Index

A
acceleration step 93, 94
active schedule 53, 57, 112, 138
active set 17, 30, 65, 130
activity 7
  - critical 15
  - fictitious 8
  - real 8
activity calendar 125, 153
activity list 78
activity-interval capacity test 26
activity-on-arc network 9
activity-on-node network 10
additional-cost function 113, 119
algorithm
  - augmenting path 153
  - best-fit search 104
  - branch-and-bound 72, 97, 120
  - capacity-scaling 86
  - column-generation 75, 80, 132
  - constructive 6, 107
  - ellipsoid 56, 85
  - feasible direction 87
  - flattest ascent 94, 95, 102
  - genetic 78
  - label-correcting 13, 71, 73, 126
  - label-setting 72
  - local search 115
  - multi-pass 79
  - parametric optimization 156
  - preflow push 43
  - priority-rule 77, 113, 119
    - bidirectional 102
    - recursive-search 99, 101, 102
    - relaxation-based 6, 65, 135, 163
    - schedule-repair 112
    - steepest descent 86, 87, 102, 156
    - stochastic dynamic programming 161
    - subgradient 76
    - tabu search 119
    - vertex-following 99
    - bidirectional 102
    - recursive-search 99, 101, 102
balance test 37, 81
batch 148, 150
batch mode 150
batch production 150
batch scheduling problem 152
batch size 150,151
batching problem 151
best-fit search algorithm 104
bill of materials explosion 143,147
binary-monotone objective function 57,92
BMR-feasible strict order 41,44
Bouligand-differentiable function 90
branch-and-bound algorithm 72,97,120
branching strategy 72
break 150
break calendar 6,123,125
C
C1-diffeomorphism 56,99
calendar
  activity 125,153
  break 6,123,125
  time lag 125
calendar constraint 126
calendar-feasible schedule 126
calendarization 124
capacitated master production scheduling 147
capacity
  interval 25,27
  resource 16
capacity-scaling algorithm 86
capital-rationed net present value problem 105
cash flow 58
cancelover time
  sequence-dependent 6,123,128
cancelover-feasible schedule 129
characteristic curve 86
cleaning time 150
column-generation algorithm 75,80,132
common part 29,146
comparable elements (in preorder) 39
complete preorder 39
conjugate functions 85
consistency test 23,24,36,73,97
  activity-interval capacity 26
  balance 37,81
  disjunctive activities 24,73,102
  - energy precedence 28
  - general interval capacity 27
  - interval capacity 25
  - profile 36,82
  - unit-interval capacity 25,26,73
  - calendar 126
  - cumulative-resource 30,113
  - disjunctive precedence 22,36,67,72
  - linear reverse-convex 22
  - mode assignment 133
  - nonrenewable-resource 133
  - precedence 8,10,22,36,83
  - renewable-resource 17,111,134
  - resource 2,66
  - temporal 1,8,134
constructive algorithm 6,107
continuation (of a function) 86
continuous cumulative resource 6,124,135
continuously differentiable function 86
convexifiable product structure 146
convex objective function 50,85,137,
162
convex-cost flow problem 85
convexifiable objective function 56,57,82
core loading profile 25,119
covering relation 40
CPM see Critical Path Method
CPM network 9
criterion see rule
critical activity 15
Critical Path Method 10
cross-pruning 98
cumulative resource 5,28,153
  - continuous 6,124,135
  - discrete 124
cumulative-resource constraint 30,113
cyclic product structure 150
D
deadline 8,75
decision set 110,119
degenerate point 89,92,116
delaying alternative 19,33
  - minimal 19,21,33,35
delaying mode
  - minimal 76,83
depth (of enumeration tree) 69
depth-first search 72, 97
derivative
    - directional 86
    - one-sided 87
descent direction 87
    - steepest feasible 87
directed cycle 13
directed path 13
directed walk 13
direction
    - descent 87
    - flattest feasible ascent 94
    - optimal 89, 96
    - steepest feasible descent 87
directional derivative 86
discount rate 59, 156
discrete time-resource tradeoff problem 132
disjunctive activities 24, 74
disjunctive activities test 24, 73, 102
disjunctive precedence constraint 22, 36, 67, 72
distance matrix 13-15, 41
dominance rule 77, 98, 102, 139
    - subset 98
dual flattest ascent approach 94
E
earliest schedule 9, 14
    - calendar-feasible 126, 127
early free float 16, 161
ellipsoid method 56, 85
energetic reasoning 24, 74
energy precedence test 28
entering arc 115
enumeration scheme 66, 83, 127
    - for convexifiable objective functions 84, 163
    - for multi-mode problems 135
    - for regular objective functions 68
equal-order set 45
equal-preorder set 52, 107
event 8
event-on-node network 10, 156
execution mode 3, 6, 123, 131, 153
experimental performance analysis 79, 81, 102, 120
extension (of assignment) 133
extension (of relation) 39
extremal node 91
extreme point
    - global 52
    - local 53
F
feasibility version (of optimization problem) 62
feasible assignment 134
feasible direction 87
feasible direction method 87
feasible relation 40, 43, 46, 48, 49, 66, 114, 162, 163
feasible schedule 17, 31, 66, 137
    - with respect to assignment 134
feasible set 19
    - maximal 19
feasible solution 135
feasible start time 111
feedback mechanism 149
Fibonacci heap 72, 93
fictitious activity 8
flattest ascent algorithm 95, 102
flattest ascent direction problem 95
flattest feasible ascent direction 94
float
    - early free 16, 161
    - late free 16, 161
    - total 15
flow network 43
forbidden set 7, 19, 33, 77
    - breaking up 22, 36
    - minimal 19, 33
forest 91
forward arc 109, 111, 116, 157
full assignment 133
function see also objective function
    - additional-cost 113, 119
    - Bouligand-differentiable 90
    - continuously differentiable 86
    - lower semicontinuous 9, 17, 55
    - neighborhood 115
    - net present value 157, 158, 160
    - positively homogeneous 87
    - step 17
    - subadditive 90
    - sublinear 87, 90
188  Index

- sum-separable 85, 86

G
general interval capacity test 27
general product structure 146
genetic algorithm 78
go-zinto graph 142
gross requirements 143, 147

H
head see release date
Helly property 21, 42
hierarchical planning 147

I
incomparable elements (in preorder) 39
inf-stationary point 87
initial inventory level 30
input coefficient 142
input proportion 151
interior-point method 56
internal rate of return 159
interval capacity 25, 27
interval capacity test 25
interval graph 130
interval order 40, 44, 129, 130
investment project 155

K
k-shortage set 32
- minimal 33
k-surplus set 32
- minimal 32

L
label-correcting algorithm 13, 71, 73, 120
label-setting algorithm 72
Lagrangian relaxation 80, 97, 149
late free float 16, 161
latest schedule 9
- calendar-feasible 127
leaving arc 115
length (of directed walk) 13
life cycle 1
line-search phase 88, 92, 97
linear objective function 57
linear product structure 146
linearizable objective function 56, 57
loading profile 17, 30, 74, 136
- core 25, 119
local extreme point 53
local minimizer 56, 57, 83
local search 115
locally concave objective function 60, 107
locally regular objective function 60, 107, 161
lot see also batch, 148
lot size 148
- transportation 145
lower bound 36, 74, 97, 98, 132, 138
lower semicontinuous function 9, 17, 55

M
make-to-order production 142
make-to-order production scheduling problem 143
makespan 150
manufacturing industries 147
master production schedule 147
material flows 124
materials requirements planning 142
maximal element (in preorder) 40
maximal feasible set 19
maximum (s, t)-cut 151, 163
maximum time lag 8
maximum-cut problem 114
maximum-flow problem 43
maximum-weight clique 130
maximum-weight stable set 43, 130
method see algorithm
Metra Potential Method 10, 11
min-cost flow problem 86
minimal delaying alternative 19, 21, 33, 35
minimal delaying mode 76, 83
minimal forbidden set 19, 33
- breaking up 22
minimal k-shortage set 33
minimal k-surplus set 32
minimal point 41, 45, 52, 53
minimum execution time 124
minimum (s, t)-flow 43, 50, 130, 163
minimum time lag 8
minimum-cut problem 76
minimum-flow problem 50, 114, 153
mode assignment constraint 133
mode assignment problem 3, 133
mode relaxation 133, 135
MPM see Metra Potential Method
MPM network 10
multi-level capacitated lot sizing problem 149
multi-level lot sizing 148
multi-mode project duration problem 132
multi-mode project network 134
multi-mode resource allocation problem 3, 124
multi-mode resource-constrained project scheduling problem 134
multi-pass heuristic 79

N
neighborhood 115
neighborhood function 115
neighborhood graph 115, 118
net present value 155
net present value function 157, 158, 160
net present value problem
- capital-rationed 105
- time constrained 99
- with cumulative resources see capital-rationed
- with renewable resources 102
net requirements 147
network
- activity-on-arc (CPM) 9
- activity-on-node 10
- event-on-node 10, 156
- flow 43
- MPM 10
- project 9
- relation 41, 110, 162
- schedule 44, 52, 54, 110, 111
- strongly connected 12
nondelay schedule 52, 102
nonregular objective function 55
nonrenewable resource 5, 28, 131
nonrenewable-resource constraint 133

O
objective function 3, 9
- antiregular 93
- binary-monotone 57, 92
- convex 56, 85, 137, 162
- convexifiable 56, 57, 82
- linear 57
- linearizable 56, 57
- locally concave 60, 107
- locally regular 60, 107, 161
- makespan 58
- net present value 59, 156
- nonregular 55
- preorder-decreasing 64, 120
- project duration 58
- quasiconcave 57
- regular 22, 55, 57, 66, 93, 161
- total adjustment cost 63
- total earliness-tardiness cost 59, 163
- total inventory holding cost 58
- total procurement cost 61, 64
- total squared utilization cost 62, 148
- total tardiness cost 58
- total weighted free float 59, 162
one-sided derivative 87
operation 143, 150
optimal direction 89, 96
optimal schedule 18, 31, 137
optimal solution 135
optimal-potential problem 85
order
- interval 40, 44
- strict 40
- weak 40, 52
output proportion 151
overlapping operations 144

P
parametric optimization 156
partial schedule 112
perishable product 149
polytope
- relation 40, 46, 57, 83, 162
- schedule 44, 52
positively homogeneous function 87
potential 12
precedence arc 104, 109, 116
precedence constraint 8, 10, 22, 36, 83
- disjunctive 22, 36, 67, 72
precedence graph 40, 43, 130
precedence relationship 7, 39
predecessor (in preorder) 39, 48, 114
preemptive one-machine problem 75
preemptive project scheduling problem 124
preflow push algorithm 43
preorder 39
- complete 39
- schedule-induced 108
preorder-decreasing objective function 64, 120
preprocessing 73
primal steepest descent approach 86
primary requirements 143, 147, 150
priority rule 78
priority-rule method 77, 113, 119
- bidirectional 102
problem
- assignment sequence 146
- batch scheduling 152
- batching 151
- convex-cost flow 85
- discrete time-resource tradeoff 132
- flattest ascent direction 95
- lot sizing
- multi-level capacitated 149
- single-level uncapacitated 149
- make-to-order production scheduling 143
- maximum-cut 114
- maximum-flow 43
- min-cost flow 86
- minimum-cut 76
- minimum-flow 50, 114, 153
- mode assignment 3, 133
- multi-mode project duration 132
- net present value
- capital-rationed 105
- time-constrained 99, 156
- with cumulative resources see capital-rationed
- with renewable resources 102
- optimal-potential 85
- preemptive one-machine 75
- preemptive project scheduling 124
- project duration 3
- with cumulative resources 81
- with renewable resources 76
- resource allocation 2, 120, 133
- multi-mode 3, 124
- resource investment 120
- resource levelling 4, 60, 61, 113, 118, 148
- resource-constrained project scheduling 3, 66, 152
- multi-mode 134
- stochastic 161
- with cumulative resources 31, 137
- with renewable resources 17
- sequencing 3, 40
- steepest descent 89
- time-constrained project scheduling 3, 9, 18, 41
- time-cost tradeoff 3
- total earliness-tardiness cost
- time-constrained 101
- with renewable resources 104
- total squared resource utilization cost 121
- total weighted free float 162
procedure see algorithm
process industries 149
process plan 143
processing unit 149
product structure 147
- convergent 146
- cyclic 150
- general 146
- linear 146
production
- batch 150
- make-to-order 142
- small-batch 147
production order 147
profile test 36, 82
progress payment 156
project 1, 7
project deadline 156
project duration 153
project duration problem 3
- multi mode 132
- with cumulative resources 81
- with renewable resources 76
project generator 79
project network 9
- multi-mode 134
project planning 2
project scheduling problem
- preemptive 124
Index

- resource-constrained 3, 66, 152
  - stochastic 161
  - with cumulative resources 31, 137
  - with renewable resources 17
  - with sequence-dependent changeover times 129
- time-constrained 3, 9, 18, 41
pseudo-stable schedule 53, 57

Quarantine time 8, 75
quasi-topological ordering 119
quasipactive schedule 54, 60, 69, 107, 111
quasiconcave objective function 57
quastable schedule 54, 60, 107, 109

Range 61
reactive approach 163
real activity 8
recognition version (of optimization problem) 62
recursive-search algorithm 99, 101, 102
recyclable resource 29
reflexive preorder
  - schedule-induced 51
regular objective function 22, 55, 57, 66, 93, 161
relation 5
  - binary 39
  - covering 40
  - feasible 40, 43, 46, 48, 49, 66, 114, 162, 163
  - time-feasible 40, 42, 46, 66
relation network 41, 110, 162
relation polytope 40, 46, 57, 83, 162
relaxation 69, 85
  - Lagrangean 80, 97, 149
  - mode 133
  - resource 18, 31, 65
  - temporal 18, 31
relaxation-based algorithm 6, 65, 135, 163
release date 8, 75, 77
renewable resource 3, 16, 153
renewable-resource constraint 17, 111, 134
requirement
  - resource 16
  - storage 30
requirements
  - gross 143, 147
  - net 147
  - primary 143, 147, 150
resource
  - cumulative 5, 28, 153
  - continuous 6, 124, 135
  - discrete 124
  - nonrenewable 5, 28, 131
  - recyclable 29
  - renewable 3, 16, 153
resource allocation 2, 17
resource allocation problem 2, 120, 133
  - multi-mode 3, 124
resource capacity 16
resource conflict 21, 35
resource constraint 2, 66
resource investment problem 120
resource levelling problem 4, 60, 61, 113, 118, 148
resource relaxation 18, 31, 65
resource requirement 16
resource-constrained project scheduling problem 3, 66, 152
  - multi-mode 134
  - with cumulative resources 31, 137
  - with renewable resources 17
  - with sequence-dependent changeover times 129
resource-feasible assignment 133
resource-feasible schedule 17, 21, 31, 137
  - with respect to assignment 134
robust plan 161
rule
  - dominance 77, 98, 102, 139
  - priority 78
Safety stock 30
scattered search 73
schedule 9
  - active 53, 112, 138
  - calendar-feasible 126
  - changeover-feasible 129
  - earliest 9, 14
calendar-feasible 126, 127
feasible 17, 31, 66, 137
with respect to assignment 134
latest 9
calendar-feasible 127
nondelay 52, 102
optimal 18, 31, 137
partial 112
pseudostable 53, 57
quasiactive 54, 60, 69, 107, 111
quasistable 54, 60, 107, 109
resource-feasible 17, 21, 31, 137
with respect to assignment 134
semiactive 53
stable 53, 57, 102, 112
time-feasible 9
with respect to assignment 134
time-optimal 9
schedule network 44, 52, 54, 110, 111
schedule polytope 44, 52
schedule sets 54, 55
schedule-assignment pair 135
schedule-generation scheme 109
for locally concave objective functions 110
serial 78, 107
schedule-induced preorder 108
reflexive 51
schedule-induced strict order 44, 129
schedule-repair method 112
search space 65, 67, 83
search strategy 72
depth-first 72, 97
self-concordant barrier 56
semiactive schedule 53
sequence-dependent changeover time 6, 123, 128, 153
sequencing problem 3, 40
serial schedule-generation scheme 78, 107
set
active 17, 30, 65, 130
decision 110, 119
equal-order 45
equal-preorder 52, 107
feasible 19
forbidden 19, 33, 77
k-shortage 32
k-surplus 32
setup time see also changeover time, 143
shaving 25
shelf life time 149
shift
against arc 116
along arc 116
single-level uncapacitated lot sizing problem 149
small-batch production 147
solution 115
feasible 135
optimal 135
spanning forest 89, 95
spanning outtree 54, 111, 117
spanning tree 54, 110, 115
stable schedule 53, 57, 102, 112
stable set
maximum-weight 43, 130
start time 8
feasible 111
steepest descent algorithm 87, 88, 102, 156
steepest descent problem 89
steepest feasible descent direction 87
step function 17
stepsize 88, 93, 97, 115
optimal 92
stochastic dynamic programming 161
stochastic project scheduling problem 161
storage capacity 30
storage facility 149
storage requirement 30
stream of payments 155
strict order 40
BMR-feasible 41, 44
schedule-induced 44, 129
strong component 78
strongly connected network 12
subadditive function 90
subgradient algorithm 76
sublinear function 87, 90
subset-dominance rule 98
sum-separable function 85, 86
support-point representation 112
supremum norm 88, 95
symmetric triple 24
Index

T

tabu search 119
tail see quarantine time
task 149
temporal arc 109, 116
temporal constraint 1, 8, 134, 137
temporal plus capacity planning 149
temporal relaxation 18, 31
temporal scheduling 11
tension 12
time lag
  - maximum 8
  - minimum 8
time lag calendar 125
time window 9
time-constrained net present value problem 99, 156
time-constrained project scheduling problem 3, 9, 18, 41
time-constrained total earliness-tardiness cost problem 101
time-cost tradeoff problem 3
time-feasible assignment 134
time-feasible relation 40, 42, 43, 66
time-feasible schedule 9
  - with respect to assignment 134
time-optimal schedule 9
time-resource tradeoff problem 132
total earliness-tardiness cost problem
  - time-constrained 101
  - with renewable resources 104
total float 15

U

uniformly directed cut 131
unit-interval capacity test 25, 26, 73
unscheduling step 78, 112

V

validity domain 157, 159
variance 62
vertex 45, 52, 53
vertex-following algorithm 99

W

weak order 40, 52
weak triangle inequality 128
weakly optimally connected 115
workload 25, 74

Z

zigzagging phenomenon 92

total squared resource utilization cost problem 121
total variation 63
total weighted free float problem 162
total working time 125
totally unimodular matrix 49, 114
transfer time 145
transitive directed graph 43, 130
transitive hull (of relation) 39
transitive reduction (of acyclic directed graph) 131
transportation lot size 145
triangle inequality 14
  - weak 128