
SCHEDULING CONSTRUCTION PROJECTS

EDWARD M. WILLIS

*Department of Engineering Technology
College of Engineering
University of North Carolina at Charlotte*

TECHNISCHE HOCHSCHULE DARMSTADT	
Fachbereich-1	
<u>Gesamtbibliothek</u>	
<u>Betriebswirtschaftslehre</u>	
Inventar-Nr. :	38.033
Abstell-Nr. :	A.14/1140
Sachgebiete:	1.6.3.1

JOHN WILEY & SONS,
NEW YORK • CHICHESTER • BRISBANE • TORONTO • SINGAPORE

CONTENTS

CHAPTER 1	INTRODUCTION TO SCHEDULING	1
	Objectives	1
	Requirements for Construction Schedules	1
	<i>Significance of Costs and Time</i>	1
	<i>Sophisticated Versus Simple Scheduling Methods</i>	2
	<i>Appropriate Level of Detail for a Schedule</i>	2
	<i>Scheduling and Uncertainty</i>	3
	Essential Terms	3
	Participants in the Construction Process	4
	<i>The Owner</i>	4
	<i>The Designers</i>	5
	<i>The Contractor and Subcontractors</i>	5
	<i>The Construction Manager</i>	6
	<i>The Design-Build Firm</i>	6
	<i>Fabricators and Vendors</i>	6
	Bases for Preparation of the Construction Project Schedule	6
	<i>Arbitrary Basis</i>	6
	<i>Intuitive Basis</i>	7
	<i>Scientific Basis</i>	7
	The Contract Construction Industry	7
	The Construction Contract	8
	<i>Legal Considerations</i>	8
	<i>Types of Construction Contracts</i>	9

<i>Selection of Contractors</i>	11
<i>Contract Requirements</i>	11
Uses of Construction Project Schedules	13
<i>To Predict Progress</i>	13
<i>To Serve as a Record</i>	14
<i>To Satisfy a Contract Requirements</i>	15
Examples of Use of Schedules for Construction Projects	15

CHAPTER 2 TASK DEFINITION: THE FOUNDATION OF A SCHEDULE **19**

Objective	19
Task Definition	19
<i>Breakdown of Total Project Work</i>	20
<i>Task Attributes</i>	20
<i>Relationship Between Work Breakdown and Attributes</i>	21
Task Attributes	21
<i>Quantitative Task Attributes</i>	22
<i>Qualitative Task Attributes</i>	24
Work Breakdown	26
<i>Comprehensive Listing</i>	26
<i>Descriptive Title</i>	30
<i>Logical Grouping of Work Activities</i>	31
<i>Appropriate Level of Detail</i>	33
Estimated Task Costs and Task Durations	34
<i>Cost Estimates</i>	35
<i>Task Durations</i>	37
Exercises	50

CHAPTER 3 GANTT CHARTS **55**

Objective	55
Content of Bar Charts	55
<i>Content of Simple Bar Chart</i>	55
<i>Content of Minimum Bar Chart</i>	59
<i>Content of More Elaborate Bar Charts</i>	59
Use of Bar Chart as the Only Scheduling Tool	62
Use of the Bar Chart as A Format	62

Advantages and Disadvantage of the Bar Chart Method	68
Exercises	69

CHAPTER 4 LOGIC DIAGRAMS AND SCHEDULING **71**

Objectives	71
Essential Terms	71
Logical Relationships	74
<i>Types of Logical Relationships</i>	74
<i>Depicting the Logical Relationships</i>	75
<i>Activity On Arrow (AOA) Logic Diagrams</i>	76
<i>Activity On Node (AON) Logic Diagrams</i>	78
Precedence of Nodes and Arrows	80
<i>Precedent</i>	80
<i>Immediately Precedent</i>	81
Structured Logic Diagrams	81
Comparison of AOA and AON Techniques	82

CHAPTER 5 THE CRITICAL PATH METHOD (CPM) **87**

Objectives	87
Logic Diagrams and Scheduling	87
<i>Activity On Arrow (AOA) Diagrams</i>	87
<i>Logical Relationships</i>	88
Introduction to CPM	89
<i>CPM Logic Diagram</i>	89
<i>Attributes of Arrows and Nodes</i>	89
<i>Paths Through the Logic Diagram</i>	90
<i>Conventions</i>	90
<i>The Basic CPM Logical Relationship</i>	94
Logical Relationships as Applied to Scheduling	95
<i>Putting on Your Shoes</i>	95
<i>Real Projects</i>	97
Dummy Tasks	98
<i>Activity Splitters</i>	99
<i>Dummy Tasks as Logical Constraints</i>	99
<i>Unnecessary Constraints</i>	100
Contingencies	102

<i>Contingencies Are Exceptional Events</i>	103
<i>Why Worry About Contingencies?</i>	104
<i>Impact of Contingencies on Task and Project Duration</i>	104
<i>Allowing for Contingencies</i>	105
Strengths and Weaknesses of the Critical Path Method	105
Exercises	106

CHAPTER 6 CALCULATION OF CPM EVENT AND TASK TIMES **109**

Objective	109
Essential Terms	109
<i>Related to the Network Diagram</i>	109
<i>Related to the Time of Day</i>	111
<i>Related to the Type of Schedule</i>	111
<i>Related to Time</i>	113
Methodology	116
<i>Phases in Preparation of the CPM Schedule</i>	117
<i>Forward Pass for Early Event Times (EETs)</i>	118
<i>Backward Pass for Late Event Times (LETs)</i>	124
<i>Calculate Task Times</i>	127
<i>Calculate Float Times</i>	130
CPM Scheduling on Microcomputers	137
<i>Scheduling Programs Versus Integrated Construction Management Programs</i>	137
<i>Computer Memory Requirements</i>	137
<i>Computer Speed</i>	138
<i>Should You Buy a Package?</i>	138
Limitations of the Critical Path Method	139
<i>Simple Nature of CPM Logical Relationship</i>	139
<i>Reliability of Task Times</i>	139
Advantages of the Critical Path Method	139
Exercises	139

CHAPTER 7 THE PRECEDENCE METHOD (PM) **143**

Objectives	143
Introduction to the Precedence Method (PM)	143
<i>Comparison of CPM and PM Logic Diagrams</i>	144

<i>Logical Relationships</i>	145
Examples of PM Logical Relationships	149
<i>End-to-Start (ES) Relationships</i>	150
<i>Start-to-Start (SS) Relationships</i>	151
<i>End-to-End (EE) Relationships</i>	153
<i>Combined Use of SS and EE Relationships</i>	155
<i>Combined Use of ES and SE Relationships</i>	159
Exercises	161

CHAPTER 8 CALCULATION OF PRECEDENCE METHOD TASK TIMES AND FLOATS **163**

Objectives	163
Tasks and Relationships	163
Diagramming the Project	165
<i>Characteristics of Logic Diagrams</i>	166
<i>Drawing the Logic Diagram</i>	172
Methodology	180
<i>Phases of Schedule Preparation</i>	180
<i>The Forward Pass</i>	181
<i>Project Duration</i>	183
<i>The Backward Pass</i>	185
The Critical Path and Float Values	187
<i>Float Values</i>	187
<i>The Critical Path</i>	187
<i>A Computer Solution</i>	189
Advantages and Disadvantages of the Precedence Method	193
Exercises	194

CHAPTER 9 PROGRAM EVALUATION REVIEW TECHNIQUE (PERT) **199**

Objective	199
Introduction to PERT	199
PERT Task and Event Values	200
<i>Estimates of Task Duration</i>	201
<i>Effective Task Duration (t_e)</i>	202
<i>Task Standard Deviations (d)</i>	202
<i>Task Variance (v)</i>	203

<i>Event Variance (V)</i>	203
<i>Event Deviation (D)</i>	203
Normal Distribution	203
<i>Normal Distribution Concept</i>	203
<i>Frequency Distribution Analysis</i>	204
The PERT Network and Computation of Event Times	209
Impact of Noncritical Paths on Project Duration	212
PERT Task Times by Computer Scheduling	215
Advantages and Disadvantages of the PERT Method	219

CHAPTER 10 PROBABILISTIC SCHEDULING (MONTE CARLO METHOD) **221**

Objectives	221
Overview of the Monte Carlo Method	222
<i>Reasons for Using the Monte Carlo Technique</i>	222
<i>A Brief Description of the Monte Carlo Method</i>	223
Essential Terms	224
More on Estimating Task Durations and Relationship Lags	230
<i>Task Durations</i>	230
<i>Relationship Lags</i>	231
Computer Programs AOAPERT and AONPERT	231
Manual and Computer Solutions Using PERT and Monte Carlo Methods	233
<i>Manual Solutions</i>	233
<i>Computer Solutions</i>	236
Summary	252

CHAPTER 11 CALENDAR DAY SCHEDULING **255**

Objectives	255
Work Date Scheduling Versus Calendar Date Scheduling	255
Essential Terms	256
Methods for Preparing Calendar Day Schedules	260
<i>Method 1: Hybrid Schedule</i>	260
<i>Method 2: Bar Chart Method of Preparing Calendar Date Schedules</i>	264
<i>Method 3: An Exact Method, CPM Analysis Based on Calendar</i>	

Dates 266
 Summary 266

CHAPTER 12 UPDATING THE SCHEDULE 268

Objectives 268
 Reasons for Updating Construction Schedules 268
 Method 1: Updating the Schedule Using the Bar Chart 271
Task Status as of End of Eighth Week 272
Utility of the Updated Bar Chart 276
 Method 2: Updating the Schedule By Network Analysis 276
Essential Terms 276
Preparatory Steps: Status As of End of Workday Zero 279
First Update As of End of Workday 10 282
Second Update As of End of Workday 20 289
 Summary 293

CHAPTER 13 EXPEDITING THE PROJECT 295

Objective 295
 Essential Terms 295
 Crashing Tasks and Crashing the Project 298
 Estimates of Task Costs and Task Durations 302
 Expediting Projects at Least Cost by CPM 306
 Expediting Projects Diagrammed with AON Notation 319
 Summary 319

CHAPTER 14 RESOURCE-CONSTRAINED SCHEDULING AND RESOURCE LEVELING 321

Objective 321
 Constraints 321
 Resource-Constrained Scheduling Problem 323
 Resource Leveling 332
 Summary 337
 Exercise 338

CHAPTER 15 CASH FLOW ANALYSIS BASED ON CONSTRUCTION SCHEDULES 341

Objective	341
Essential Terms	341
Cash Flow As Applicable to An Individual	344
Cost Functions in the Construction Industry	347
Summary	354
Exercises	354

CHAPTER 16 APPLICATIONS OF COMPUTERS TO SCHEDULING 357

Objectives	357
Computer Systems	357
Software and Firmware	362
Evaluation of a System's Capability to Solve Scheduling Problems	363

APPENDIX A THE SCIENTIFIC COST ESTIMATING METHOD 365

Objective	365
Components of the Contractor's Bid	366
Estimating Task Costs and Task Durations	369
Example Problem: Balancing Resources	375

APPENDIX B COMPUTER PROGRAMS FOR SCHEDULING 379

Objective	379
Abbreviated Description of Programs	379
Hardware and Software Requirements	381
Program CPM (25,967 Bytes)	383
Program AON (30,589 Bytes)	388
Program REGIME (3905 Bytes)	391
CPM-MIN: A Minimal CPM Program (6057 Bytes)	391
AON-MIN: A Minimal Precedence Method Program (13,661 Bytes)	
AOA-PERT: A Program Evaluation Review Technique (15,641 Bytes)	392
AON-PERT: A PERT and Monte Carlo Program (22,393 Bytes)	392
JULIAN: A Julian Date Calendar Program	393

RAMTEST1 and RAMTEST2: Network Data File Generator	
Programs	393
Disclaimer	393
Availability of Programs on Floppy Disks	393

APPENDIX C TABLE OF RANDOM NUMBERS **457**

INDEX **459**