECENTRALISED GOAL SETTINGS (WITH UPPER AND LOWER BOUNDS ON FUNDS) (CATEGORY IV)

6.1	GENERAL	225
6.2	INCIDENCE OF INACCESSIBILITY	225
6.3	RECOGNITION OF PROBLEM ENVIRONMENT	226
6.4	ASSIGNMENT OF PRIORITY AMONGST GOALS	226
6.5	PARAMETERS OF THE CASE STUDY	228
6.6	PROBLEM FORMULATION	232
6.6.1	Deviations and their Minimization	232
6.6.2	Assigning Priority Weightages	233
6.6.3	Preliminary Goals to be Programmed for the Case Study	233
6.6.4	First Search for Management Decision	235
6.6.5	Results of First Run	239
6.6.6	Reviewing the Achievement of Goals	240
6.7	SEARCH TO IMPROVE THE MANAGEMENT DECISION	241
6.7.1	Results of Second Run	242
6.7.2	Further Review of the Achievement of Goals	243
6.8	TO CONTINUE THE SEARCH IN MANAGEMENT DECISION	244
6.8.1	Results of Third Run	244
6.8.2	Results of Fourth Run	246

6.9	GOAL IMPROVEMENTS BETWEEN FIRST AND FOURTH RUNS	247
6.10	A CRITIQUE ON SUCCESSIVE ITERATIONS	247
6.11	CONCLUSIONS	248

CHAPTER VII

CONCLUSIONS

7.1	SUMMARY OF FINDINGS	250
7.2	AN EXTENDED CRITIQUE AND POSSIBLE EXTENSION	255

BIBLIOGRAPHY	257
--------------	-----

ADDENDUM TO BIBLIOGRAPHY	270
--------------------------	-----

APPENDIX I	A ₁ -A ₄
------------	--------------------------------

(After Page 282)