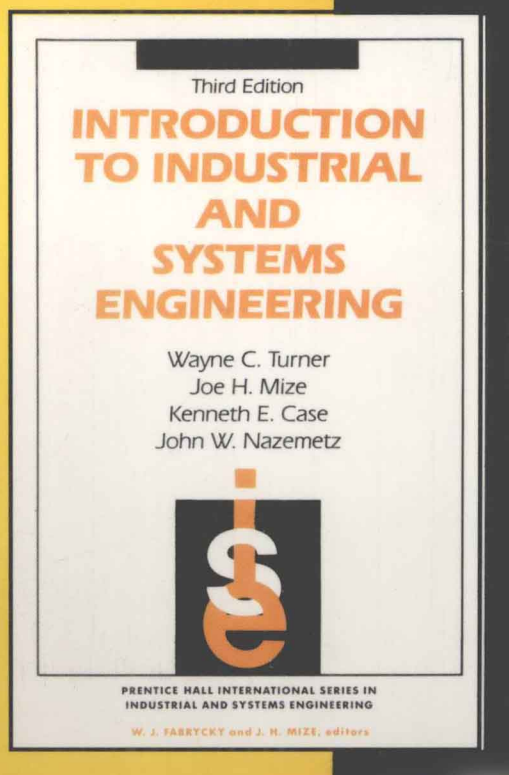


国外大学优秀教材——工业工程系列（影印版）

Wayne C. Turner, Joe H. Mize  
Kenneth E. Case, John W. Nazemetz

# 工业与系统工程概论

（第3版）



清华大学出版社

<http://www.tup.tsinghua.edu.cn>

<http://www.tup.tsinghua.edu.cn>

<http://www.tup.tsinghua.edu.cn>

国外大学优秀教材——工业工程系列（影印版）

# Introduction to Industrial and Systems Engineering

THIRD EDITION

## 工业与系统工程概论 (第3版)

WAYNE C. TURNER  
JOE H. MIZE  
KENNETH E. CASE  
JOHN W. NAZEMETZ  
Oklahoma State University



清华大学出版社

Prentice  
Hall

培生教育出版集团

(京)新登字 158 号

工业与系统工程概论 (第 3 版)

Introduction to Industrial and Systems Engineering, third edition.

EISBN: 0-13-481789-3

Copyright © 1993, 1987, 1978, 2001 by Prentice-Hall, Inc. All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

本书影印版由 Prentice-Hall 教育出版集团授权清华大学出版社在中国境内 (不包括香港特别行政区、澳门特别行政区和台湾地区) 独家出版、发行。

未经出版者书面许可, 不得以任何方式复制或抄袭本书的任何部分。

本书封面贴有 Prentice Hall 激光防伪标签, 无标签者不得销售。

北京市版权局著作权合同登记号: 图字: 01-2002-3103

书 名: 工业与系统工程概论 (第 3 版)

作 者: WAYNE C. TURNER JOE H. MIZE KENNETH E. CASE JOHN W. NAZEMETZ

出 版 者: 清华大学出版社 (北京清华大学学研大厦, 邮编 100084)

[http:// www.tup.tsinghua.edu.cn](http://www.tup.tsinghua.edu.cn)

责任编辑: 张秋玲

印 刷 者: 北京市牛山世兴印刷厂

发 行 者: 新华书店总店北京发行所

开 本: 787×960 1/16 印张: 35

版 次: 2002 年 6 月第 1 版 2002 年 6 月第 1 次印刷

书 号: ISBN 7-302-05602-1/TB·44

印 数: 0001~3000

定 价: 49.00 元

---

# Forward

---

This textbook series is published at a very opportunity time when the discipline of industrial engineering is experiencing a phenomenal growth in China academia and with its increased interests in the utilization of the concepts, methods and tools of industrial engineering in the workplace. Effective utilization of these industrial engineering approaches in the workplace should result in increased productivity, quality of work, satisfaction and profitability to the cooperation.

The books in this series should be most suitable to junior and senior undergraduate students and first year graduate students, and to those in industry who need to solve problems on the design, operation and management of industrial systems.

  
Gavriel Salvendy

Department of Industrial Engineering, Tsinghua University

School of Industrial Engineering, Purdue University

April, 2002

---

# 前 言

---

本教材系列的出版正值中国学术界工业工程学科经历巨大发展、实际工作中对工业工程的概念、方法和工具的使用兴趣日渐浓厚之时。在实际工作中有效地应用工业工程的手段将无疑会提高生产率、工作质量、合作的满意度和效果。

该系列中的书籍对工业工程的本科生、研究生和工业界中需要解决工程系统设计、运作和管理诸方面问题的人士最为适用。

加弗瑞尔·沙尔文迪  
清华大学工业工程系  
普渡大学工业工程学院（美国）  
2002 年 4 月

# Preface

This book provides an introduction to industrial and systems engineering. It is especially designed for use as a text in an introduction to industrial engineering course. The purpose is to define industrial and systems engineering, describe its place in the business world, and give a broad picture of the functional areas with some solution techniques. The book is also useful to anyone desiring an overview of industrial engineering.

This book is not a detailed text for any of the individual techniques presented, but it does show what an industrial and systems engineer is capable of doing in a wide variety of organizations. Special attention is given to describing situations in which the tools or techniques may be applied. Instead of taking the classical "technique looking for a problem approach," the problems are first described and then the technique(s) applicable to the problems is (are) discussed.

The book is divided into three parts. In Part 1 the history of engineering in general and industrial engineering specifically is given in an attempt to show the range and growth of the discipline's objectives. Then, a modern definition and discussion of industrial and systems engineering are given. They define the purpose and objectives of the discipline and show areas where it is applicable. Part 1 discusses the place of industrial and systems engineering in an organization and how to manage and control the function. Finally, Part 1 introduces the concepts of elementary systems theory and feedback.

Part 2 constitutes the largest portion of the book, with a chapter devoted to each of the major methodologies of the discipline of industrial and systems engineering. For each general area of industrial and systems engineering, a typical problem is presented to provide a concrete framework, and then the tools and techniques appropriate for that situation are developed. The purpose in this approach is to emphasize the proper use of the various techniques. Since modern computing methods have had a significant effect on industrial and systems engineering, almost all chapters in Part 2 discuss computerization of the techniques. Included in Part 2 are some of the newer tools, such as CAD/CAM, robotics, and resource management, as well as tools that have been around for many years. The relationship of industrial engineering to such areas as operations research and ergonomics is emphasized.

Part 3, Integrated Systems Design, is intended to show how the I.E. must bring together all the detailed pieces into an integrated system. Elementary concepts from systems engineering are used as a vehicle for portraying the complex interactions among system components. A chapter is included on computers and information systems because of their critical importance in the design of integrated systems.

Those familiar with the second edition of this book will notice that we have added a new chapter on simulation. All chapters have been thoroughly updated, with some being completely revised. Also, other chapters have been combined and rearranged for a more effective organization of topics.

We are very grateful to our many colleagues who, having taught from the first and second editions of this book, provided many helpful suggestions for the third edition. We have incorporated most of their suggestions, and we feel that the book is stronger because of them. We would also like to thank the following reviewers: Avinash Waikar, Louisiana State University; Roger Berger, Iowa State University; Paul McCright, Kansas State University; Sabah U. Randhawa, Oregon State University; Chris Styliandis, North Dakota State University; John R. English, Texas A & M University; Robert L. Williams, Ohio University; Jill A. Swift, University of Miami; and Timothy J. Greene, Virginia Polytechnic University. We also wish to acknowledge the useful comments offered by many students who have studied using this text.

In using the book at Oklahoma State University for many years, we have found that the course is greatly enhanced through the use of a workbook containing laboratory exercises, which give the students hands-on experience in applying the concepts covered in the text. This workbook is now available from Prentice Hall. We wish to acknowledge the help of our colleagues Pat Koelling and Jim Shamblin in preparing the workbook.

W. C. TURNER  
J. H. MIZE  
K. E. CASE  
J. W. NAZEMETZ

# Contents

## **PREFACE**

**xvii**

## **Part 1 History and Perspective of Industrial Engineering 1**

### **1 HISTORY OF ENGINEERING AND DEVELOPMENT OF INDUSTRIAL ENGINEERING 1**

- 1.1. Introduction 1
- 1.2. Early Developments 2
- 1.3. The Modern Era 3
- 1.4. The Engineering Process 5
- 1.5. Engineering as a Profession 6
- 1.6. Professional Ethics 8
- 1.7. Professional Licensing 8
- 1.8. Engineering Education and ABET Accreditation 10
- 1.9. Chronology of Industrial Engineering 12



- 1.10. Industrial Engineering Organizations 15
- 1.11. Definition of Industrial Engineering 18
- 1.12. Industrial Engineering Education 18
- 1.13. Impact of Related Developments 19
  - 1.13.1 *Impact of Operations Research*, 19
  - 1.13.2 *Impact of Digital Computers*, 20
  - 1.13.3 *Emergence of Service Industries*, 21
- 1.14. Relationship to Other Engineering Disciplines 21
- 1.15. Challenges of the Future 23

## **2 INDUSTRIAL AND SYSTEMS ENGINEERING**

**25**

- 2.1. Introduction 25
- 2.2. Industrial and Systems Engineering Design 26
  - 2.2.1 *Human Activity System*, 26
  - 2.2.2 *Management Control System*, 26
- 2.3. Typical I.&S.E. Activities 28
  - 2.3.1 *Production Operations*, 28
  - 2.3.2 *Management Systems*, 30
  - 2.3.3 *Corporate Services*, 31
- 2.4. Relationship to Total Organization 33
- 2.5. Internal Organization of the I.&S.E. Function 36
- 2.6. Effectiveness Measures for the I.&S.E. Function 36
- 2.7. The Nature of "Systems" 36
  - 2.7.1 *Definitions*, 37
  - 2.7.2 *System Classifications*, 38
- 2.8. Feedback Control in Systems 38

## **Part 2 Industrial and Systems Engineering Methodologies**

**43**

## **3 MANUFACTURING ENGINEERING**

**43**

- 3.1. Introduction 43
- 3.2. Product–Production Design Interaction 44
- 3.3. Process Engineering 45
  - 3.3.1 *Defining Product Structure and Specifications*, 45
  - 3.3.2 *Assessing Manufacturability*, 48
  - 3.3.3 *Determining Processes Capable of Producing the Part*, 48
  - 3.3.4 *Evaluating the Cost of Each Process*, 50

3.3.5	<i>Determining the Sequence of Operations</i>	55
3.3.6	<i>Documenting the Process</i>	55
3.4.	<b>Industrial Processes</b>	56
3.4.1	<i>Refining and Alloying</i>	56
3.4.2	<i>Casting</i>	58
3.4.3	<i>Metal Forming</i>	59
3.4.4	<i>Metal Cutting</i>	60
3.4.5	<i>Welding</i>	64
3.4.6	<i>Assembly</i>	67
3.4.7	<i>Finishing</i>	67
3.5.	<b>Ancillary Functions</b>	68
3.5.1	<i>Tool, Jig, and Fixture Design</i>	68
3.5.2	<i>Cost Estimating</i>	70
3.5.3	<i>Maintenance Systems Design</i>	71
3.5.4	<i>Packaging Systems</i>	72
3.6.	<b>Example</b>	73
3.7.	<b>Computer Applications</b>	73
<b>4</b>	<b>FACILITIES LOCATION AND LAYOUT</b>	<b>80</b>
4.1.	<b>Introduction to Facilities Location</b>	80
4.2.	<b>Considerations</b>	81
4.3.	<b>Analytical Techniques</b>	83
4.3.1	<i>Transportation Method of Linear Programming</i>	84
4.3.2	<i>Multiple Objectives</i>	88
4.3.3	<i>Mathematical Programming (Optional)</i>	89
4.3.4	<i>Public-Sector Location Problems</i>	96
4.4.	<b>Introduction to Facilities Layout</b>	99
4.5.	<b>General Considerations</b>	102
4.6.	<b>Systematic Layout Planning</b>	102
4.7.	<b>Computerized Layout Planning (Optional)</b>	113
4.8.	<b>Impact of Computers</b>	118
<b>5</b>	<b>MATERIAL HANDLING, DISTRIBUTION, AND ROUTING</b>	<b>125</b>
5.1.	<b>Introduction</b>	125
5.2.	<b>Material Handling</b>	126
5.2.1	<i>Equipment Concepts</i>	127
5.2.2	<i>Principles of Material Handling</i>	131
5.2.3	<i>Quantitative Techniques</i>	134

- 5.3. Distribution 137
  - 5.3.1 Warehouse Location, 137
  - 5.3.2 Operations Management—Routing, 137
  - 5.3.3 Routing in the Public Sector, 145

## **6 WORK DESIGN AND ORGANIZATIONAL PERFORMANCE—WORK MEASUREMENT**

**151**

- 6.1. Introduction 151
- 6.2. Methods Improvement 154
  - 6.2.1 Flow Process Charts, 155
  - 6.2.2 Left-Hand–Right-Hand Charts, 156
  - 6.2.3 Other Charts, 160
  - 6.2.4 Principles of Motion Economy, 163
  - 6.2.5 Human Engineering, 164
- 6.3. Work Measurement 165
  - 6.3.1 Direct Time Study, 167
  - 6.3.2 Time Study Standard Data, 171
  - 6.3.3 Predetermined Times, 173
  - 6.3.4 Predetermined Time Standard Data, 174
  - 6.3.5 Work Sampling, 174
- 6.4. Organizational System Performance Measurement 175
  - 6.4.1 Productivity Measurement Basics, 175
  - 6.4.2 Normative Productivity Measurement Model, 176
  - 6.4.3 Multifactor Productivity Measurement Model, 178
- 6.5. Computers and Work Measurement and Design 178

## **7 OPERATIONS PLANNING AND CONTROL**

**183**

- 7.1. Introduction 183
- 7.2. Overview of Operations Planning and Control 184
  - 7.2.1 Demand Forecasting (I), 184
  - 7.2.2 Operations Planning (II), 186
  - 7.2.3 Inventory Planning and Control (III), 187
  - 7.2.4 Operations Scheduling (IV), 188
  - 7.2.5 Dispatching and Progress Control (V), 188
  - 7.2.6 Interfaces, 189
  - 7.2.7 Integrating the Functions, 190
- 7.3. Techniques for Demand Forecasting 190
  - 7.3.1 Moving Average, 190
  - 7.3.2 Exponentially Weighted Moving Average, 191
  - 7.3.3 Regression Analysis, 192

- 7.4. Techniques for Operations Planning 194
- 7.5. Techniques for Inventory Planning and Control 197
- 7.6. Techniques for Operations Scheduling 200
  - 7.6.1 *Purpose of Operations Scheduling, 201*
- 7.7. Dispatching and Progress Control 203
- 7.8. MRP Systems 203
- 7.9. Just-in-Time Manufacturing 207

## **8 QUALITY CONTROL**

**212**

- 8.1. Introduction 212
- 8.2. A Bit of History 213
- 8.3. The Malcolm Baldrige National Quality Award 213
- 8.4. Deming's Thoughts on Continuous Improvement 216
- 8.5. Juran's Contributions to Quality Thought 217
- 8.6. Tools for On-line vs. Off-line Quality Control 218
- 8.7. Quality Function Deployment 218
- 8.8. Quality Cost Systems 220
- 8.9. Benchmarking 221
- 8.10. Tools of Statistical Process Control 223
  - 8.10.1 *Flowchart, 223*
  - 8.10.2 *Cause-and-Effect Diagram, 226*
  - 8.10.3 *Data Collection Form, 227*
  - 8.10.4 *Pareto Analysis, 228*
  - 8.10.5 *Histogram, 230*
  - 8.10.6 *Scatter Plot, 232*
  - 8.10.7 *Designed Experimentation, 233*
- 8.11. Background on Control Charts 234
- 8.12. Control Charts for Variables 236
- 8.13. Sensitivity Checks for Control Charts 241
- 8.14. Process Capability Analysis 241
- 8.15. Control Charts for Attributes 243
  - 8.15.1 *The p Control Chart, 243*
  - 8.15.2 *The c Control Chart, 244*

## **9 FINANCIAL COMPENSATION**

**252**

- 9.1. Introduction 252
- 9.2. Job Analysis 253

- 9.3. Job Evaluation 254
  - 9.3.1 *Ranking Method of Job Evaluation*, 256
  - 9.3.2 *Classification or Grade Description*, 256
  - 9.3.3 *Factor Comparison*, 257
  - 9.3.4 *Point Rating*, 259
- 9.4. Wage Surveys 262
- 9.5. Wage Payment 266
  - 9.5.1 *Daywork*, 267
  - 9.5.2 *Measured Daywork*, 267
  - 9.5.3 *Piecework Incentive*, 267
  - 9.5.4 *Standard Hour*, 268
  - 9.5.5 *Group Plans*, 269

## **10 CAD/CAM, ROBOTICS, AND AUTOMATION**

**275**

- 10.1. The Second Industrial Revolution 275
  - 10.1.1 *A Brief History of Manufacturing*, 275
  - 10.1.2 *Impact of Computers and Electronics*, 277
  - 10.1.3 *Other Recent Developments*, 277
  - 10.1.4 *The Factory of the Future*, 278
- 10.2. Computer-Aided Design 279
  - 10.2.1 *Computers in Product Design*, 279
  - 10.2.2 *Computers in Process Design*, 280
  - 10.2.3 *Computers in Electronics Design*, 281
- 10.3. Computer-Aided Manufacturing 282
  - 10.3.1 *Computer-Aided Process Planning*, 282
  - 10.3.2 *Numerical Control*, 283
  - 10.3.3 *The Concepts of Group Technology*, 285
  - 10.3.4 *Automated Storage, Retrieval, and Handling*, 286
  - 10.3.5 *Computer-Aided Testing and Inspection*, 288
  - 10.3.6 *Computer-Aided Factory Management*, 290
  - 10.3.7 *The Concepts of Flexible Manufacturing Systems*, 290
- 10.4. Robotics 291
  - 10.4.1 *Definition and Basic Concepts*, 293
  - 10.4.2 *Physical and Technical Aspects of Robots*, 293
  - 10.4.3 *Robotic Applications*, 295
- 10.5. Automation 296
- 10.6. The Promise of CIM 297
- 10.7. Opportunities for I.E.'s 298

**11 HUMAN FACTORS****301**

- 11.1. Perspective 301
- 11.2. Physiological Aspects of Human Performance 302
- 11.3. Psychological Aspects of Human Activities 304
- 11.4. Human Interface with the World of Work 305
  - 11.4.1 *Human Interface with the Work Environment, 306*
  - 11.4.2 *Human Interface with Machines, 307*
  - 11.4.3 *Human Interface with Information/Communication Systems, 308*
  - 11.4.4 *Human Interface with Organizational/Supervisory Structure, 308*
  - 11.4.5 *Human Interface with Robots and Intelligent Machines, 309*

**12 RESOURCE MANAGEMENT****312**

- 12.1. Introduction 312
  - 12.1.1 *Energy Management, 312*
  - 12.1.2 *Water Management, 313*
  - 12.1.3 *Hazardous Material Management, 313*
  - 12.1.4 *This Chapter, 314*
- 12.2. Energy Management 314
  - 12.2.1 *Why Bother?, 315*
  - 12.2.2 *Why Industrial Engineering?, 315*
  - 12.2.3 *Required Ingredients, 315*
  - 12.2.4 *Understanding Rate Schedules, 316*
  - 12.2.5 *Alternate Rate Schedules, 319*
  - 12.2.6 *Energy Management Opportunities, 319*
- 12.3. Water Management 322
- 12.4. Hazardous Material Management 324
  - 12.4.1 *Government Regulations, 324*
  - 12.4.2 *The Role of Industrial Engineering, 325*
- 12.5. Summary 327

**13 FINANCIAL MANAGEMENT  
AND ENGINEERING ECONOMY****329**

- 13.1. Introduction 329
- 13.2. Accounting 330
- 13.3. Cost Accounting 333

- 13.4. Engineering Economy 336
- 13.5. Interest Factors 337
  - 13.5.1 *Single-Payment Compound Amount Factor, 338*
  - 13.5.2 *Other Interest Factors, 339*
  - 13.5.3 *Examples, 341*
- 13.6. Back to Gadgets—Present Worth Calculations 343
- 13.7. Impact of the Computer on Accounting and Engineering Economy 345

## **14 DETERMINISTIC OPERATIONS RESEARCH**

**349**

- 14.1. Introduction—Definition 349
- 14.2. Similarity to Industrial Engineering 350
- 14.3. Nature of Operations Research 351
  - 14.3.1 *Economic Order Quantity, 351*
  - 14.3.2 *Plant Location, 351*
  - 14.3.3 *Job Evaluation, 352*
  - 14.3.4 *Quality Control, 352*
  - 14.3.5 *Others, 352*
- 14.4. Categorization of Operations Research 352
  - 14.4.1 *Deterministic Approach, 353*
  - 14.4.2 *Probabilistic Approach, 353*
- 14.5. Deterministic Operations Research 354
- 14.6. Mathematical Programming 354
- 14.7. Unconstrained Optimization 355
- 14.8. Linear Programming 362
  - 14.8.1 *Assignment Problem, 367*
  - 14.8.2 *Transportation Problem, 369*
- 14.9. Other Techniques 372
  - 14.9.1 *Nonlinear Programming, 372*
  - 14.9.2 *Integer Programming, 373*
  - 14.9.3 *Zero-One Programming, 373*
  - 14.9.4 *Quadratic Programming, 373*
  - 14.9.5 *Geometric Programming, 373*
  - 14.9.6 *Other Programming, 373*
- 14.10. Impact of Computers 373

## **15 PROBABILISTIC MODELS**

**378**

- 15.1. Introduction 378
- 15.2. Queueing Theory 378

15.2.1	<i>Queueing System Structure, 379</i>	
15.2.2	<i>Queueing Notation, 380</i>	
15.2.3	<i>Single-Service Channel, 381</i>	
15.3.	Inventory Control 384	
15.3.1	<i>Single-Period Model—No Setup Cost, 384</i>	
15.3.2	<i>Lot Size—Reorder Point Models, 387</i>	
15.3.3	<i>Periodic Review Models, 388</i>	
15.4.	Markov Chains 389	
15.4.1	<i>Regular Markov Chains, 390</i>	
15.4.2	<i>Absorbing Markov Chains, 392</i>	
15.5.	Impact of Statistics and Computers 393	
<b>16</b>	<b>SIMULATION</b>	<b>396</b>
16.1.	Introduction 396	
16.2.	Simulation Examples 397	
16.3.	Random Number Generation 403	
16.4.	Time-Flow Mechanism 407	
16.5.	Simulation Languages 407	
<b>17</b>	<b>PROJECT MANAGEMENT</b>	<b>411</b>
17.1.	Introduction 411	
17.2.	Project Planning Networks 413	
17.3.	Critical Path Method 415	
17.3.1	<i>Forward Pass, 417</i>	
17.3.2	<i>Backward Pass, 417</i>	
17.3.3	<i>Total Activity Slack, 419</i>	
17.3.4	<i>Critical Path, 419</i>	
17.4.	Program Evaluation and Review Technique 419	
17.5.	Time—Cost Trade-offs 424	
17.6.	Resource Leveling 429	
<b>Part 3</b>	<b>Integrated Systems Design</b>	<b>432</b>
<b>18</b>	<b>SYSTEMS CONCEPTS</b>	<b>432</b>
18.1.	Introduction 432	
18.2.	Introduction to Systems Thinking 433	
18.2.1	<i>Origin of Systems Thinking, 433</i>	
18.2.2	<i>Hierarchical Nature of Systems, 434</i>	



- 18.3. Definitions and Terminology 436
- 18.4. Systems Engineering 440
  - 18.4.1 *Systems Analysis and Design*, 440
  - 18.4.2 *The Systems Design Process*, 440
- 18.5. System Representation 442
  - 18.5.1 *Block Diagrams*, 442
  - 18.5.2 *Transfer Functions*, 443

## **19 MANAGEMENT SYSTEMS DESIGN**

448

- 19.1. Introduction and Perspective 448
- 19.2. A Systems View of an Organization 449
  - 19.2.1 *Gaining a Perspective*, 449
  - 19.2.2 *Finding a Starting Point*, 450
  - 19.2.3 *Universal Outcome Goals*, 452
  - 19.2.4 *Determining Goals and Objectives*, 453
  - 19.2.5 *A Unified Framework*, 454
- 19.3. Organization Design 456
  - 19.3.1 *Specification of Objectives*, 458
  - 19.3.2 *Determination of Functions*, 459
  - 19.3.3 *Grouping the Functions*, 459
  - 19.3.4 *Functional Objectives*, 460
  - 19.3.5 *Job Descriptions*, 460
  - 19.3.6 *Management Controls*, 460
  - 19.3.7 *Organization Design Is Continuous and Dynamic*, 461
  - 19.3.8 *Organization Structures*, 461
  - 19.3.9 *Coordination within the Organization*, 462
  - 19.3.10 *Keeping the Design Current*, 463
- 19.4. Providing Management Controls 463
- 19.5. The Organization Life Cycle 464
  - 19.5.1 *Life Cycle Stages of an Organization*, 464
  - 19.5.2 *Organizational Renewal and Redesign*, 465
  - 19.5.3 *The Learning Organization*, 466

## **20 COMPUTERS AND INFORMATION SYSTEMS**

469

- 20.1. Perspective 469
- 20.2. Basic Concepts of Information Systems 470
- 20.3. The Process of Designing Information Systems 472
  - 20.3.1 *Feasibility Study*, 472
  - 20.3.2 *Systems Analysis*, 472
  - 20.3.3 *General Systems Design*, 474
  - 20.3.4 *Systems Evaluation and Justification*, 474