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Civil Engineering Systems

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CONTENTS

<i>Preface</i>	<i>viii</i>
1 Systematic Decision-making in Civil Engineering	1
1.1 What is Civil Engineering Systems?	1
1.2 The Civil Engineering Project	4
1.3 Systematic Decision-making	11
1.4 Mathematical Decision-making Models	14
Summary	16
2 Systematic Mathematical Modelling – Linear Problems	17
Introduction	17
Example 2.1 – Earthmoving Operations	17
Example 2.2 – Precasting Plant	22
Example 2.3 – Rigid-Plastic Design of Frameworks	25
2.4 The General Linear Programming Problem	30
Summary	37
3 Solution Techniques for Linear Problems	38
Introduction	38
3.1 The Simplex Method for Linear Programming Problems	38
3.2 Sensitivity Analysis and LPs	58
3.3 Duality in Linear Programming	63
3.4 Other Methods for Solving LP Problems	66
3.5 Negative Variables	67
3.6 Problems with Integer or Discrete-valued Variables	70
3.7 Civil Engineering Uses for Linear Programming	73
Example 3.8 – Water Resource Management	75
Summary	78
Bibliography	78
Exercises	78

4 Project Planning Methods, Networks and Graphs	82
Introduction	83
4.1 Construction Planning Networks	83
4.2 Linear Programming and Construction Planning Networks	97
4.3 Resource Allocation and Project Control	102
4.4 Generalised Network Problems	105
4.5 Directed Networks	108
4.6 Undirected Networks and Graphs	119
Summary	125
Bibliography	125
Exercises	126
5 Serial Systems and Dynamic Programming	129
Introduction	129
Example 5.1 — A Critical Path Problem	129
5.2 Generalisation of the Network Approach	135
Example 5.3 — Allocating a Tower Crane	144
Example 5.4 — A Purification Process	148
Example 5.5 — Drainage Design	152
5.6 Further Aspects of Dynamic Programming	157
Summary	163
Bibliography	163
Exercises	164
6 Systematic Design and Non-linear Problems	167
Introduction	167
6.1 Systematic Design	167
6.2 Simple Design Examples	171
6.3 Features of Non-linear Programming Problems	176
6.4 Engineering and Mathematical Viewpoints on Non-linear Optimisation	184
Summary	185
7 Non-linear Unconstrained Optimisation Methods	186
Introduction	186
7.1 The Classical Differential Method	186
7.2 Zeroth-order Methods	190
7.3 First-order Methods	213
7.4 Second-order Methods	224
7.5 Appropriate Methods for Engineering Problems	232
Summary	234
Bibliography	234
Exercises	235

8 Non-linear Constrained Optimisation Methods	237
Introduction	237
8.1 Simple Solution Devices	238
8.2 Lagrange Multiplier Methods	241
8.3 Penalty Function Methods	249
8.4 Linearisation Methods	257
8.5 Direct Numerical Search Methods	263
8.6 Geometric Programming	265
Summary	286
Bibliography	287
Exercises	287
 9 Non-linear Optimisation in Civil Engineering	 291
Introduction	291
9.1 Example — A Pumped Pipeline	292
9.2 Micro-design of Engineering Elements	297
9.3 Design of Multi-element Structural Systems	301
9.4 Other Non-linear Problems	307
Summary	309
Bibliography	309
 10 Probabilistic Decision-making	 310
Introduction	310
10.1 Deterministic and Probabilistic Quantities	311
10.2 Probabilistic Decision-making Problems	313
10.3 Random Variables and their Properties	315
10.4 The Use of Expected Values for Decision-making	325
10.5 Maintenance and Replacement Problems	340
10.6 Reliability	343
Summary	355
Bibliography	355
Exercises	356
 <i>Solutions to Exercises</i>	 360
 <i>Index</i>	 366

PREFACE

Operations research, management science, mathematical optimisation and statistical decision-making are specialised disciplines which have blossomed since the Second World War. They are all concerned with quantitative methods for the solution of decision-making, planning and control problems in industrial and commercial enterprises. Many of the methods are applicable to a wide range of civil engineering problems and the profession is gradually accepting some of them and benefiting from their use. This book introduces some of the methods and concepts of these specialised disciplines which are particularly useful and applicable to practical civil engineering problems.

Civil engineering systems is, however, far more than a convenient holdall for diverse specialist mathematical methods. Civil engineering systems is concerned with decision-making processes within the civil engineering profession. It provides a logical, comprehensive framework for the study of civil engineering decision-making, and consequently many techniques from other disciplines which are concerned with decision-making naturally find a place in civil engineering systems.

The book is based on lecture courses given over a number of years to civil engineering students at the University of Liverpool. These courses present the practice of civil engineering as a creative, decision-making process for which a systematic approach and a knowledge of some efficient decision-making methods are invaluable. The material in this book is aimed at final-year undergraduate and master's degree levels although some of the topics could easily and appropriately be taught earlier. The book assumes a knowledge of simple differential calculus, vectors and matrices but all the mathematical methods described are developed simply and are self-contained. Only an elementary knowledge of technological theory and analysis, for example, structural mechanics and hydromechanics, is assumed. An important feature of the book is that civil engineering considerations are always uppermost. All mathematical methods are developed in a rigorous mathematical fashion but are only developed when a number of practical civil engineering problems have clearly

demonstrated the need for a mathematical solution method. The theoretical aspects are illustrated as much as possible with detailed examples drawn from civil engineering. The arrangement of the book is as follows.

Chapter 1 is of an introductory nature, characterising civil engineering as a decision-oriented profession and examining the nature of the decisions that have to be made during the planning, design, construction and operation phases of a civil engineering project. The underlying aim of making the best possible decisions is presented as a process of optimisation. A four-stage systematic approach to decision-making, used frequently throughout the book, is introduced.

The next three chapters deal with linear decision-making models and methods. Chapter 2 uses civil engineering examples to illustrate the systematic approach and derives linear programming problems for each example. The nature of LP problems is examined. This leads naturally into chapter 3 where the simplex method for solving LP problems is presented. Several aspects of linear programming and its uses in civil engineering are examined. Chapter 4 deals with networks. It describes the critical path method of construction planning in its usual form, and then shows the basic linearity of the method by relating it to linear programming. The linearity is then used to examine other network problems and some simple graph problems are explained.

Chapter 5 covers dynamic programming in a non-classical fashion. A construction planning example is solved by constructing a network of possible solution policies. Methods from chapter 4 are then used to find an optimal path through the network and the algorithm is then generalised to become the DP method. Several further civil engineering problems are described and solved to illustrate many aspects of dynamic programming.

Chapters 6 to 9 are concerned with non-linear decision-making models and methods. Chapter 6 shows by simple examples that almost all civil engineering design problems are non-linear. Some general characteristics of non-linear optimisation problems are examined. Chapter 7 deals with solution methods for unconstrained optimisation problems and chapter 8 with methods for constrained optimisation. These chapters are the most mathematical in the book with very little civil engineering content. Chapter 9 balances the two previous chapters by concentrating on the civil engineering applications of non-linear optimisation. Several examples are studied in detail.

Chapter 10 deals with uncertainty in the decision-making process. The nature of the solutions to be expected when statistical information is introduced into a problem is examined and several statistical decision-making methods are presented using civil engineering examples. The concepts of reliability-based decision-making are examined.

Many of the chapters have a bibliography which suggests specialised texts for further reading. Also many chapters have a final section of problems for the reader to solve. For each problem the briefest of numerical solutions is provided at the back of the book. My experience is that students tend not to attempt to

solve problems unless they have some way of telling whether their solutions are right or wrong.

The most difficult aspect of writing this book has been the conscious omission of useful and interesting topics. Those included are probably the major ones of interest to civil engineers, but who could argue that, for example, queuing theory or inventory theory are not also of use in civil engineering? They are omitted with reluctance along with many equally relevant and useful topics. The book is an introductory one to a very wide and diverse discipline. I hope that it will encourage others to explore this field for themselves and to be rewarded by the pleasure and stimulus which I have found there.

ANDREW TEMPLEMAN