Index

absolute deviation, 15, 29
absolute deviation robust schedule, 27
Absolute Deviation Robust Scheduling Problem, 13, 17, 27
absolute robust single-machine sequence, 16
activity duration, 145, 151
activity network, 143, 146, 154
activity-on-arc network, 143, 149–151
activity-on-node network, 144, 148
agile, 8
almost surely smallest sequence, 8
analytical expression, 94
approximation algorithm, 149
approximation procedure, 147
approximations of expectation and variance, 114, 143
arbitrary probability distribution, 43
assembly system, 68
assignment problem structure, 15
assignment problem with a single side constraint, 14
asymptotic property, 96
Bernoulli distribution, 59
beta distribution, 146, 151
bi-criteria assignment problem, 34, 35
bicriteria parallel-machine scheduling, 39
bicriteria scheduling problem, 39
bicriteria single machine scheduling, 36
binary tree structure, 147
bounding process, 29
branch-and-bound, 24, 26, 28, 31
branch-and-bound algorithm, 16
branch-and-bound solution procedure, 15

Clark's equations, 58, 62, 65, 67, 68, 74, 77, 86, 88, 89, 111, 154
Clark's formulae, 136, 146, 150
Clark's method, 94
closed-form expression, 7, 11, 65, 93, 153
close-to-accurate approximation, 53
combined nondominated schedule, 38
correlation, 68, 77, 78, 80, 135, 146, 154
correlation coefficient, 78, 79, 88
correlation structure, 75, 154
covariance, 53, 118, 131, 139, 150
covariance matrix, 96, 130, 150
covariance of the mixture model, 137
covariance terms, 118, 120, 124
cumulative distribution function of a standard normal distribution, 37
customer satisfaction, 2
cycle-time, 6, 7
cycling, 26
decomposition heuristic, 26
degenerate multivariate normal, 132
deterministic, 3, 8, 130
deterministic activity network, 145
deterministic optimal-path problem, 146

candidate schedule, 154
central limit theorem, 23, 146
Index

deterministic problem, 145
deterministic scheduling, 2
directed arc, 149
discounted weighted completion time, 65
discrete processing time scenario, 13, 14, 24, 27, 28, 30
discretization scheme, 146
dissimilarity measure, 142
distance measure, 139
diverse scheduling environments, 153
dominance property, 24, 26
dominance relation, 35
due date, 44, 153
due-date-based, 43, 52, 65, 116, 154
dynamic programming approach, 35
dynamic programming-based, 34
earliest start time, 144
earliness, 4
efficient sequence, 32, 36
EM iteration, 101, 104
endpoint product, 17
endpoint sum, 17
endpoint sum heuristic, 17
equivalent problem, 16
E-step, 99, 101, 107, 108
exact methodology, 31
expectation, 2–4, 7, 9–11, 32, 44, 52, 127, 150, 155
expectation and variance, 54, 59, 62, 65, 72, 80, 82, 88–90, 92–94, 111, 113, 114, 116, 118, 120–123, 126, 131
expectation of a performance measure, 103, 109, 137, 141, 153, 154
expectation and variance of job tardiness, 111–113
expectation and variance of makespan, 67, 74, 86, 133–136, 150
expectation and variance of the maximum for a multivariate normal distribution, 146
expectation and variance of the total weighted number of tardy jobs, 125
expectation of the mixture model, 104, 137
Expectation of the Total Weighted Completion Time, 46
expectation vector, 130, 150
Expectation(E)-step, 97
Expectation-Maximization algorithm, 97
expectation-variance, 11, 66
expectation-variance analysis, 92
expectation-variance considerations in stochastic scheduling, 155
expectation-variance efficient, 34, 45, 155
expectation-variance efficient sequence, 11, 33–35, 42, 52, 60
expected completion time, 2
expected total weighted flowtime, 5
expected total weighted tardiness, 5
expected value, 3, 9, 37
expected value of makespan, 145
expected value of the processing time, 43
expected weighted discounted completion time, 50
exponential, 49
exponential processing time distribution, 7
exponentially distributed job processing time, 50, 65
extreme expectation-variance efficient, 36
extreme point scenario, 15
feasible candidate schedule, 40
financial investment, 4
finite buffer capacities, 69
finite mixture model, 11, 94
first come first served, 66
first moment, 80, 88, 89
first two moments, 141
flow shop, 10, 11, 26, 111, 134, 154
Flow-shop Models, 66
flow shop with unlimited buffer capacity, 72
flow shop with unlimited intermediate storage, 154
flow time, 6, 7
flow time variance, 24
fluctuation smoothing policies, 6
four-step procedure, 69
Gantt chart, 75, 92
Gaussian mixture reduction, 139
general parallel-machine case, 41
general processing time distribution, 11, 94, 111
generation of nondominated schedules, 153
given schedule, 135, 137
good sequence, 45
gradient-descent method, 139
greedy algorithm, 139
heuristic approach, 17, 24, 26, 29
heuristic method, 40
heuristic methodology, 31
heuristic procedure, 8, 37
hierarchical structure, 79
holding cost per unit time, 46
identical machines in parallel, 9, 154
incumbent, 30
independent random variables, 55
individual evaluation, 39
Index

infinite buffer capacities, 69
initial operations, 75, 78
in-process inventory, 44
interactive stochastic multiobjective scheduling system, 37
iterative procedure, 70
iterative updating scheme, 102

job completion time, 126
job processing time, 32, 90, 153
job shop, 9–11, 73, 75, 86, 111, 128, 131, 136, 149, 154
job-shop makespan, 131
job shop with unlimited buffer and without circulation, 82
job shop with unlimited intermediate storage, 74, 84, 154
Johnson’s algorithm, 26, 28, 29
Johnson’s order, 29, 30
Johnson’s sequence, 30

known distribution, 103

lateness, 44
latest finish times, 145
latest nodes, 149, 150
latest operations, 152, 149
law of total expectation, 130
law of total variance, 130
lean manufacturing, 8
likelihood value, 103
linear assignment problem, 34, 35, 36
linear correlation, 54
log likelihood, 99, 100, 104
log likelihood function, 101
log likelihood value, 97, 101, 102
lower bound, 24, 25, 28

machine configuration, 94
makespan, 2, 10, 26, 28, 29, 66, 67, 71, 72, 74, 80, 87, 90, 130, 135, 145, 146, 150, 151, 154
Markov chain, 7
Markov decision model, 5
Markov process, 7
maximization(M)-step, 97
maximum function, 68
maximum likelihood estimator, 97
maximum likelihood method, 97
maximum operator, 53, 67, 74, 154
mean, 6, 32, 37, 53, 68, 75, 78, 139
mean and variance of completion time, 70, 79, 80, 84
mean and variance of makespan, 84
mean lateness, 10, 43, 61
media planning, 4
method of moments, 97, 103
methodology, 153
mixing proportions, 95, 104
mixture, 141
mixture components, 118, 137
mixture distribution, 135
mixture model, 95, 104, 109, 112–114, 116, 124, 126, 128, 134–136, 151, 152, 154
mixture normal distribution, 130
mixture of normal components, 117
mixture proportions, 102
mixture reduction, 137
mixture reduction algorithm, 143

m-machine flow shop, 5
Modeling Uncertainty in Scheduling, 2
moment-generating function, 48–50
moments of performance measures of a schedule, 109
Monte Carlo simulation, 136, 146
M-step, 100, 101, 108

multi-criteria, 6
multicriteria scheduling problem, 33
multidimensional normal components, 128
multimachine environment, 66, 154
multimachine scheduling, 9
multiobjective, 6
multiobjective Multicriteria Stochastic Scheduling, 5
multiobjective scheduling problem, 33
multiple criteria, 32
multiple machine, 1
multiple objective, 34
multivariate case, 96
multivariate distribution, 149
multivariate normal, 130, 146
multivariate normal distribution, 67, 74, 80

no preemption, 10, 34, 87, 90, 93
no recirculation, 74
nondecreasing order, 24
nondominated schedule, 11, 33, 36–41, 154
nondominated set, 33
nonincreasing order, 24
nonlinear optimization, 139
nonlinear optimization problem, 141
nonlinear programming, 6
nonparametric, 103
normal, 49
normal approximation, 122, 124
normal components, 101, 103, 118, 124, 135, 143
normal density function, 107, 141
normal distribution, 3, 23, 37, 53, 94, 109, 114, 117, 118, 121, 126, 133–136, 143, 146, 150–152
normal mixture, 102, 112, 126, 128
normal mixture model, 121
normal processing time distribution, 116
normally distributed, 62, 88, 146
normally distributed job processing time, 51, 65, 93
normally distributed random variable, 111, 154
notation, 43
NP-hard, 27
number of components in a mixture, 103
numerical integration, 58, 60
optimization, 139
optimization process, 141
optimize, 2
original distribution, 139
original mixture, 142
overall evaluation, 39
overall expectation and variance of makespan, 130
pairwise correlations, 69, 75
pairwise interchange, 30
parallel machine, 11, 41, 87, 90, 92, 93, 154
parallel-machine model, 10
parallel-machine problem, 111, 134
parallel-machine scheduling problem, 39
parallel machine with preemptions, 92, 136
parallel machines without preemption, 135
parallel M-machine scheduling problem, 40
parameters of the normal mixture, 102
pareto-optimal, 33
pareto-optimal solution, 5, 6
partial schedule, 28, 29, 129
partial sequence, 24, 34
performance criterion, 16
performance measure, 1, 2, 11, 32, 65, 94, 111, 116, 129
permutation flow shop, 9, 67
permutation sequence, 26
PERT, 143, 144, 146
posterior probability, 98, 102, 107
preemption, 10, 87, 90, 92, 154
preferred schedule, 39
preferred schedule selection, 38, 41
primary criterion, 5
probability density function, 49, 55, 94, 108, 117, 126, 142
processing time, 43, 128
processing time distribution, 94
processing time uncertainty, 12, 25
processing time variability, 153
processing time variance, 25, 26
processing time variance in Scheduling, 8
production environment, 153
production lines, 7
progression of the EM algorithm, 103
project evaluation and review technique, 143
project network, 143
pseudo activity, 148
pseudodeterministic sequence, 8
pull-based, 6
random components, 111
random matrix, 32
random processing time, 2, 7, 34
random variable, 2, 43, 48, 49, 59, 90, 94, 146, 149, 153
randomness, 1, 32
reasonably optimal sequence, 45
recirculation, 73, 84, 86
reduced distribution, 139
reduced mixture, 142
relative Deviation Robust Scheduling Problem, 14
reproductive property, 88
reproductive property of normal random variables, 53, 54
resource-allocation, 25
robust schedule, 15, 27, 30, 153
robust scheduling, 12, 13, 26, 153
robust scheduling model formulation, 153
robust scheduling problem, 16
schedule, 11, 32, 116, 154, 155
scheduling, 1, 3–6, 8–10, 31
scheduling theory, 8
second moment, 54, 81, 88, 89
secondary criterion, 5
semicontinuous distribution, 113
semiconductor manufacturing, 6, 73
service level, 2
shortest expected processing time, 3, 45
shortest processing time, 13
shortest processing time variance, 45
simulation, 8
simulation results, 152
single machine, 1, 2, 9, 11, 31, 39, 41, 66, 87, 154
single-machine environment, 111, 116
single-machine model, 10, 43
single-machine problem, 116, 124
single-machine robust scheduling problem, 16
single-machine scheduling, 5
single-machine scheduling problem, 23
Index

single-machine system, 13, 22
software, 155
software package, 11
solution methodology, 12
stability of the production system, 155
stable schedule, 3
standard normal distribution, 37
starting values, 103
statistical distribution, 2
stepwise interactive algorithm, 38
stochastic, 5, 6, 8, 146
stochastic activity network, 143, 145
stochastic bicriteria scheduling, 41
stochastic multiobjective scheduling, 32
stochastic multiobjective scheduling problem, 33, 37
stochastic scheduling, 2, 10, 42
stochastically optimal sequence, 32
stochastically smallest sequence, 8
stochasticity, 145
stopping criteria, 103
surrogate bounding approach, 16
surrogate relaxation approach, 16
tardiness, 2, 4, 6, 44, 111
tardiness random variable, 53
tardiness value, 113
tardiness variable, 113
tardiness-based, 10, 154
telecommunication networks, 4
throughput, 6
throughput rate, 7
throughput time variance, 8
total completion time, 3, 10, 44, 65, 90, 92, 93
total discounted weighted completion time, 65
total expectation, 126
total expected value, 35
total flow time, 23, 34, 37
total number of tardy jobs, 10, 43, 58, 123
total tardiness, 10, 43, 52, 117, 118
total variation, 126
total weighted completion time, 10, 46, 65
total weighted discounted completion time, 10, 47
total weighted number of tardy jobs, 10, 43, 60, 124
total weighted tardiness, 10, 43, 58, 122

two-dimensional normal components, 128
two-dimensional normal distribution, 128
two-machine flow shop, 26–28, 31

uncertainty, 2, 10, 12
uncertainty in manufacturing, 1
uncertainty in processing times, 155
uniform distribution, 108, 112, 121
uniform probability density function, 109
unit penalty, 44
unit penalty function, 58, 114
unit penalty measure, 111
univariate distribution, 101
unlimited intermediate storage, 9, 67
upper bound, 24, 101
utility function, 32

variability, 1, 10, 153
variable processing times, 9
variance, 2–4, 6, 7, 9–11, 32, 37, 44, 52, 53, 68, 75, 78, 127, 131, 150, 155
variance of the mixture model, 105
variance of the processing time, 44
variance of the Performance Measure: Other Production Systems, 6
variance of the Total Weighted Completion Time, 46
variance reduction, 25

weight, 44, 46, 95
weighted completion time, 46
weighted discounted completion time, 51, 52
weights, 139
worst-case absolute deviation, 15
worst-case absolute deviation scenario, 15, 28
worst-case deviation, 28, 30
worst-case percentage deviation, 14
worst-case scenario, 28

XVA-Sched, 155

β-heuristic, 26
β-robust schedule, 23
β-robust scheduling, 22
β-Robust Scheduling Problem with Variance Reduction, 25