

LIST OF FIGURES

Figure 2.1	Sample of Labor Estimates Based on Time Standards	4
Figure 2.2	Comparing Alternatives Using Time Standards	6
Figure 2.3	Sample Comparison of Productivity Gains Before and After WMS and RF	7
Figure 2.4	Industry Throughput Standards	8
Figure 2.5	Summary of Time Standard Techniques	9
Figure 2.6	Sample Output of a Time Study on a Manual Batch Pick Operation	11
Figure 2.7	Sample Warehouse-Specific Activity Measurement Software	13
Figure 2.8	Steps for Establishing Warehouse Time Standards	15
Figure 2.9	Element-by-Element Breakdown of Pallet Putaway	16
Figure 2.10	Pallet Putaway Into Storage Area	18
Figure 2.11	Impact of Technology on Warehouse Time	20
Figure 2.12	Operation: Retrieving and Putting Away a Pallet Using a 24-Volt Narrow Aisle Reach Truck	21
Figure 2.13	Operation: Retrieving and Putting Away a Pallet Using a 36-Volt Narrow Aisle Reach Truck	22
Figure 2.14	Operation: Document Processing — Per Line Item Received	23
Figure 2.15	Operation: Document Processing — Checking Per Line Item Packed	24
Figure 2.16	Operation: Document Processing — Per Pallet Received or Shipped	24
Figure 2.17	Operation: Obtain and Operate Manual Pallet Jack	25
Figure 2.18	Operation: Turn Container (Slide)	25
Figure 2.19	Operation: Travel Times for Manual Pallet Jack	26

LIST OF FIGURES

Figure 2.20	Operation: Package Handling — Mixed Loads	27
Figure 2.21	Operation: Package Handling — Solid Loads	28
Figure 2.22	Operation: Non-Powered Equipment and Pedestrian Travel Times	29
Figure 2.23	Operation: Lift Truck, Travel Into and Out of Trailer	30
Figure 2.24	Operation: Lift Truck (6000 Pounds)	30
Figure 2.25	Operation: Lift Truck (4000 Pounds, Electric), Travel with Pallet	31
Figure 2.26	Operation: Lift Truck (6000 Pounds, Electric), Travel with Pallet	31
Figure 2.27	Operation: Operate Lift Truck 1 (Electric)	31
Figure 2.28	Operation: Operate Lift Truck 2 (Electric)	32
Figure 2.29	Operation: Pallet, Load Into and Out of Trailer With Lift Truck	32
Figure 2.30	Operation: Material, Pick Up, Transport, Drop with Lift Truck	32
Figure 2.31	Operation: Unit Load Handling Times	33
Figure 2.32	Operation: Loading and Unloading Times	34
Figure 2.33	Operation: Assemble Carton	34
Figure 2.34	Operation: Push Cart (Loaded)	35
Figure 2.35	Miscellaneous Material Handling Standards	35
Figure 3.1	Sample Cross Dock Facility	38
Figure 3.2	Sample Storage Facility	39
Figure 3.3	General Approach to Warehouse Design	40
Figure 3.4	Product Flow Patterns	41
Figure 3.5	Comparison of Traditional and Modern Trailers	42
Figure 3.6	Sample Truck Apron Diagram	43
Figure 3.7	Sample Dock Leveler	45
Figure 3.8	Sample Truck Leveler	45
Figure 3.9	Mechanized Receiving with Elevated Sortation System	46
Figure 3.10	Sample Dock Layout with Staging Areas Defined	46

Figure 3.11	Safety Lip Truck Barrier	48
Figure 3.12	Various Ways of Placing Compactor on Dock	49
Figure 3.13	Bin Drawers	50
Figure 3.14	Open Shelving	50
Figure 3.15	Mobile Shelving	50
Figure 3.16	Horizontal and Vertical Carousels	51
Figure 3.17	Cart, Hand Truck, and Platform Truck	52
Figure 3.18	Electric Sit-Down Counterbalanced Truck	53
Figure 3.19	Stand-Up Counterbalanced Truck	53
Figure 3.20	Walkie Stacker	54
Figure 3.21	Narrow Aisle Reach Truck	54
Figure 3.22	Operator-Up Turret (Swing Reach) Truck	55
Figure 3.23	Articulating Truck	55
Figure 3.24	Side-Loader Truck	56
Figure 3.25	Omni-Directional Truck	56
Figure 3.26	Relative Storage Height Capabilities of Lift Trucks	57
Figure 3.27	Material Handling Equipment and Appropriate Storage Module	57
Figure 3.28	Sample Inventory Profile and Corresponding Storage Modules	61
Figure 3.29	Sample Excess Inventory Analysis	62
Figure 3.30	Effects of Honeycombing	63
Figure 3.31	Calculating Effects of Honeycombing And Storage Utilization	64
Figure 3.32	Effects of Column Spacing	65
Figure 3.33	Optimal Column Spacing Example (Perpendicular to Aisles)	66
Figure 3.34	Optimal Column Spacing Example (Parallel to Aisles)	66
Figure 3.35	Trucks Versus Storage Modules	67
Figure 3.36	Comparison of Storage Densities	68
Figure 3.37	Pallet Storage Examples	69

LIST OF FIGURES

Figure 3.38	Space Per Pallet Comparison	69
Figure 3.39	Design Year Inventory Profile	70
Figure 3.40	Generation of Storage Concepts	72
Figure 3.41	Space Requirements	72
Figure 3.42	Handling Requirements	73
Figure 3.43	Pick-to-Light Modules	74
Figure 3.44	Picking from Pallet Flow Racks	74
Figure 3.45	Carousels with Pick-to-Light Technology	75
Figure 3.46	A-Frame — Automated Order Selection Device	76
Figure 3.47	Automated Full Case Order Selection System	76
Figure 3.48	Electric Pallet Truck	77
Figure 3.49	Orderpicker Truck	77
Figure 3.50	Single Order–Single Picker Diagram	79
Figure 3.51	Zone Pick Diagram	80
Figure 3.52	Batch Pick Diagram	80
Figure 3.53	Sample Full Case Movement Profile	84
Figure 3.54	Sample Full Case Popularity Profile	84
Figure 3.55	Various Picking Configurations	85
Figure 3.56	Order Picking Alternatives	86
Figure 3.57	Facings and Storage Capacity of Common Pick Modules	87
Figure 3.58	Piece-Pick, Pick-to-Tote Example With Case Flow Racks	87
Figure 4.1	Typical Building/Construction Costs	90
Figure 4.2	Location Factors	91
Figure 4.3	Material Handling Equipment Costs	93–95
Figure 4.4	Conveyor Systems Project Cost Breakdown	96
Figure 4.5	Storage Equipment Costs	97–100

LIST OF FIGURES

Figure 4.6	Sample Planning and Design Costs	101
Figure 4.7	Dock Equipment Costs	103
Figure 4.8	Other Special Costs	104–105
Figure 4.9	A Worksheet for Calculating Costs of Ownership	106
Figure 4.10	Average Hourly Wages of Warehousing Jobs by Geographic Region and by Business	107
Figure 4.11	Example of Annual Operating Expenses by Category for a Sample Warehouse	111
Figure 4.12	Interest Table to Determine the Capital Recovery Factor	115
Figure 4.13	Space and Handling Requirements for Case Study	117
Figure 4.14	Base Data	117
Figure 4.15	Investment Per Pallet Stored for Each Storage Concept	118
Figure 4.16	Generation of Final Alternatives	119
Figure 4.17	Economic Summary	120