

Subject Index

- Analysis of Means (ANOM), 20–22, 42–47,
64, 68–69, 121, 135, 152, 405
assumptions, 555
for attributes data, 47
nonparametric, 47
with unequal variances, 45
- Analysis of Variance (ANOVA), 20–22, 35,
58, 62–64, 75, 81, 83, 116, 117, 123,
134, 152
identity, 40
Kruskal–Wallis, 46
- Basic concepts
blocking, 13
choice of factor levels, 14, 15, 17
experimental design objectives, 3
experimental units, 12
experimentation, 13, 162
by students, 162
steps, 13
hypothesis testing, 9
power, 38
randomization, 6, 7, 13, 223
complete, 31
restricted, 148
replication, 8, 123, 551
built in, 122
sample size determination, 9–11
selecting factors, 14
sequential experimentation, 3, 4
example of, 222–225
training for designing experiments,
544–545
use of catapult, 545
treatments, 12
unbalanced data, 40
- Bayes plot, 138
- Box–Cox transformation, 232
- Classification and regression trees (CART),
107
- Consolidated Standards of Reporting Trials
(CONSORT), 430
- Designs
Addelman, 86
analytic studies, 500
assessing the capability of a system,
528
calibration, 525–526
constrained least squares, 525
method of Lagrangian multipliers, 525
catalog of, 284
categorical response variables, 524
completely randomized design
assumptions, 32–33
checking, 34
degrees of freedom, 41

- Designs (*cont.*)
- efficiency relative to RCB design, 61
 - unequal variances, 41–42
 - computer experiments, 523
 - space-filling designs, 523–524
 - cost-minimizing, 522
 - Cotter, 487–488
 - factor correlations, 488
 - cross-classified (factorial), 292
 - crossover (changeover), 429
 - advantages, 430
 - applications, 429–430
 - computer analysis, 437
 - designs for carryover effects, 432–435
 - Williams squares, 433–434
 - example, 435–436
 - disadvantages, 430, 431
 - examples, 431
 - optimal, 431, 432
 - efficiency, 190
 - df-efficiency, 222
 - D-efficiency, 320, 330, 486, 487, 506–507
 - G-efficiency, 283, 330
 - equileverage, 501–503
 - factorial, 101
 - 2^2 , 101–102
 - example, 103–106
 - 2^3 , 119–120
 - examples, 120–122
 - 2^5 , 136
 - 2^k , 142
 - blocking, 141
 - example, 142–144
 - 3^2 , 248
 - decomposing the A*B interaction, 251
 - example, 252
 - 3^k , 248–257
 - inference, 252
 - interaction components, 250, 277, 288
 - linear effect, 253
 - quadratic effect, 253
 - bad data, 127–130
 - example, 131–134
 - blocking, 194
 - missing data, 138–140
 - mixed factorials, 263–266
 - constructing, 265
 - examples, 264, 266–273
 - need for, 263–264
 - Graeco-Latin square, 74, 80–84, 91
 - application, 82
 - degrees of freedom limitations, 81–82
 - hyper, 90–91
 - model, 80
 - power, 82
 - sets of, 82, 84
 - use of ANOM, 83
 - incomplete block designs, 65–71, 90
 - α -designs, 70–71, 90
 - balanced (BIB), 65–69, 84, 85, 526
 - analysis, 66–68
 - recovery of interblock information, 68
 - use of ANOM, 68–69
 - lattice, 70, 79
 - nonparametric analysis, 70
 - partially balanced, 69–70
 - John's 3/4 designs, 216–219
 - Latin square, 70–79, 84–85, 228, 562
 - assumptions, 72–74
 - efficiency, 77
 - example, 74–76
 - missing values, 86
 - example, 88
 - model, 74
 - standard form, 71, 72
 - use of ANOM, 76, 79
 - using multiple Latin squares, 77–79
 - microarray experiments, 529–530
 - mixture, 522–523
 - ANOM, 523
 - optimal, 523
 - model-robust, 528–529
 - multiple responses, 452–453
 - nested (hierarchical), 291
 - ANOM, 302
 - applications, 292–293
 - estimating variance components, 300–301
 - examples, 294–298
 - factor, 292
 - model, 292
 - factorial, 291
 - software shortcomings, 295–296
 - a workaround, 295–296

SUBJECT INDEX

589

- staggered, 298–300
 - with factorial structure, 300
- nonlinear models, 528
- non-normal responses, 529
- nonorthogonal, 212
 - inadvertent, 225
- nonregular, 170
 - defined, 170
- one-factor-at-a-time (OFAT) designs, 3, 115–116, 483–487
 - advantages, 486, 487
 - nonorthogonality, 486, 487
 - OFAT designs versus OFAT experimentation, 484
 - statistical process control checks, 487
 - strict, 485, 486
- optimal, 69, 503–507
 - applications, 507
 - criticisms, 504, 505
 - D-optimal, 279, 281, 282, 330, 364, 504, 507, 508, 512, 513, 532
 - Bayesian, 504–505
 - CONVERT algorithm, 505
 - E-optimal, 505
 - G-optimal, 505
 - GH-optimal, 511
 - incorporating costs, 522
 - I-optimal, 364
 - L-optimal, 505
 - model-robust, 504
 - Q-optimal, 511
- orthogonal arrays, 102, 138, 170, 229, 282, 321, 499
 - combined, 314, 316, 318
 - compound, 318, 319
 - inner, 314, 318, 321, 326
 - mixed levels, 275–277, 321
 - outer, 314, 318, 321, 326
 - product, 314–316, 318
- orthogonal main effect plans, 278, 489
- Plackett–Burman, 212, 215, 230, 231, 336, 378–379, 381, 383, 405, 489, 532
 - applications, 494–498, 542
 - foldover, 494
 - projective properties, 493, 494
- projective properties, 170
- randomized complete block (RCB) design, 56–64, 77, 195, 344
 - assumption, 57–58
- efficiency, 61
- missing values, 86–87
- number of blocks to use, 59
- use of ANOM, 64
- repeated measures, 425
 - advantages, 425
 - carryover effects, 427
 - crossover designs, 429
 - example, 428
 - how many?, 437
 - missing data and imputation, 438
- response surface, 360
 - applications of, 361
 - blocking, 394–397
 - Box–Behnken, 386–389, 477, 478, 502
 - blocking, 396
 - rotatability, 387
 - central composite (CCD), 361, 363, 365, 368, 369, 373–377, 385, 389, 395, 397, 405, 495, 502
 - blocking, 394–395
 - centerpoints, 373–376
 - example, 383–384
 - face centered cube, 377, 404
 - inscribed (CCI), 377, 388
 - uniform precision design, 375
 - comparison, 397
 - desirable properties, 360–361
 - orthogonality, 375
 - rotatability, 375–377
 - Doehlert (uniform shell) designs, 393
 - applications, 393
 - Draper–Lin (small composite) designs, 377–383
 - blocking, 396, 397
 - eligible projected, 363
 - for computer simulations, 404
 - Hoke, 394, 397
 - hybrid, 390
 - 311A, 391
 - Koshal, 393
 - noncentral composite, 405
 - number of designs to use, 362–364
 - optimal, 405
 - row-column, 406
 - small factor changes, 364
 - split factorial, 405
- restricted regions of operability, 508–514
 - examples, 508–514

- Designs (*cont.*)
- robust, 311
 - rotation, 488
 - saturated, 105, 138, 489
 - screening, 15, 360, 489–500
 - p*-efficient, 500
 - space-filling, 369, 385, 386, 514–521
 - Latin hypercube, 369, 519–521
 - example, 520–521
 - properties, 384–386
 - sphere-packing, 369, 385, 518–519
 - uniform, 364, 366, 368, 369, 389, 507, 514–518
 - applications, 386
 - definition, 515
 - split-lot, 345–346, 349
 - use of fractional factorials, 345–346
 - split-plot, 330–331, 349, 351, 560
 - blocking, 342–343
 - example, 333
 - analysis, 333–335
 - versus incorrect complete randomization analysis, 335
 - in industry, 336
 - example, 336–338, 355
 - mirror image pairs design, 336
 - Plackett–Burman designs, 343
 - subplot, 332, 349
 - error, 333
 - independent of whole plot error, 339
 - whole plot, 331–332, 338, 349
 - error, 332
 - with fractional factorials, 340–342
 - example, 341
 - with hard-to-change factors, 343
 - examples, 343–345
 - split-split-plot, 345
 - split-unit, 330–331
 - strip-plot (strip-block), 346–349
 - applications, 347–349
 - example, 346–347
 - use of fractional factorials, 346–348
 - supersaturated, 489, 498–500, 513, 563
 - nonorthogonality, 499
 - Taguchi, 312–315, 320–322, 544
 - equivalent to suboptimal fractional factorials, 313
 - trend-free, 521–522
 - unreplicated, 114, 116
 - weighing, 524–528
 - with noise factors, 316–318
 - Youden design, 84–86
 - lists of, 86
 - model, 85
 - replicated, 86
- Dual response problem, 406
- Effects
- conditional main, 107, 109, 114, 115, 121, 133, 134, 147, 179, 208, 209, 255–257, 317, 318, 372, 380, 381, 388, 389–390, 407, 467, 485, 492
 - derivation of, 152
 - example, 108, 113
 - necessary sample sizes for, 113
 - two-split, 181
 - confounded, 5, 12
 - dispersion, 150, 312
 - detecting, 150, 314
 - estimates, 114
 - precision of, 153
 - relationship with regression coefficients, 153, 177
 - interaction, 102, 106, 134
 - control \times noise, 315, 319
 - generalized, 318
 - noise \times noise, 316
 - transformations, 114
 - Tukey test for, 117–118
 - location, 312
 - main, 102
 - partial confounding, 5
 - simple, 107
- Evolutionary Operation (EVOP), 363–364, 531
- Box–EVOP, 531
 - dealing with interactions, 531
 - simplex, 364
- Expected mean squares, 144–146, 273
- for replicated 2^2 design, 153–155
 - in general, 155–157
 - simple method of determining, 146
- Factors
- control, 311, 316, 318, 321
 - fixed, 32, 101, 146

SUBJECT INDEX

591

- hard to change, 148–150, 212, 267, 332, 335, 344, 484, 487, 507, 522
 - software, 150
 - noise, 311, 312, 316, 318, 321
 - not reset, 150
 - qualitative, 6, 101
 - quantitative, 6, 101
 - random, 32, 146
 - hypothesis tests, 146–147
 - False discovery rate (FDR), 137
 - Fractional factorials, 169
 - 3/4 fractions, 216–219
 - 2^{k-p} , 176, 186
 - projective properties, 219–220
 - 2^{k-1} , 170–181
 - 2^{k-2} , 181–187
 - example, 182–184
 - 2^{3-1} , 171, 176, 178
 - 2^{4-1} , 175, 180
 - 2^{5-2} , 191
 - 2^{6-2} , 202
 - 3^{k-p} , 257–262, 362
 - constructing, 260–262
 - linear and quadratic effects, 259
 - minimum aberration, 277
 - minimum confounded effects, 277
 - projective properties, 259
 - 3^{k-1} , 262–263
 - alias structure, 262
 - 3^{3-1} , 262–263
 - 4 or more levels
 - method of replacement, 278
 - 4^{3-1} , 279
 - 16–point designs, 187
 - aliases and alias structure, 174, 177–179, 283
 - partial aliasing/partial confounding, 174
 - alternatives to, 229
 - bad data, 230
 - blocking, 195
 - examples, 196, 199
 - size two blocks, 200–201
 - confounded effects, 174
 - defining relation, 171
 - retrieving lost relation, 190–192
 - df-efficiency, 222
 - foldover, 178, 200–203
 - of a 2^{k-1} design, 201
 - mirror image, 200, 201
 - semi-foldover, 203–216, 233
 - of a 2^{k-2} design, 204
 - with software, 215
 - shortcomings, 203
 - for natural subsets of factors, 226–228
 - irregular fraction, 216, 220, 221
 - minimum aberration, 192–194
 - missing data, 230
 - mixed level, 274–275
 - linear effects, 276
 - quadratic effects, 276
 - number of clear effects criterion, 192–194
 - one fraction better than another?, 179–181
 - post-fractionation, 226, 227, 348–349
 - pre-fractionation, 226
 - projective properties, 170
 - relationship with Latin squares, 228–229
 - replicated, 223
 - resolution, 169, 187, 212, 233
 - defined, 170
 - small fractions, 220
- Gage R&R (reproducibility and repeatability) study, 295
- Gantt charts, 13
- Generalized F -test, 42, 46
- Hadamard matrix, 488
- Journal of Statistics Education*, 544
- Lenth's sample size determination applet, 11, 39, 59, 77
- Lenth's PSE method, 124, 126–129, 131, 136–139, 173, 188, 233, 252, 319, 338, 470, 485, 489, 496, 560
- Leverage values, 385, 501
 - saturated design, 501
- Lurking variable, 6
- Measurement capability studies, 523
- Missing data, 22, 39–40, 48, 230
- Modeling variability, 316
- Models
 - generalized linear, 529
 - hierarchical, 147, 390
 - mixed, 58
 - nonhierarchical, 147, 378, 390, 407
 - unrestricted, 156

- Modular arithmetic, 251, 279
 Multiple comparisons, 36, 37
 Bonferroni intervals, 37, 38
 Scheffé's procedure, 38, 59, 60
 Multiple readings, 8, 117, 123
 Multiple response optimization, 447
 desirability function, 449
 composite desirability, 450, 457
 example, 450
 exponential, 464
 importance constant, 451, 460, 461, 468
 maximization, 450, 457
 minimization, 450
 target value, 451
 weight constant, 451, 460, 461
 desirability graph, 456
 dual response optimization, 452
 examples, 453–463
 frequent assumptions, 447
 global optimum, 448
 Hooke–Jeeves method, 450, 463, 464
 local optima, 448, 450
 overlaid contour plots, 447–449
 pitfalls, 447, 455
 variations, 463–464
 genetic algorithm approach, 464
 generalized reduced gradient algorithm, 463–464
 mean squared error method, 464
 piecewise desirability function, 463
 Multi-vari plot, 530–531

NIST/SEMATECH e-Handbook of Statistical Methods, 18, 86, 111, 188, 347, 360, 525, 545
 Normal probability plot methods, 136, 187, 188, 194, 560

 Optimum operating conditions, 225, 360, 404
 methods for determining, 360
 Organizations cited
 American Society for Quality (ASQ), 1
 Booth Dispensers, Ltd., 499
 Morton Powder Coatings, 343
 National Institute of Standards and Technology (NIST), 111, 135, 225, 524, 525

 Procter and Gamble, 320
 Rayovac, 347–348
 Rothamsted Experimental Station, 179, 182

 Pareto effects chart/analysis, 126, 180, 213, 214, 255, 498
 Processes in/out of statistical control, 18, 19, 189, 255, 267
 blocking out-of-control process, 60–61
 checking for, 141, 266, 487
 check runs, 19

 Quasi-experimental design, 23

 R^2 , 208, 255, 266, 271, 273, 373, 497
 Region of operability, 364
 irregular design space, 386
 restricted, 387, 404, 508–514
 debarred observations, 387, 508, 509, 514
 Response surface methodology (RSM), 360
 analyzing fitted surface, 398–404
 contours of constant response, 398
 ridge analysis, 403–404
 method of Lagrangian multipliers, 403
 with noise variables, 404
 rising ridge, 398
 stationary points, 400–403
 confidence regions on, 402–403
 in a three-stage operation, 418
 in the food industry, 417
 method of steepest ascent/descent, 370–373, 561
 example, 371–372
 modified method, 405
 scale-independent methods, 373

 Satterthwaite's procedure, 271, 272
 Shainin's variables search approach, 500
 Six Sigma, 22
 Sliding reference distribution, 36
 Software for experimental design, 48, 89–90, 151, 333, 350, 531–532
 Cornerstone, 471
 Dataplot, 135
 Design-Expert, 1, 11, 48, 89, 90, 151, 154, 157, 175, 176, 177, 192, 201, 215,

SUBJECT INDEX

593

- 216, 217, 230–232, 246, 250, 252,
279–281, 282, 291, 295, 313, 321,
326, 328, 350, 369, 371, 379, 380,
391–393, 396, 397, 407, 438, 452,
457–462, 467–471, 480, 490, 492,
498, 504, 505, 518, 532
- D.o.E. Fusion Pro, 48, 151, 230, 232, 283,
295, 321, 350, 356, 392, 407
- Echip, 471
- Gendex DOE toolkit, 90, 408, 511, 522
- GOSSET, 1, 505
- JMP, 1, 48, 89, 90, 157, 176, 187, 192,
201, 230–233, 265, 278–279, 281,
282, 289, 295, 297, 321, 366, 370,
375, 392, 407, 408, 427, 438,
455–458, 460, 461, 464, 468–471,
480, 488, 505, 511, 512, 516–519,
532
- MathWorks, 520
- MAPLE, 403
- MINITAB, 1, 48, 64, 67, 87, 89, 90, 109,
124, 127, 131, 135, 143, 146, 149,
150, 154, 157, 176, 180, 186, 192,
201, 230–233, 243, 244, 248–250,
252, 255, 256, 269, 271–273, 275,
280, 287, 295, 300, 301, 321, 350,
365, 366, 374, 386, 392, 395, 396,
398, 401, 407, 408, 427, 438, 445,
452, 470, 471, 475, 490, 491, 493,
495, 501, 532
- MIXSOFT, 523
- R (CROSSDES), 434, 438
- RS/1, 508
- RS/Discover, 295, 350, 532
- SAS Software, 64, 89–90, 157, 230, 271,
295, 297, 347, 350, 370, 404, 425,
434, 437
- SPSS, 438
- Stat-ease, Inc., 130, 208, 221, 343
- Statgraphics, 90, 233, 408
- Statistica, 233
- Statistical process control methods, 19
- Stepwise regression, 122, 207, 208, 277,
497, 499
- Strong heredity assumption, 109
- Weak heredity assumption, 109
- Yates' algorithm, 172, 174
- Yates order, 102–103, 127, 130, 134, 354