

INDEX

- Acceptance control chart, 361–363
- Acceptance number, 13, 542, 543
- Acceptance sampling plan
 - history of, 13
 - meaning of, 13
- Accumulation analysis, 657
- Accuracy, of data set, 161–162
- Activity-based costing (ABC), 20–23
- Act stage, of Deming cycle, 63
- Adams, B. M., 345
- Additive law, of probability, 157
- Adjustment factor, 626, 627, 651–653, 655
- Aliases, 618–622
- Alias structure, 619, 622, 658
- Alt, F. B., 375
- Alternate fraction, 618
- Alternative hypothesis, 203, 211, 268
- American National Standards Institute
 - (ANSI)/American Society for Quality (ASQ). *See* entries under ANSI/ISO/ASQ
- American Society for Quality (ASQ) history of, 5
- Analysis of variance (ANOVA)
 - differences among treatment means, 579
 - F*-statistic, 579
 - Minitab for, 580–581
- Anderson-Darling test, 512
- ANSI/ISO/ASQ Q9000 Standard*, 7
- ANSI/ISO/ASQ Standard A3534-2*, 9
- ANSI/ISO/ASQ Standard A8402*, 9
- ANSI/ISO/ASQ Standard QS 9000*, 7
- Appraisal costs, 23–24, 34
- Arnold, S. F. 202, 238
- Arrays, orthogonal, 639–654
- AS 9100 Standard*, 138
- Assemblies, tolerances on, 502–509
- Association, measures of
 - mean-squared contingency Cramer's V, 251
- AT&T, 139
 - benchmarking, 107
- Attribute control charts
 - advantages of, 406–407
 - c*-chart when zero defects are not observable
 - control 427–433
 - for demerits per unit, 439–441
 - disadvantages of, 407
 - g*-chart operating characteristic curves, 447–450
 - np*-chart
 - for number of nonconforming items, 425–427

- Attribute control charts (*cont'd*)
 - for number of nonconformities, 427–433
 - for number of nonconformities per unit, 433–438
- p*-chart
 - preliminary decision making, 314–315
 - process capability analysis based on, 473–475
 - for proportion of nonconforming items, 425–427
 - risk-adjusted *p*-chart, 420–424
 - sample size, 433–436
- U*-chart, 439–441
- u*-charts
 - risk-adjusted *u*-charts, 436–438
- Attributes
 - levels of, 8
 - of quality, 8–9
- Attribute sampling plan
 - Deming's *kp* rule, 272–274
- Auditors, types of, 110
- Autocorrelation
 - Cochrane-Orcutt procedure, 690
- Automotive Industry Action Group (AIAG), 115, 132
- Availability, 534
- Average run length (ARL)
 - control charts, 344–345
 - cumulative sum chart (cusum charts) for, 344
- Balanced experiment, 579
- Balanced scorecard (BSC)
 - diagnostic measures, 94
 - outcome measures, 95
 - performance drivers, 95
 - perspectives of, 95
 - strategic measures, 95
- Banks, J., 190
- Barnard, G. A., 348
- Bathtub curve, phases in, 530
- Bayes' rule
 - posterior probability, 268
 - prior probability, 268
- Beaver, R., 193, 212
- Behrens-Fisher problem, 198
- Benchmarking
 - benefits of, 107
 - impetus for, 110
 - models for, 107
- Besterfield, D. H., 439, 530
- Big data 116
- Binomial distribution
 - calculation of, 216
 - cumulative, table for 216
 - hypergeometric distribution approximation, 216
 - normal approximation, 217–218
 - Poisson approximation, 216–218
- Blischke, W. R., 534
- Blocking, experimental design, 575
- Boudot, J. R., 638
- Box, G. E., 570, 576, 578
- Box-Cox transformation, 500
- Box plots
 - notched box plot, 238
- Boyles, R. A., 486, 489
- Bunches, control charts, 330
- Calibration of measurement instrument, 162
- Campanella, J., 23
- Capability ratio (CR), 483–484
- Cause-and-effect diagrams
 - cause enumeration, 126
 - dispersion analysis, 126
 - fishbone diagrams, 126
 - history of, 126
 - Ishikawa diagrams, 126
 - process analysis, 126
 - use of, 126
- Cause enumeration
 - c*-chart, 427–428
 - with no standard given, 428
 - and Poisson distribution, 428
 - process capability measurement, 291
 - with standard specified, 411
- Centerline
 - control charts, 288

- factors for computation of, 288
- Central limit theorem, 193
- Chambers, J. M., 236
- Chance-failure phase, 530
- Change management, and benchmarking, 109
- Check stage, of Deming cycle, 63
- Chi-squared distribution
 - chi-square values for right-tail area, 745
- Chi-squared test, 250
- Chou, Y., 246
- Chronic problems, 84
 - Malcolm Baldrige National Quality Award, 7
- Classification problems
 - performance measures, 720–722
 - accuracy, 721
 - attributable risk, 722
 - false positive, 721
 - false negative, 721
 - likelihood ratio, 722
 - negative predictive value 721
 - odds ratio, 721
 - positive predictive value, 721
 - relative risk, 721
 - sensitivity, 721
 - specificity, 721
- Clearance fits, 506
- Clement, J., 38
- Cleveland, W. S., 236
- Clustering, 240
- Cluster sample, 264
- Cochran, W. G., 479
- Coefficient of determination
 - adjusted R^2 , 684
- Cohen, L., 15
- Common causes, nature of, 289
- Competitive position, and quality improvement, 35
- Complementary events, probability, 156–157
- Completely randomized design
 - two-factor factorial experiment, 596–599
- Complex systems, and reliability, 539
- Components in parallel, and reliability, 537
- Components in series, and
 - reliability 535–537
- Compound events, probability 155–156
- Confidence coefficient
 - Bonferroni method, 691
 - family level, 691
 - Schéffe method, 693
 - Working-Hotelling method, 693
- Confidence interval
 - for difference between two binomial proportions, 200
 - for difference between two means, 198–199
 - for the mean, 196
 - one- and two-sided, 195
 - for proportion, 199–200
 - for ratio of two variances, 202–203
 - for variance, 200–202
- Confirmation experiments, 655
- Conformance, quality of, 10–11
- Conformity quality audit, 110
- Confounding
 - meaning of, 616
 - in 2^k factorial experiment, 616–617
- Constant failure rate, exponential distribution, 531
- Consumer's risk
 - acceptance sampling, 543
 - and OC curve, 543
 - single sampling plan, 543
- Contingency tables, 249–251
- Continuous quality improvement practices
 - benchmarking, 106
 - and innovation, 106
 - quality audits, 110
 - and vendors, 112
- Continuous quality improvement tools
 - cause-and-effect diagrams, 126
 - flow charts, 124–126
 - Pareto diagrams, 124
 - scatter plots, 126–127
- Continuous variables, 161
- Contrast
 - contrasts of totals, 606
 - defining contrast, 606
 - factorial experiments, 106
 - orthogonal contrasts, 608–609

Control chart construction

- acceptance control chart, 361–363
- control limits, 376
- cumulative sum chart (cusum chart)
 - risk-adjusted cusum chart, 344–345
- exponentially weighted moving average (EWMA) chart
 - risk-adjusted EWMA chart, 366–367
- geometric moving-average control chart, 354–357
- Hotelling's T^2 control chart, 373–374
- for highly conforming processes, 442–447
- for individual units, 338–342
- for mean and range, 315–333
- for mean and standard deviation, 333–338
- Minitab, 383
- modified control chart, 357–361
- moving-average control chart, 351–354
- from moving ranges, 339
- multivariate control charts, 370–383
- R -chart, 333
- risk-adjusted sequential probability ratio test, 363–364
- sample size, 321
- s -chart, 333
- short production runs, 342–344
- standardized control charts, 321–322
- steps in development, 315–321
- variable life-adjusted (VLAD) chart, 367–370
- \bar{X} chart, 342
- Z-MR chart, 342–344

Control chart patterns

- bunches/groups, 330
- cyclic patterns, 329
- freaks, 330
- gradual shifts in level, 327–328
- interaction patterns, 332
- mixture patterns, 330–331
- natural patterns, 327
- stratification patterns, 331–332
- sudden shifts in level, 327
- trending pattern, 328
- wild patterns, 330

Control charts

- for attributes. *See* Attribute charts
 - average run length, 299–301
 - benefits of, 289
 - characteristics for investigation, 313–314
 - construction of. *See* Control chart construction
 - control limits effects, 297
 - control limits selection, 291–292
 - data recording forms, 315
 - history of, 287–289
 - instant-of-time method for sample observations, 301
 - interpretation of plots, 304–306
 - lines, meaning of, 288
 - maintenance of, 306–307
 - measuring instrument selection, 315
 - and online process control, 290
 - operating characteristic curve, 296–297
 - out-of-control points, cause of, 306
 - out-of-control process identification, 302–304
 - pattern analysis, steps in, 302–303
 - pre-construction decisions, 291
 - process capability analysis based on, 291
 - purpose of, 290
 - rational samples, selection of, 314–315
 - sample size, 301
 - sample size effects, 298–299
 - sampling frequency, 301–302
 - for service industries, 363
 - statistical process control (SPC), 306
 - and type I error, 293
 - and overall type I errors, 293
 - and type II errors, 293–296
 - variation, causes of, 289
 - warning limits, 298
- Control limits
- compared to specification limits, 472–473
 - control chart construction, 291–292
 - for control charts, 291–292
 - factors for computation of, 300
- Convenience sampling, 53

- Corporate culture, 58
- Corrective action
 - process of, 327
- Correlation coefficient
 - calculation of, 174
 - degrees of correlation, types of, 174
- Cost base index, quality cost measure, 27
- Costs, product and service
 - batch level, 20
 - direct, 20
 - drivers of, 20
 - indirect, 20
 - product/service level, 20
 - production/service sustaining, 21
 - unit level, 20
- Count data, analysis, 248–251
- C_p index, 479–480
- C_{pk} index, 481–483
- Critical to quality (CTQ) characteristics, 137
- Crosby, Philip B.
 - absolutes of quality management, 76
 - background information, 75
 - 14-step quality improvement plan, 76–78
 - quality management grid, 77
- Cumulative binomial distribution, table for, 733–742
- Cumulative distribution function, 179–180
- Cumulative Poisson distribution, table for, 738–739
- Cumulative sum chart (cusum charts)
 - for average run length (ARL), 349
 - process variability, for, 351
 - pros/cons of, 344
 - tabular method, 345–348
 - V-mask parameters, 348–351
- Customers
 - Deming's view of, 56
 - Juran's view, 79
 - needs of, 137
 - and quality function deployment (QFD), 102
 - satisfaction, 124
 - and total quality management (TQM), 90
- Cyclic patterns, control charts, 329
- Data collection
 - accuracy and precision, 161–162
 - continuous and discrete variables, 161
 - by observation, 160
- Debugging phase, 530
- Defect, 9
- Deming's view of
 - meaning of, 56
- Defining contrast, 618
- Degrees of freedom, 197
- Dehnad, K., 623
- Demerits per unit, chart for, 439–441
- Deming's kp rule
 - basic assumptions in, 272
 - evaluation of, 272
- Deming, W. Edwards
 - deadly diseases of, 72
- Deming cycle
 - extended process of, 63
 - 14 points for management, 58–72
 - philosophy of, 56
 - system of profound knowledge, 56
- Department of Defense (DOD), 5
- Descriptive statistics, nature of, 160
- Design for manufacturability, 11
- Design, quality of, 10
- Design resolution, 2^k factorial experiment, 612–616
- Diagnostic arm, 81
- Direct observation, 160
- Discrete variables, 161
- Dispersion analysis, 126
- Do stage, of Deming cycle, 64
- Double-blind study, 576
- Draper, N. R., 570, 576, 659
- Duncan, A. J., 193, 212
- Durbin-Watson test, 689
- Eastman Chemical Company, and total quality management (TQM), 93
- Eco-Management and Auditing Scheme (EMAS), 37
- Effectiveness, service business, 51
- Efficiency, service business, 51

- Ehrlich, B. H., 133
- EI-Haik, B., 132
- Elsayed, A., 623
- Empirical distribution plots, 234–239
- Employee
 quality and service industries, 48
- Environmental management
 benefits of, 38
 scope of activities, 37
 standards development, 37
- Error bound, 264
- Error component
 independence, 699–700
 mean, 678
 mean square, 660
 probability distribution, 679
 variance, 679
- Errors in sampling
 misspecification, 262
 nonresponse, 262
 random variation, 262
- Estimation
 mean response, 693
 simultaneous confidence intervals, 693
- Ethical characteristics, of quality, 8
- Expected opportunity loss, 270
- Expected value of perfect information (EVPI), 271
- Experimental design
 analysis of variance (ANOVA), 578
 balanced/unbalanced experiment, 577
 blocking, 577
 completely randomized design, 577
 confirmation experiments, 627
 design elements, 575–576
 double-blind study, 576
 factorial experiments, 595
 fixed effects model, 576
 Latin square design, 587–595
 measurement bias, 576
 random effects model, 576
 randomization, 588–595
 randomized block design, 582–587
 replication, 574
 single-blind study, 576
 usefulness of, 575
 variables, 595
 See also Factorial experiments; Taguchi method
- Experimental error, 571
- Experimental unit, in experiment, 571
- Exponential distribution
 calculation of, 532
 for model failure rate, 531
 standby system, 540–542
 systems with components in parallel, 537–539
 systems with components in series, 535–537
 systems with components in series/parallel, 539–540
- Exponentially weighted moving average (EWMA) chart, 366
- Extended process, Deming's view, 57–58
- External failure costs, 24
- External noise, 24
- F*, values for right-tail area, 747–754
- Factorial experiments
 contrast, role of, 606–612
 2^k factorial experiment, 612–617
 two-factor with completely randomized design, 596–599
 two-factor with randomized block design, 600–606
 uses of, 596–599
- Factors, in experiment, 571
- Failure mode and effects criticality analysis (FMECA)
 risk priority number (RPN), 131
- Failure-rate function
 exponential distribution, 531
 Weibull distribution, 533
- Failure-terminated test
 with *Handbook H-108*, 544–545
- F*-distribution, 202
- Federal Express Company, performance measures of, 113
- Feigenbaum, A. V., 4–6

- Fellers, G., 58
- Fishbone diagrams, history of, 6
- Fixed effects model, 576
- Flow charts, use of, 124–126
- Ford Motor Company, 6
- Foreman Quality Control period, 4
- Forms 1 and 2
variable sampling plans, 270
- 14 points for management, of Deming, 47,
58–75
- 14-step quality improvement, plan Crosby's,
76–78
- Freaks, control charts, 330
- Frequency distribution, 234–235
- Frequency histogram, 235
- F*-statistic
analysis of variance (ANOVA), 579
Latin square design, 587
randomized block design, 582
- Gage, study of
bias, 493
design of, 494
linearity, 493
repeatability, 492
reproducibility, 492
R&R, 494
stability, 493
- Gamma distribution
probability density function, 192
- Gap analysis, 92
- Garvin, D. A., 7
- Generator, in 2^k factorial experiment, 618
- Geometric moving-average control chart,
354–357
- Gitlow, H. S., 58
- Gitlow, S. J., 58
- Goals
Crosby's view, 78
Deming's view, 56
- Godfrey, A. B., 447
- Goh, T. N., 444
- Goodness-of-fit tests, 241
- Graeco-Latin square design, 639
- Graphical methods
box plots, 236–238
cause-and-effect diagrams, 126
frequency distribution, 234–235
histogram, 234–235
matrix plots, 129
normal probability plots, 241
Pareto diagrams, 124
run charts, 239–241
scatter diagrams, 126–127
stem-and-leaf plots, 235–236
three-dimensional scatter plot, 129–130
- Gunter, B. H., 481
- Half-fraction, of, 618
 2^k factorial experiment, 612–616
- Hawkins, D. M., 345, 346
- Health care analytics
data visualization, 116
predictive models, 116
prescriptive models, 116
- Health information technology
health care decision support systems, 122
- Henley, E. J., 190
- Highly conforming processes
control charts, 442
exponential distribution, use of,
442–443
geometric distribution, use of, 443
power transformation, 442
probability limits, 443–445
- Histogram, 234
- Homoscedasticity, 679
- Hotelling, H., 373
- Hotelling's T^2 control chart
construction of, 373
control ellipse procedure, 373
percentile points, values of, 374
- House of quality, 100
- Hsiang, T., 623
- Human factors, service industries, 51
- Hunter, J. S., 570
- Hunter, W.G., 570
- Hurley, P., 485

- Hyatt Hotel Corporation, performance standards, 96
- Hybrid orthogonal arrays, 648
- Hypergeometric distribution, 180–181
- Hypothesis testing
 alternative hypothesis, 203
 correlation coefficient, 209
 difference between two means from paired samples, 209–211
 for difference between two binomial proportions, 212–213
 of difference between two means, 209
 of mean
 null hypothesis, 203
 one-tailed test, 205
 for proportion, 211–212
 for ratio of two variances, 214
 steps in, 203
 test statistic, 203
 two-tailed test, 205
 type I/type II errors, 206
 for variance, 213–214
- IBM Direct, and total quality management (TQM), 93
- Incomplete block design, Latin square design as, 588
- Independent events, probability, 159
- Indirect observation, 160
- Infant mortality phase, 530
- Inferential statistics
 confidence interval 194
 hypothesis testing 197–215
 interval estimation, 195–197
 nature of, 193
 point estimation, 194–195
 sampling distributions, 193–194
 simultaneous intervals 194, 195
- Influential observations
 Cook's distance, 705
- Innovation
 benefits of, 106
 and continuous improvement, 106
 Deming's view, 60
- Inspection and Quality Control Handbook H108*, 6
- Inspection quality control period, 4
- Instant-of-time method, for sample observations, 301
- Interaction patterns, control charts, 332
- Interactions, experiments, 573
- Interference fits, 506
- Internal failure costs, 24
- Internal noise, 625
- International Organization for Standardization (ISO), 7
 vendor certification, 114
See also entries under ISO and ANSI/ISO/ASQ
- Interquartile range, calculation of, 169–170
- Interval estimation
 calculation of, 195
 confidence interval, 196–198
- Interval scale, 162
- Ishikawa diagrams
 history of, 6
- ISO 9000-9004*, 7
- ISO 13485 Standard*, 139
- ISO 14000: An International Environmental Management Standard*, 38
- ISO 14001*, 38
- ISO 14010*, 38
- ISO 14020*, 38
- ISO 14031*, 38
- ISO 14040*, 38
- ISO 14060*, 38
- ISO/TS 16949 Standards*, 115
- Japan
 and Deming, 63
 and Juran, 78
- Johnson, N. L., 215
- Joint Commission on Accreditation of Healthcare Organizations, 121
- Judgment sampling, 53
- Juran Institute, 78

- Juran, Joseph M
 background information, 78
 quality trilogy, components of, 79
- Kackar, R. N., 624
- Kane, V. E., 479
- Kano model, 15–16
- Kaplan, R. S., 94
- Kendall, M. G., 202
- Kotz, S., 215
- kp* rule, 272–274
- Kumamoto, H., 190
- Kuralmani, V., 444
- Kurtosis coefficient, calculation of, 171
- Kushler, R. H., 485
- Kutner, M. H., 689, 691, 693
- Labor base index, quality cost
 measure, 27
- Latin square design
 ANOVA table for, 590
 difference among treatment means, 591
 F-statistic, 591
 Graeco-Latin square design, 639
 as incomplete block design, 588
 pros/cons of, 587
 randomization of, 588–589
- Leadership, Deming's view, 66
- Leadership Through Quality program, 93
- Least squares method, 680–686
- Lefevre, H. L., 51
- Leon, R. V., 638
- Levels, in experiment, 571
- Leverage, 703
- Life-cycle curve
 phases in, 530
- Life testing plans
 failure-terminated test, 544–545
 sequential life testing plan, 545–546
 time-terminated test, 545
- Likert scale, 252
- Limiting quality level
 in acceptance sampling, 13
 Dodge-Romig plans, 5
- Linear graphs
 and orthogonal arrays, 639–649
- L. L. Bean, benchmarking, 108
- Log odds ratio test, 722–723
- Logistic function, 708
- Logistic regression
 nominal binary, 708–709
 nominal polytomous, 712–715
 ordinal polytomous, 715–719
- Lognormal distribution
 cumulative distribution function 192
 probability density function, 192
 scale parameter, 192
 shape parameter, 192
- Loss functions
 and larger values, 631–632
 manufacturing tolerances, 630–631
 and smaller values, 632–633
 Taguchi method, 627
- Lowe, T. A., 82
- Lower capability index, 480
- Lower control limit, control charts, 288
- Lower tolerance limits
 natural tolerance limits, 472
- Lucas, J. M., 345
- Mage, D. T., 479
- Malcolm Baldrige National Quality Award
 eligibility categories, 113
 eligibility criteria, 133
 evaluation criteria, 133
 and vendor certification, 113
- Management
 Deming's view, 58–75
- Management practices
 continuous improvement, 96
 performance standards, 96–99
 quality function deployment (QFD), 99–106
 total quality management (TQM), 90–92
- Manufacturing industry
 compared to service industry, 49
- Manufacturing tolerances, 630–631
- Marcus, P. A, 38
- Mason, R. L., 246

- Massey, F. J., Jr, 241, 479
- Mass inspection, limitations of, 60–61
- Mating parts
 clearance fits, 506
 interference fits, 506
 transition fits, 506–507
- Matrix plots, 129, 130
- Minitab software, 124, 129
- Mazzeo, J. M, 82
- McGill, R, 239
- Mean
 calculation of, 163
 confidence interval, 693
 hypothesis testing, 208–209
 population mean, 163
 sample mean, 163
 trimmed mean, 165
- Mean time between failure, exponential distribution, 531
- Mean time to failure
 exponential distribution, 531
 Weibull distribution, 532
- Mean time to repair, 534
- Measurement bias, experimental design, 576
- Measurement error
 gage repeatability, 492
 gage reproducibility, 492
 and precision-to-tolerance ratio, 491
- Measurement scales
 interval scale, 162
 nominal scale, 162
 ordinal scale, 162
 ratio scale, 162–163
- Measurement systems, evaluation of, 493
 accuracy of, 493
 metrics, 493
- Measures of association
 correlation coefficient, 174–176
- Measures of central tendency
 mean, 163
 median, 163–164
 mode, 164–165
 trimmed mean, 165
- Measures of dispersion
 interquartile range, 169–170
 range, 165–167
 standard deviation, 167–169
 variance, 166–167
- Median, calculation of, 163–164, 239
- Mendenhall, W, 193, 212
- Military standards. *See entries under MIL-STD*
- MIL-STD-105E, 5
- MIL-STD-414, 5
- Mission statements, Deming's view, 59
- Mode, calculation of, 164
- Models
 additive, 696–697
 deterministic, 676–678
 F-test, 703
 multiplicative, 688
 probabilistic, 676–678
 t-test, 701
 utility of, 685
 validation, 686–690
- Modified control chart, 357–361
- Montgomery, D. C, 307, 507, 658
- Motorola, Inc.
 benchmarking, 107
 six sigma quality, 96
- Moving-average control charts
 exponentially weighted moving average (EWMA) charts, 354–357
 geometric moving-average control charts, 354–357
 moving-average span, 355
 step in construction of, 351–352
- Moving range, control charts, 339
- Multicollinearity, 706–707
- Multinomial experiment, 249
- Multiplicative law, of probability, 158
- Multivariable charts
 types of, 127–129
- Multivariate control charts
 generalized variance chart, 378–383
 quality characteristics, control of, 370, 372–373
 T^2 . control chart, 373–374

- Murthy, D. N. P., 534
- Mutually exclusive events, probability, 158
- Nachtsheim, C. I., 174
- Nair, V. N., 623
- Natural tolerance limits
 upper and lower natural tolerance limits, 475
- Nelson, L. S., 322
- Nelson, W., 479
- Neter, J., 174
- Noise
 internal and external, 625
 noise factors in experiment, 571
- Nominal scale, 162
- Nonconformance rate, and process capability indices, 497–498
- Nonconforming items
 chart for number of items, 425
 chart for proportion of items, 425
 cost of correction, 17
 meaning of, 9
- Nonconformity
 chart for number of, 433
 chart for number of per unit, 433
 classification of defects, 439
 meaning of, 8
 service industries, 51
- Nonparametric statistical tolerance limits, 510–511
- Normal distributions
 approximation to binomial, 216–217
 approximation to Poisson, 216
 calculation of, 216
 standard normal distribution, table for, 740–743
 statistical tolerance limits based on, 476
- Normal probability plots, 241
- Normann, R., 51
- Norton, D. P., 94
- Notched box plot, 238
- np*-chart
 limitations of, 425
 with no standard given, 425–426
 process capability measurement, 500
 with standard specified, 426–427
- Null hypothesis, 203
- Observation, for data collection, 160
- Odds ratio, 721
- Off-line quality control, 12
- O’Hagan, A., 202
- 100% sampling, 53
- One-tailed test, 205
- Online statistical process control and control charts, 12
- Operating characteristic (OC) curve
 attribute charts, 447–450
 control charts, 447–450
 and producer/consumer risk, 543
 and reliability, 542–544
- Operator quality control period, 4
- Optimal quality level, 29
- Ord, J. K., 202, 238
- Ordinal scale, 162
- Organizational barriers, Deming’s view, 67–72
- Original equipment manufacturer (OEM)
 core competencies, 31
- Orthogonal arrays
 hybrid orthogonal arrays, 648
 and Latin square design, 639
 and linear graphs, 639
- Orthogonal contrasts, 608–609
- Outliers, 164
- Out-of-control points, determination of cause, 306
- Out-of-control processes, identification of, 302–304
- Paired samples
 confidence interval for difference between two means, 199
- Parameter, statistical, 154
- Parameter design, Taguchi method, 654–658
- Pareto diagrams
 steps in construction of, 124
 use of, 124

- Parry, P., 38
- Patton, F., 48
- Payment schemes in health care
- bundled payment, 120–121
 - capitation, 120
 - diagnosis-related groups, 118–119
 - fee-for -services, 118
 - pay-for-participation, 119
 - pay-for-performance, 119–120
- p*-chart
- basic assumptions for, 424
 - construction of, 409–416
 - data sheet for, 410
 - with no standard specified, 410–416
 - process capability measurement, 500
 - with standard specified, 424
 - usefulness of, 409
 - and variable sample size, 416–420
- Pearn, W. L., 484
- Performance, quality of, 11–12
- Performance evaluation
- benchmarking, 107–110
 - Deming's view, 70
 - quality auditing, 110–112
- Performance measures, for vendors
- adjusted coefficient of determination, 684
 - coefficient of determination, 684
- Performance standards
- components of, 96
 - six sigma quality, 96–99
- Performance statistic, 635
- PERMIA method, 638
- Peterson, R. G., 570, 578, 622
- Philpot, J. W., 305
- Plan stage, of Deming cycle, 63–64
- Point estimation, calculation of, 194
- Poisson distribution
- approximation to binomial, 216
 - calculation of, 216
 - c*-chart, 428
 - cumulative, table for, 738–739
 - normal approximation to, 218
- Polansky, A. M., 246
- Population
- estimating parameters, 154
 - statistical, 154
- Population mean, calculation of, 163
- Population variance, calculation of, 166
- Posterior probability, 269
- Power of test, 207
- Precision, of data set, 162
- Precision-to-tolerance ratio, 491
- Prevention costs, 23
- Pride of worker, Deming's view, 69
- Principal fraction, 618
- Prior probability, 269
- Probability
- additive law, 157
 - complementary events, 156
 - compound events, 155–156
 - independent events, 158–160
 - meaning of, 155
 - multiplicative law, 158
 - mutually exclusive events, 158–160
 - relative frequency definition of, 155
 - simple events, 155–156
- Probability distributions
- approximations for, 216–218
 - binomial distribution, 181–183
 - continuous distributions, 184–190
 - cumulative distribution function, 179
 - expected value, 179–180
 - exponential distribution, 188–190
 - gamma distribution, 192
 - hypergeometric distribution, 180–183
 - lognormal distribution, 192
 - normal distribution, 184–188
- Poisson distribution
- probability density function, 177
 - probability distribution function 177
 - Weibull distribution, 190–191
- Probability limits, control charts, 430–431
- Probability plotting
- construction of, 241
 - exponential plot 240
 - and Minitab, 241
 - normal plot, 241

- Probability sampling, 53
- Process audit, 111
- Process capability, indices
 - comparison of, 486–490
 - confidence intervals on, 485–486
 - C_p index, 479–480
 - C_{pk} index, 481–483
 - C_{pm} index, 484
 - C_{pmk} index, 484–485
 - C_{pq} index, 501
 - hypothesis testing on, 485–486
 - lower capability index, 480–481
 - measurement error effects, 490–492
 - and nonconformance rate, 497–498
 - Taguchi capability index C_{pm} , 484
 - upper capability index, 480–481
- Process capability, meaning of, 291
- Process capability analysis
 - with attribute chart information, benefits of, 474–475
 - Box-Cox transformation, use of, 500
 - capability ratio (CR), 483–484
 - identification of distribution, 500
 - with individual observations, 498
 - non-linear combinations, 508–509
 - non-normal distributions, 509–510
 - nonparametric approach, 510
 - and specification limits, 472–473
 - statistical tolerance limits, 476
 - and tolerance limits, 472
 - with variable control chart information, 498–499
- Process capability limits. *See* Natural tolerance limits
- Process capability ratio, 501
- Process costs, 26–27
- Process map, 125
- Process spread
 - meaning of, 473
 - and specification limits, 477
- Producer's risk, 543
- Product audit, 111
- Product improvement cycle, 59
- Productivity, relationship to quality, 34
- Proportion
 - confidence interval, 199–200
 - hypothesis testing, 211–212
- Public Law, *p-value*, hypothesis testing, 207
- Quality
 - attributes related to, 8
 - characteristics of, 8
 - of conformance, 10
 - defect, 9
 - definition of, 7
 - of design, 10
 - of performance, 11
 - relationship to productivity, 4
 - and reliability, 18
 - standard, 9
 - variables related to, 8
- Quality assurance
 - definition of, 13
- Quality audits
 - conformity quality audit, 110
 - influencing factors, 109
 - location/function-oriented audits, 111, 112
 - process audit, 111
 - product audit, 111
 - purposes of, 110
 - suitability quality audit, 110
 - system audit, 111
 - usefulness of, 111
- Quality awareness, 76
- Quality breakthrough sequence, 79
- Quality circles
 - history of, 6–7
 - operation of, 14
- Quality control, 12
 - acceptance sampling plans, 13
 - benefits of, 16
 - evolution of, 4
 - Juran's view, 8
 - off-line quality control, 12
 - statistical process control, 12

Quality Control and Reliability Handbook
H-108

- failure-terminated test, 544–546
- time-terminated tests, 545, 547
- Quality costs
 - appraisal costs, 23
 - data requirements for, 24, 25
 - external failure costs, 24
 - hidden failure costs, 24
 - impact of quality improvement, 29
 - improved productivity, impact of, 29
 - internal failure costs, 24
 - measurement of, 27
 - prevention costs, 23
 - quality cost report, 24
- Quality councils, 78, 83
- Quality function deployment (QFD)
 - effects of, 99
 - house of quality, 99
 - step in process, 100
- Quality improvement, 81
 - Crosby's 14-step plan, 76
 - Juran's view, 99
- Quality improvement teams, operation of, 14
- Quality management
 - absolutes of, 76
 - quality systems, 17
- Quality management grid, 75
- Quality measurement, function of, 76
- Quality philosophies
 - comparison of philosophies, 82
 - of Crosby, 75
 - of Deming, 56
 - of Juran, 78
- Quality planning
 - Juran's view, 79
- Quality system, 17
- Quantile ratio, 246
- Quartile, 169
- Quota system, Deming's view, 69

- Radial plot, 127
- Raghavarao, D., 570
- Random effects model, 576

- Randomization, experimental design, 575
- Randomized block design
 - blocking, 575
 - difference among treatment means, 584–587
 - F*-Statistic, 584
 - pros/cons of, 582
 - two-factor factorial experiment, 600–606
- Randomness, of a sequence, 239–241
- Random numbers, uniform, table for, 754
- Range, calculation of, 165–166
- Rating scale
 - importance rating, 261
 - satisfaction rating, 261
- Rational sample, control charts, 301–302
- Ratio scale, 162–163
- R*-chart
 - analysis and \bar{X} -chart, 342
 - control limits, 360
 - Minitab construction, 320
 - standardized values, 321
 - variable sample size, 322
- Receiver operating characteristic curve
 - false positive rate, 723
 - true positive rate, 723
 - sensitivity, 723
 - specificity, 723
- Regression models
 - assumptions, 709–712
 - coefficients, 691
 - logistic, 707–719
 - multiple, 702–707
 - parameters, 691
 - performance measures, 720–722
 - prediction, from, 693
 - residuals, 688
 - response variable, 708–709
 - simple, 678
 - simultaneous prediction intervals, 693–696
 - standardized, 705
 - studentized 705
 - sum of squares, 683
- Reinmuth, J. E. 193
- Rejection region, 206

- Reliability
 - and complex systems, 539
 - and components in parallel, 537–539
 - and components in series, 535–537
 - failure-terminated test, 544–545
 - and life-cycle curve, 530–534
 - and life testing plans, 544–552
 - meaning of, 530
 - and operating characteristic curves, 542–544
 - probability distributions, 530–534
 - and quality, 548
 - sequential life testing plan, 545
 - standardized plans, 544
 - and standby systems, 540
 - system reliability, 534–542
 - time-terminated test, 545
- Replication, experimental design, 617–623
- Resolution III designs, 619
- Resolution IV designs, 620
- Resolution V designs, 620
- Response surface design, 659
- Response variable, in experiment, 537
- Robustness, 623
- Romig, H. G., 5
- Roy, D. M., 132
- Run charts
 - clustering, 239
 - mixture pattern, 239
 - oscillation, 239
 - patterns, 239
 - random pattern, 239
 - trend, 239
- Ryan, T. P., 570
- Sales base index, quality cost measure, 27
- Sample, statistical, 182
- Sample mean, calculation of, 174, 315, 379, 395
- Sample size
 - attribute charts, 500
 - control charts, 301
 - determination of, 264
 - estimation in sampling, 194
- Sample space, 155
- Sample variance, calculation of, 166, 167
- Sampling
 - advantages of, 262
 - cluster sample, 264
 - designs, 262
 - element, 262
 - errors in, 262
 - estimation of sample size, 264
 - frame, 262
 - precision, 162
 - proportional allocation, 263
 - simple random sample, 262
 - stratified sample, 263
 - unit, 262
- Sampling distributions
 - calculation of, 167
 - central limit theorem, 193
- Sampling frequency, control charts, 301, 315
- Sampling plans
 - convenience sampling, 53
 - function of, 410
 - judgment sampling, 53
 - 100% sampling, 53
 - probability sampling, 53
 - for service business, 93
 - See also* Acceptance sampling plan; Attribute sampling plan
- Sampling unit, in experiment, 571
- Scaled distance k , 481–482
- Scanlon, J., 5
- Scanlon plan, 5
- Scatter diagrams
 - construction of, 126
 - use of, 127
 - s -chart, 335
- Schmidt, S.R., 638
- Screening design, 659
- Sensory quality, 8
- Sequential life testing plan, 545
- Sequential sampling plan
 - item-by-item sampling, 13

- Service industries
 - compared to manufacturing industries, 48
 - control chart applications, 363
 - effectiveness/efficiency factors, 51
 - quality, 47, 48, 49, 53–56
- Shapiro, S.S., 246
- Shewhart, W.A., 63
- Shewhart control charts. *See* Control charts
- Shewhart cycle, 63
- Signal-to-noise ratio (SIN)
 - evaluation of, 634
 - and larger values, 637
 - PERMIA method, 638
 - relationship of variance to mean, 638
 - and smaller values, 637
- Simple events, probability, 155
- Simple random sample, 262
- Single-blind study, 576
- Single sampling plan, 4
- Six sigma quality
 - analyze phase, 99
 - control phase, 99
 - define phase, 98
 - features of, 90
 - improve phase, 99
 - measure phase, 98
- Skewness coefficient
 - calculation of, 170
- Slifker, J.F., 246
- Special causes, nature of, 66
- Specification, meaning of, 9
- Specification limits
 - compared to control limits, 472
 - compared to tolerance limits, 472
 - definition of, 9
 - and process capability analysis, 471–514
- Spider chart, 107
- Sporadic problems, 84
- Stacked bar chart, 257
- Standard, meaning of, 9
- Standard deviation
 - calculation of, 303
 - control charts for, 333
- Standardized control charts, 321
- Standardized reliability plans, 544
- Standard normal distribution, table for, 185
- Star plot, 129
- Statistic, meaning of, 154
- Statistical control
 - meaning of, 473
- Statistical process control (SPC)
 - control charts, 287–307
 - data collection, 160
 - meaning of, 12
 - online, 12
- Statistical quality control period, 5
- Statistical tolerance limits
 - based on normal distribution, 509
 - meaning of, 476
 - nonparametric, 510–511
- Statistics
 - analysis of variance (ANOVA), 578
 - approximations, 216
 - data collection, 160
 - descriptive statistics, 160
 - inferential statistics, 193
 - kurtosis coefficient, 171
 - measurement scales, 162
 - measures of association, 173
 - measures of central tendency, 163
 - measures of dispersion, 165
 - parameter, 154
 - population, 154
 - probability, 155
 - probability distribution, 177
 - sample, 291
 - sampling, 193
 - skewness coefficient, 170
 - See also* Inferential statistics
- Steering arm, 83
- Stem-and-leaf plots, 235
- Stephens, K.S., 307
- Stephens, M.A., 241
- Strategic quality management, Juran's view, 79
- Stratification patterns, control charts, 331, 332, 363, 420
- Stratified random sample, 263

- Structural characteristics, of quality, 8
- Subassemblies, tolerances on, 502
- Suitability quality audit, 110
- Supervisors, training of, 14
- Supplier relationship management, 133
- Supply chain management, 8, 31
- Survey data analyses, 17
- Survival analysis
 - confidence interval, 557
 - Kaplan-Meier estimator, 555
 - log-rank statistic, 560
 - survival function, 552, 555
- System audit, 111
- System design, Taguchi method, 625
- System of profound knowledge,
 - 56, 138
- System reliability, 534–535
- Systems approach, quality, 17
 - green supply chain, 39
- Taguchi, Genichi, 623
- Taguchi capability
 - Index C_{pm} , 484, 486, 488
- Taguchi method
 - attribute data, use of, 656
 - concept of quality, 6, 624
 - critique of, 658–659
 - estimation of effects, 649
 - linear graphs, 639
 - loss functions, 627
 - manufacturing tolerances, determination of,
 - 630, 631
 - orthogonal arrays, 639
 - parameter design, 625, 654
 - purpose of, 624
 - signal-to-noise ratio (S/N), 634
 - system design, 625
 - tolerance design, 627
- Target value
 - t-distribution, 196
 - t , values for right-tail area, 580
- Test statistic, hypothesis testing, 203
- Three-dimensional plot, 129
- 3M Company, vendor certification, 114
- Time-based competition, and benchmarking,
 - 107
- Time-oriented characteristics of quality
 - timeliness and service industries, 51
- Time-terminated test
 - with *Handbook H-108*, 549
- TL 9000 Standard, 138
- Tolerance design, Taguchi method, 627
- Tolerance limits
 - on assemblies and subassemblies, 502
 - definition of, 472
 - on individual components, 504
 - limits, 510
 - on mating parts, 505
 - natural tolerance limits, 475
 - nonparametric statistical tolerance limits, 510
 - statistical tolerance limits, 476
 - upper and lower tolerance limits, 472
- Total quality control organization wide phase,
 - 6
- Total quality control period, 6
- Total quality management (TQM)
 - basic values in, 95
 - company vision, 90
 - examples of practitioners, 93
 - features of, 90, 91
- Total quality system, definition of, 6
- Training
 - Deming's view, 58
 - supervisory, 66
- Transformations, to achieve normality
 - dependent variable, 682
 - independent variable, 682
 - Johnson transformation, 245
 - power transformation, 244
 - variance stabilizing, 687
- Transition fits, 506–507
- Treatment, in experiment, xx, 570, 571,
 - 575–596, 607, 612, 614, 616, 618, 620, 622, 660, 668
- Trend chart (regression control chart)
 - construction of, 291, 301, 306, 342, 373, 388, 409, 420, 425, 428, 439–440
- Trending patterns, control charts, 328

- Trimmed mean, calculation of, 165
- Tsui, K.L., 658
- Tukey, J.W., 239
- Tukey, P.A., 236
- Two-tailed test, 205
- Type I errors
 and control charts, 293
 hypothesis testing, 203
 and sample size, 206
- Type II errors
 and control charts, 293
 hypothesis testing and sample size, 206
- U*-chart
 construction of, 439–441
 process capability measurement, 442
- u*-chart
 process capability measurement, 442
 with variable sample size, 433
- Unbalanced experiment, 577
- Unit base index, quality cost measure, 27
- Upper capability index, 480
- Upper control limit, control charts, 288
- Upper natural tolerance limits, 475–476, 509
- Upper tolerance limits, 97
- U.S. Department of Defense, 90, 544, 554
- U.S. Food, Drug, and Cosmetic Act, 5
- Variables
 binary, 708
 continuous, 161
 dependent, 18
 discrete, 161
 experimental design, 569–660
 independent, 676, 680
 qualitative, 696
 of quality, 8–9
 quantitative, 258, 707
 response, 571, 576
- Variance
 calculation of, 166
 confidence interval, 194
 hypothesis testing, 203
 population variance, 166, 167
 sample variance, 166–168
- Variance inflation factor, 706
- Vendor certification
 example programs, 112
 quality levels, 61
- Vendors
 performance measurement of, 76
 selection of, 112
- Vision of company, and total quality management (TQM), 90
- V-mask parameters, cumulative sum chart (cusum chart), 344, 348–349
- Wadsworth, H.M., 447, 570
- Walker, E., 305
- Warning limits, control charts, 298, 303
- Wasserman, W., 174
- Wear-out phase, 530, 532
- Weibull distribution
 calculation of, 533
 failure-rate function, 531, 533
 mean time to failure, 191, 531–548
 for model failure rate, 531
- Welch, T.E., 38
- Whiskers, 236, 689
- Wild patterns, control charts, 330
- Willig, J.T., 38
- Wilson, K.B., 570, 659
- Woodall, W.H., 345
- Work standards, Deming's
 view, 69
- Wu, Y., 19, 623
- \bar{X} -chart
 control limits, 316
 interpretation of, 376
 Minitab construction, 320
 standardized values, 186, 194
 steps in construction of, 332
 variable sample size, 321

- Xerox Corporation
 - benchmarking, 38
 - and total quality management (TQM), 37
- Xie, M., 444
- Zeithaml, V. A., 48
- Zero defects (ZD)
 - ad hoc committee for, 98
 - day, 78
 - history of, 6
 - and tolerance limits, 97