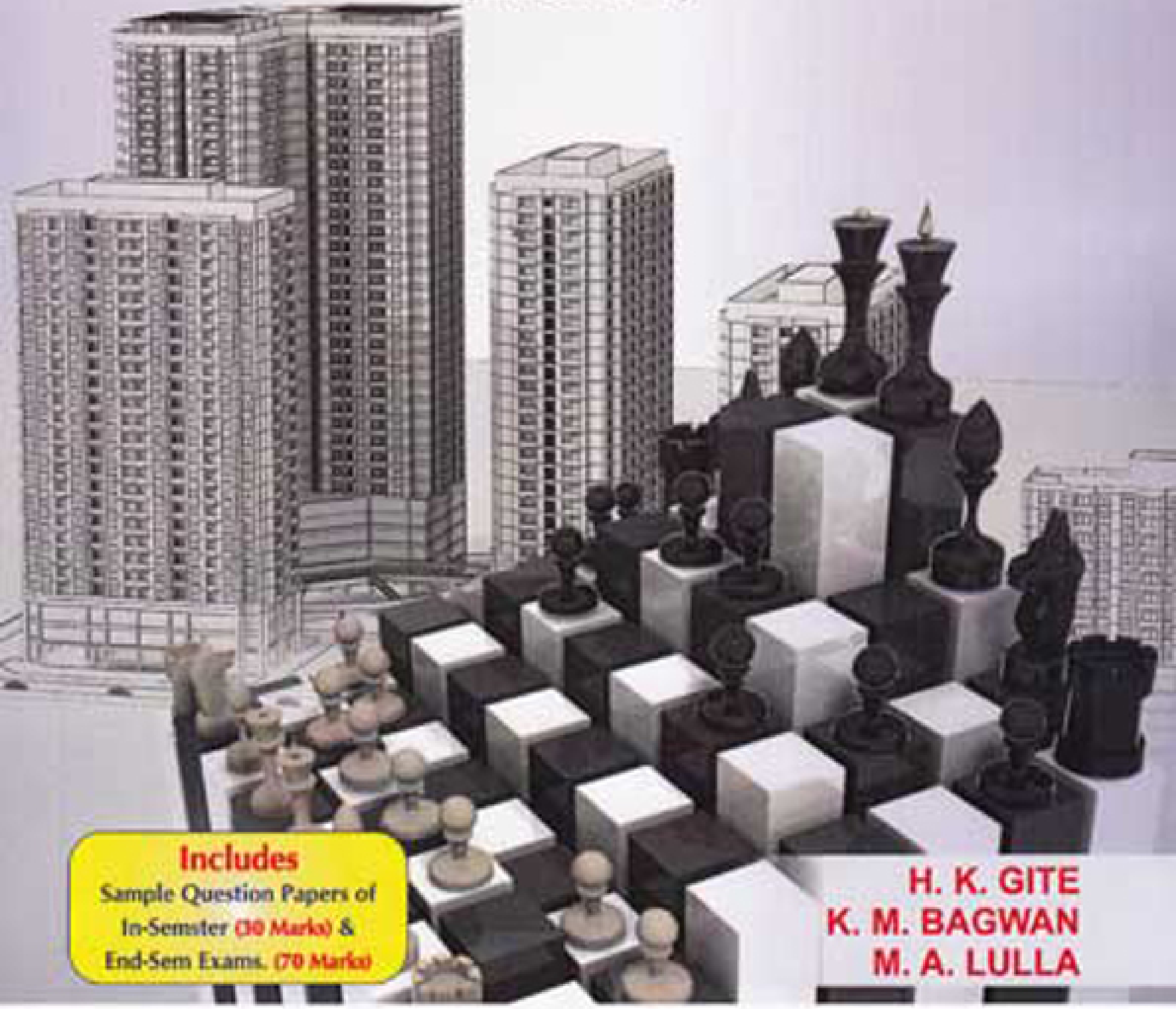
Final Year Degree Course In
CIVIL Engineering (SEM - I)

SPPU

SYSTEMS APPROACH IN CIVIL ENGINEERING

(ELECTIVE - I)



Includes
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H. K. GITE
K. M. BAGWAN
M. A. LULLA

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NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

A TEXT BOOK OF

SYSTEMS APPROACH IN CIVIL ENGINEERING

(Elective-I)

For

(Semester-I)

FINAL YEAR (B.E.) DEGREE COURSE IN CIVIL ENGINEERING

ACCORDING TO NEW REVISED SYLLABUS OF SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE. (2012 PATTERN)

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PREFACE

It gives us great pleasure in presenting the book on **"Systems Approach in Civil Engineering"**, which is written as per Savitribai Phule Pune University Revised Syllabus (2012 Pattern) and in most concised form. The book will also be very useful for Master of Civil Engineering Construction Management Course.

The book is as per New Revised Examination Scheme which has been implemented from this academic year. According to this, In-Semester Examination carries 30 Marks over first three units and End-Semester Examination carries 70 Marks over entire syllabus of which the first three units will carry 20 Marks and units 4, 5 and 6 will carry 50 Marks.

The subject matter is presented in simple and easy form so as to enable the students to understand the subject easily. Sufficient care is taken to present the subject matter in the point wise form in most of the chapters. **Sample Question Papers for the In-Semester and End-Semester University Examination are also included in this book for practice to students.**

Authors are extremely grateful to, **Shri Vijay Pandare**, Chief Engineer, META Nashik, **Shri R. D. Pantankar**, Superintending Engineer, **Shri S. M. Sangle**, Executive Engineer, PH-Division 4, CDO Nashik, **Dr. P. P. Vitkar**, Director JSPM's Pune. **Dr. D. S. Bormane**, Principal RSCOE, Pune. **Prof. Dr. S. J. Wagh** Principal KJE's KJCOE&MR, Pune, **Prof. M. E. Dhanak**, HOD, Civil Engg. Dept., KJCOE&MR Pune and all staff of for providing conclusive environment and facilities for completing this book.

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Also, it is important to mention invaluable moral support of our beloved family members, who consistently encouraged us for better work.

Despite the best efforts taken by authors, it is possible that some unintentional errors might have taken place. Authors would gratefully acknowledge if any of these is pointed out. Suggestions and comments for further improvement of this book will be gratefully received and acknowledged from the students, teachers and others to our following Emails.

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Pune **Authors**

SYLLABUS

Unit 1: Introduction of Systems Approach (06 Hours)

Introduction to System Approach, Operations Research and Optimization Techniques, Use of Systems Approach in Civil Engineering, Methods, Introduction to Linear and Non-linear Programming Methods (with reference to objective function, constraints), Local and Global Optima, Unimodal Function, Convex and Concave Function.

Unit 2: Non-Linear Programming (06 Hours)

Single Variable Unconstrained Optimization: Sequential Search Techniques - Dichotomous, Fibonacci, Golden Section.

Multivariable Optimization without Constraints: The Gradient Vector and Hessian Matrix, Gradient Techniques, Steepest Ascent/Decent Technique, Newton's Method Multivariable Optimization with Equality Constraints - Lagrange Multiplier Technique.

Unit 3: Stochastic Programming (06 Hours)

Sequencing - n jobs through 2, 3 and M machines.

Queuing Theory: Elements of Queuing System and its Operating Characteristics, Waiting Time and Ideal Time Costs, Kendall's Notation, Classification of Queuing Models, Single Channel Queuing Theory: Model I (Single Channel Poisson Arrival with Exponential Services Times, Infinite Population (M/M/I) : (FCFS/∞/∞).

Simulation : Monte Carlo Simulation.

Unit 4: Dynamic Programming (06 Hours)

Multi Stage Decision Processes, Principle of Optimality, Recursive Equation, Applications of D.P.

Unit 5: Linear Programming (A) (06 Hours)

Formulation of Linear Optimization Models for Civil Engineering Applications. The simplex Method, Model of Big M, Two Phase Method, Duality.

Unit 6: Linear Programming (B) (06 Hours)

The Transportation Model and its variants, Assignment Model and its variants.

■■■

CONTENTS

■■■

Unit 1

INTRODUCTION OF SYSTEMS APPROACH

1.1 INTRODUCTION

Now-a-days Civil Engineering projects complexity is increased, but the abilities of the engineers, planners, managers, decision makers remains limited. There are many conflicts between the complexity of the limited no. of ides that can be included in considerations of decisions. So system approach provides a general decision making scheme that makes involvement in broadly based decisions accessible.

System approach is nothing but a line of thought in the management which stresses the interactive nature and interdependence of external and internal factors in an organisation. A system approach is commonly used to evaluate market elements which affect the profitability of a business.

System approach is the systematic application of quantitative methods, techniques and tools to the analysis of problem involving operation of system.

This new decision making field has been characterized by the use of scientific knowledge through inter disciplinary team effort for the purpose of determining the best utilization of limited resources.

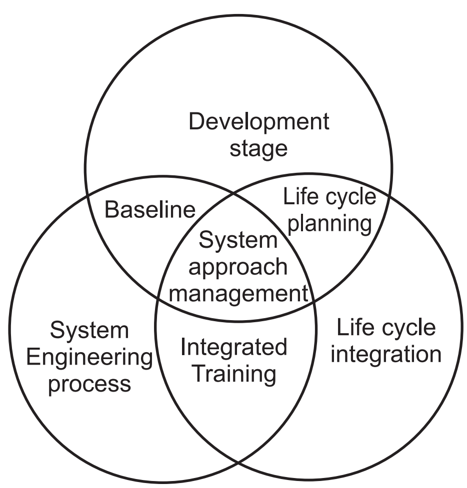


Fig. 1.1: The scope of system approach.

1.2 INTRODUCTION TO OPTIMIZATION AND OPERATION RESERACH

Optimization (maximization or minimization) is an art of obtaining the best result under a given situation. In design, construction and planning of any engineering system, engineers have to make many technical and managerial decisions at several stages. The final goal to be achieved from all such decisions is either to minimize the efforts required or to maximize the desired benefit.

Operation research is a branch of mathematics concerned with the application of scientific methods and techniques to decision making problems and with establishing the best optimal solutions. The table given below list down the various mathematical programming techniques;

Table 1.1

Mathematics Programming Techniques	Stochastic Process Techniques	Statistical Methods
• Non-linear programming • Linear programming • Dynamic programming • Network methods – **CPM OR PERT** • Game theory	• Queuing theory • Simulation methods	• Regression analysis • Design of experiments

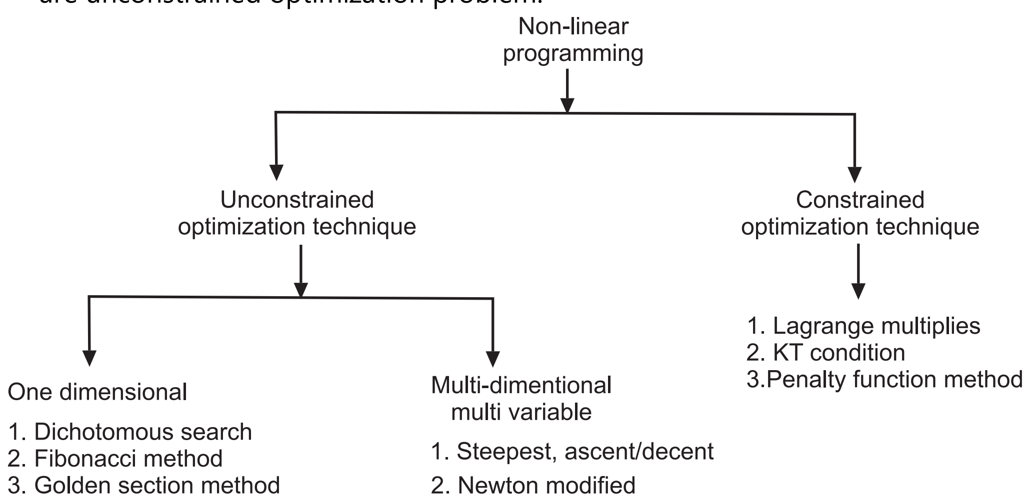
1.3 USE OF SYSTEM APPROACH IN CIVIL ENGINEERING

- Design of civil engineering structures such as frames, foundations, bridges, towers, chimneys and dam for minimum cost.
- Design of water resources systems for maximum benefit.
- Minimum weight design of structures for earthquake, wind and other types of random loading.
- Optimal plastic design of structures.
- Design of optimal pipeline networks for process industries.
- Selection of a site for an industry.
- Planning of maintenance and replacement of equipment to reduce operating costs.
- Planning of maintenance and replacement of equipment to reduce operating costs.
- Inventory control.
- Allocation of resources or services among several activities to maximize the benefit.

1.4 VARIOUS MODELS WHICH ARE USED IN SYSTEM APPROACH

1. **Linear Programming:** Linear programming is an optimization method applicable for the solution of problems in which the objective function and the constraints appear as linear functions of the decision variables. The constraints equations in a linear programming problem may be in the form of equalities or inequalities. Linear programming is considered as a revolutionary development that permits us to make optimal decisions in complex situations.
2. **Non-Linear Programming:** A key assumption of linear programming is that all its functions are linear. Although this assumption does not hold for all problems. As a result the objective function of / or one or more of the constraints will have non-linear relationship among decision variables.

   If the problem is to optimize the objective function without any constraints then they are unconstrained optimization problem.



3. **Dynamic Programming:** Dynamic programming is a mathematical technique well suited for the optimization of multistage decision problems. The dynamic programming technique, when applicable, represents or decomposes a multistage decision problem as a sequence of single stage decision problems.
4. **Sequencing Model**
5. **Simulation**
6. **Queuing Theory**
7. **Game Theory**
8. **Replacement Model**

1.5 OBJECTIVE FUNCTION

In general there will be more than one acceptable design, of the purpose of optimization is to choose the best one of the many acceptable design available. Thus a criterion has to be chosen for comparing the different alternative acceptable designs and for selecting the best one. The criterion with respect to which the design is optimized, when expressed as a function of the design variables, is known as the criterion or objective function. The choice of objective function is governed by the nature of problem. In civil engineering structural design, the objective is usually taken as the minimization of cost.

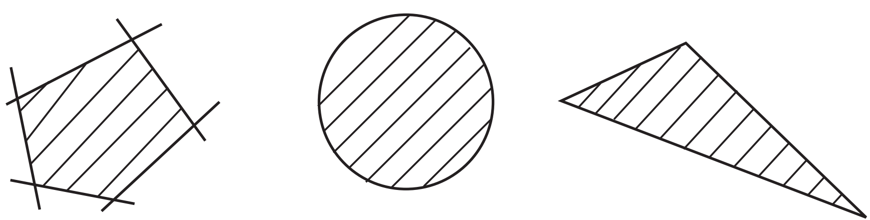
1.6 CONSTRAINT

Constraints is the element factors or a subsystem that works as a bottle neck. It restricts an entity, project, or system from achieving its potential with reference to its goal. The constraints represent uncontrollable variables. They define system boundary.

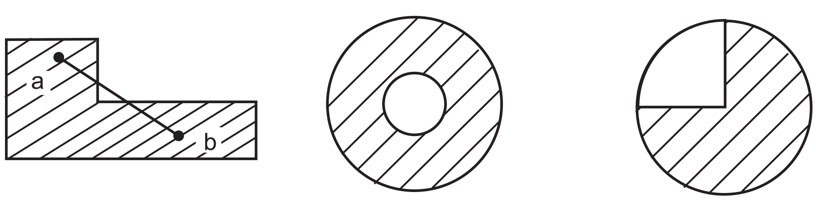
1.7 CONVEX AND CONCAVE SET

A convex set is a collection of points such that if x_1 of x_2 are the two points in a collection and line segment joining them is also in the collection.

On the other hand, it is not possible to find two points a and b in the set such that not all the points on the line joining them belong to the set, and this set is called as non convex or concave set.



Convex set



Non-convex or concave set

Fig. 1.2

1.8 CONVEX AND CONCAVE FUNCTIONS

A function f (x) is said to be convex if for any pair of points.

$$x_1 = \begin{Bmatrix} x_1^{(1)} \\ x_2^{(1)} \\ \vdots \\ x_n^{(1)} \end{Bmatrix} \text{ and } x_2 = \begin{Bmatrix} x_1^{(2)} \\ x_2^{(2)} \\ \vdots \\ x_n^{(1)} \end{Bmatrix}$$

And all λ ⸧ o ≤ λ ≤ 1

$$f [\lambda x_2 + (1-\lambda) x_1] \leq \lambda f (x_2) + (1-\lambda) f (x_1)$$

That is, if the segment joining the two points lies entirely above or on the graph of f (x).

The following fig. Shows the convex function of single variable.

So let λ = ½

$$f \left[\frac{1}{2} x_2 + \left(1 - \frac{1}{2}\right) x_1\right] \leq \frac{1}{2} f(x_2) + \left(1 - \frac{1}{2}\right) f(x_1)$$

$$f \frac{1}{2} [x_2 + x_1] \leq \frac{1}{2} [f (x_2) + f (x_1)]$$

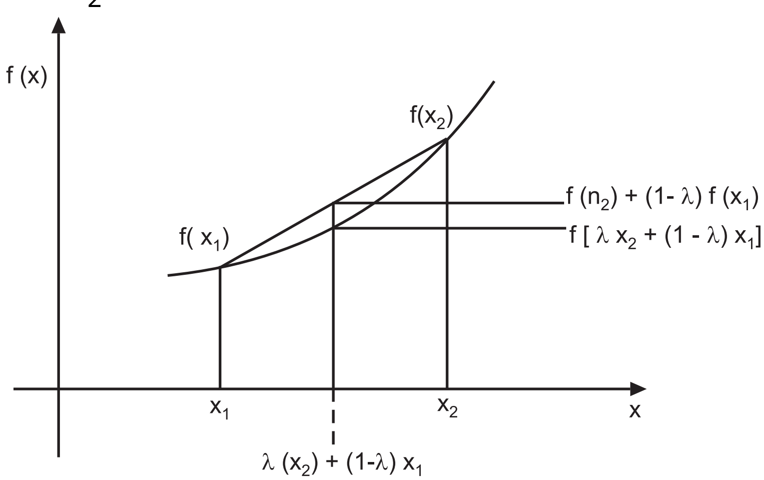


Fig. 1.3

It is can be seen that a convex function is always bending upward and hence it is apparent that the local minimum of a convex function is also a global minimum.

A function f (x) is called a concave function if for any two points x_1 and x_2 and for all 0 ≤ 1 ≤ 1

$$F [\lambda x_2 + (1 - \lambda) x_1] \geq \lambda f(x_2) + (1 - \lambda) f(x_1)$$

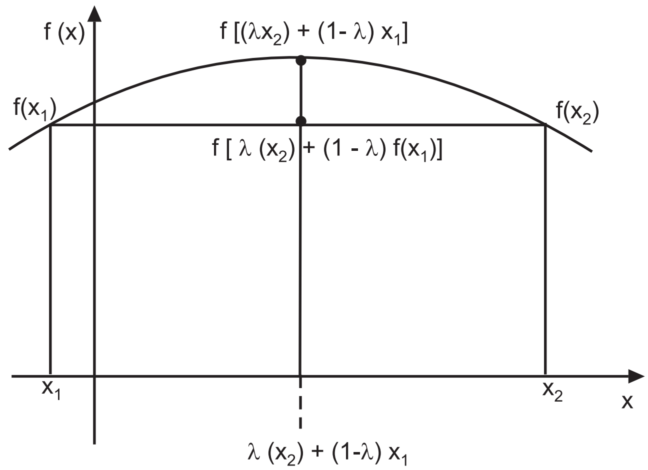


Fig. 1.4

That is, if the line segment joining the two points lies entirely below or on the graph of f(x).

It can be seen that a concave function bends downward and hence the local maximum will also be its global maximum. It is also seen that the negative of a convex function is a concave function and vice versa.

1.9 LINEAR PROGRAMMING

The word "Linear" is used to describe the proportionate relationship of two or more variables. The word "programming" is used to specify a sort of planning that involves economic allocation or strategy from various alternative strategies to achieve the desired objective.

Linear programming is a general technique which deals with the optimisation (maximization or minimization) of a function of variables known as objective function subject to a set of linear equalities and /or inequalities known as constraints. The objective function may be increment, cost, profit, production capacity or any other measure which is to be optimised. The constraints which are imposed are market condition, demand, requirement, production process, and equipments, machineries etc.

The objective function and constraints are linear to the decision variables. The variables which are directly under control of the manager who takes decision for the organization are known as decision variables.

Some Important Definitions in Linear Programming

1. **Decision Variable:** Decision variables are the unknowns to be determined from the solution to the model.

   Example, quantity of product to be produced, quantity of different foods, etc.