

C O N T E N T S

Preface

xiii

C H A P T E R 1

SOME BASIC CONCEPTS 1

1.1	Statistics: An Information Science	2
1.2	Types of Data	5
1.3	Graphical Methods for Describing Qualitative Data	6
1.4	Graphical Methods for Describing Quantitative Data	12
1.5	Numerical Methods for Describing Quantitative Data	18
1.6	Measures of Central Tendency	18
1.7	Measures of Variation	20
1.8	Measures of Relative Standing	26
1.9	Methods for Detecting Outliers	28
1.10	Sample Statistics and Population Parameters	31
1.11	The Role of Statistics in the Sciences	31
1.12	Summary	32

C H A P T E R 2

USING THE COMPUTER (OPTIONAL) 47

2.1	Introduction	48
2.2	Entering Data into the Computer: SAS	49
2.3	Entering Data into the Computer: SPSS ^x	54
2.4	Entering Data into the Computer: Minitab	57
2.5	Entering Data into the Computer: BMDP	60
2.6	Generating a Relative Frequency Histogram and Computing Numerical Descriptive Measures: SAS	64
2.7	Generating a Relative Frequency Histogram and Computing Numerical Descriptive Measures: SPSS ^x , Minitab, and BMDP	67
2.8	Summary	69

C H A P T E R 3

PROBABILITY 71

3.1	The Role of Probability in Statistics	72
3.2	Events, Sample Spaces, and Probability	72
3.3	Some Counting Rules	82
3.4	Compound Events	93
3.5	Complementary Events	95
3.6	Conditional Probability	99
3.7	Probabilities of Unions and Intersections	104
3.8	Bayes' Rule	115
3.9	Probability and Statistics: An Example	118
3.10	Random Sampling	121
3.11	Summary	123

C H A P T E R 4**DISCRETE RANDOM
VARIABLES 131**

4.1	Discrete Random Variables	132
4.2	The Probability Distribution for a Discrete Random Variable	133
4.3	The Expected Value for a Random Variable y or for a Function $g(y)$ of y	137
4.4	Some Useful Expectation Theorems	140
4.5	The Binomial Probability Distribution	142
4.6	The Negative Binomial and the Geometric Probability Distributions	149
4.7	The Hypergeometric Probability Distribution	153
4.8	The Poisson Probability Distribution	158
4.9	Moments and Moment Generating Functions (Optional)	164
4.10	Summary	168

C H A P T E R 5**CONTINUOUS
RANDOM
VARIABLES 175**

5.1	Continuous Random Variables	176
5.2	The Density Function for a Continuous Random Variable	178
5.3	Expected Values for Continuous Random Variables	181
5.4	The Uniform Probability Distribution	187
5.5	The Normal Probability Distribution	190
5.6	Gamma-Type Probability Distributions	195
5.7	The Weibull Probability Distribution	201
5.8	Beta-Type Probability Distributions	204
5.9	Moments and Moment Generating Functions (Optional)	208
5.10	Summary	210

C H A P T E R 6**BIVARIATE
PROBABILITY
DISTRIBUTIONS 215**

6.1	Bivariate Probability Distributions for Discrete Random Variables	216
6.2	Bivariate Probability Distributions for Continuous Random Variables	221
6.3	The Expected Value of Functions of Two or More Random Variables	225
6.4	Independence	228
6.5	The Covariance of Two Random Variables	230
6.6	The Correlation Coefficient ρ	232
6.7	The Expected Value and Variance of Linear Functions of Random Variables	234
6.8	Summary	237

C H A P T E R 7**SAMPLING
DISTRIBUTIONS 241**

7.1	Sampling Distributions	242
7.2	Probability Distributions of Functions of Random Variables	242
7.3	Finding a Sampling Distribution by Simulation	249
7.4	The Sampling Distributions of Means and Sums	257
7.5	Normal Approximation to the Binomial Distribution	263
7.6	Sampling Distributions Related to the Normal Distribution	266
7.7	Generating Random Numbers by Computer (Optional)	270
7.8	Summary	274

C H A P T E R 8		
ESTIMATION	279	
8.1	Estimators	280
8.2	Properties of Point Estimators	281
8.3	Finding Point Estimators: Methods of Estimation	286
8.4	Finding Interval Estimators: The Pivotal Method	295
8.5	Estimation of a Population Mean	306
8.6	Estimation of the Difference Between Two Population Means: Independent Samples	311
8.7	Estimation of the Difference Between Two Population Means: Matched Pairs	319
8.8	Estimation of a Population Proportion	324
8.9	Estimation of the Difference Between Two Population Proportions	327
8.10	Estimation of a Population Variance	331
8.11	Estimation of the Ratio of Two Population Variances	335
8.12	Choosing the Sample Size	341
8.13	Summary	345
C H A P T E R 9		
TESTS OF HYPOTHESES	355	
9.1	Statistical Tests of Hypotheses	356
9.2	Evaluating the Properties of a Statistical Test	357
9.3	Finding Statistical Tests: An Example of a Large-Sample Test	362
9.4	Choosing the Null and Alternative Hypotheses	368
9.5	Hypothesis Tests About a Population Mean	369
9.6	Hypothesis Tests About the Difference Between Two Population Means: Independent Samples	374
9.7	Hypothesis Test About the Difference Between Two Population Means: Matched Pairs	382
9.8	Hypothesis Test About a Population Proportion	386
9.9	Hypothesis Test About the Difference Between Two Population Proportions	389
9.10	Hypothesis Test About a Population Variance	394
9.11	Hypothesis Test About the Ratio of Two Population Variances	397
9.12	The Observed Significance Level for a Test	402
9.13	Tests of Hypotheses About Means Using the Computer (Optional)	405
9.14	Summary	410
C H A P T E R 10		
SIMPLE LINEAR REGRESSION ANALYSIS	419	
10.1	Introduction	420
10.2	A Simple Linear Regression Model: Assumptions	421
10.3	Estimating β_0 and β_1 : The Method of Least Squares	424
10.4	Properties of the Least Squares Estimators	432
10.5	An Estimator of σ^2	434

10.6	Assessing the Utility of the Model: Making Inferences About the Slope β_1	438
10.7	The Coefficient of Correlation	445
10.8	The Coefficient of Determination	448
10.9	Using the Model for Estimation and Prediction	455
10.10	Simple Linear Regression: An Example	463
10.11	A Computer Printout for Simple Linear Regression	467
10.12	Summary	470

C H A P T E R 11**MULTIPLE
REGRESSION
ANALYSIS 477**

11.1	Linear Models for a Multiple Regression Analysis	478
11.2	Model Assumptions	481
11.3	Fitting the Model: The Method of Least Squares	482
11.4	The Least Squares Equations and Their Solution	483
11.5	Properties of the Least Squares Estimators	488
11.6	Estimating σ^2 , the Variance of ϵ	490
11.7	Confidence Intervals and Tests of Hypotheses for $\beta_0, \beta_1, \dots, \beta_k$	491
11.8	Checking the Utility of a Model: R^2 and the Analysis of Variance F Test	498
11.9	A Confidence Interval for a Linear Function of the β Parameters: A Confidence Interval for $E(y)$	505
11.10	A Prediction Interval for Some Value of y to Be Observed in the Future	512
11.11	Computer Printouts for a Multiple Regression Analysis	514
11.12	Some Pitfalls: Estimability, Multicollinearity, and Extrapolation	519
11.13	Residual Analysis	528
11.14	Running a Multiple Regression Analysis on the Computer (Optional)	536
11.15	Summary	539

C H A P T E R 12**INTRODUCTION
TO MODEL
BUILDING 555**

12.1	Introduction	556
12.2	The Two Types of Independent Variables: Quantitative and Qualitative	557
12.3	Models with a Single Quantitative Independent Variable	559
12.4	Models with Two Quantitative Independent Variables	566
12.5	Coding Quantitative Independent Variables (Optional)	572
12.6	Model Building: Testing Portions of a Model	579
12.7	Models with One Qualitative Independent Variable	587
12.8	Comparing the Slopes of Two or More Lines	593
12.9	Comparing Two or More Response Curves	605
12.10	Model Building: Stepwise Regression	610
12.11	Stepwise Regression on the Computer (Optional)	619
12.12	Summary	621

C H A P T E R 13**THE ANALYSIS OF
VARIANCE FOR
DESIGNED
EXPERIMENTS 631**

13.1	Introduction	632
13.2	Experimental Design: Terminology	632
13.3	Controlling the Information in an Experiment	633
13.4	The Logic Behind an Analysis of Variance	634
13.5	The Analysis of Variance for a Completely Randomized Design	637
13.6	The Analysis of Variance for a Randomized Block Design	648
13.7	The Analysis of Variance for a Two-Way Classification of Data: Factorial Experiments	661
13.8	The Relationship Between Analysis of Variance and Regression	677
13.9	The Analysis of Variance for a k -Way Classification of Data (Optional)	692
13.10	A Procedure for Making Multiple Comparisons	702
13.11	Assumptions	705
13.12	Computer Printouts for an Analysis of Variance	706
13.13	Computer Programs for the Analysis of Variance (Optional)	709
13.14	Summary	714

C H A P T E R 14**THE ANALYSIS OF
VARIANCE FOR
NESTED SAMPLING
DESIGNS 727**

14.1	Introduction	728
14.2	The Analysis of Variance for a Two-Stage Nested Sampling Design	729
14.3	The Analysis of Variance for a Three-Stage Nested Sampling Design	737
14.4	Estimating a Population Mean Based on Nested Sampling	745
14.5	Some Comments on the Theory Underlying a Nested Sampling Design	749
14.6	Comparing Two or More Population Means Using Nested Sampling	753
14.7	Computer Printouts for a Nested Sampling Design	761
14.8	Computer Programs for a Nested Sampling Design (Optional)	762
14.9	Summary	769

C H A P T E R 15**THE ANALYSIS OF
ENUMERATIVE
DATA 773**

15.1	Count Data and the Multinomial Experiment	774
15.2	The Multinomial Probability Distribution	775
15.3	Estimating Category Probabilities	777
15.4	Testing Hypotheses About the Category Probabilities	781
15.5	Contingency Tables	785
15.6	Contingency Tables with Fixed Marginal Totals	793
15.7	Computer Printouts for a Contingency Table Analysis	798
15.8	Computer Programs for a Contingency Table Analysis (Optional)	799
15.9	Summary	806

C H A P T E R 16**NONPARAMETRIC
STATISTICS 815**

16.1	Introduction	816
16.2	The Sign Test for a Single Population	817
16.3	Comparing Two Populations: The Wilcoxon Rank Sum Test for Independent Random Samples	822

CONTENTS

16.4	Comparing Two Populations: The Wilcoxon Signed Ranks Test for a Matched-Pairs Design	831
16.5	The Kruskal–Wallis H Test for a Completely Randomized Design	839
16.6	The Friedman F_r Test for a Randomized Block Design	845
16.7	Spearman's Rank Correlation Coefficient	851
16.8	Summary	858

C H A P T E R 17**APPLICATIONS:
PRODUCT AND
SYSTEM
RELIABILITY**

869

17.1	Introduction	870
17.2	Failure Time Distributions	870
17.3	Hazard Rates	871
17.4	Life Testing: Censored Sampling	876
17.5	Estimating the Parameters of an Exponential Failure Time Distribution	877
17.6	Estimating the Parameters of a Weibull Failure Time Distribution	881
17.7	System Reliability	887
17.8	Summary	892

C H A P T E R 18**APPLICATIONS:
QUALITY
CONTROL**

899

18.1	Introduction	900
18.2	Control Chart for Means: \bar{x} -Chart	901
18.3	Control Chart for Process Variation: R -Chart	910
18.4	Detecting Trends in a Control Chart: Runs Analysis	912
18.5	Control Chart for Percent Defectives: p -Chart	914
18.6	Control Chart for the Number of Defects per Item: c -Chart	918
18.7	Tolerance Limits	922
18.8	Acceptance Sampling for Defectives	926
18.9	Other Sampling Plans	932
18.10	Evolutionary Operations	933
18.11	Summary	935

A P P E N D I X I**MATRIX ALGEBRA**

I.1	Matrices and Matrix Multiplication	940
I.2	Identity Matrices and Matrix Inversion	945
I.3	Solving Systems of Simultaneous Linear Equations	949
I.4	A Procedure for Inverting a Matrix	952

A P P E N D I X II**USEFUL STATISTICAL
TABLES**

Table 1	Random Numbers	959
Table 2	Binomial Probabilities	962
Table 3	Exponentials	965
Table 4	Normal Curve Areas	967
Table 5	Gamma Function	968
Table 6	Critical Values of t	969
Table 7	Critical Values of χ^2	970

Table 8	Percentage Points of the F Distribution, $\alpha = .10$	972
Table 9	Percentage Points of the F Distribution, $\alpha = .05$	974
Table 10	Percentage Points of the F Distribution, $\alpha = .025$	976
Table 11	Percentage Points of the F Distribution, $\alpha = .01$	978
Table 12	Critical Values of the Sample Coefficient of Correlation, r	980
Table 13	Percentage Points of the Studentized Range $q(p, \nu)$, $\alpha = .05$	981
Table 14	Percentage Points of the Studentized Range $q(p, \nu)$, $\alpha = .01$	983
Table 15	Critical Values of T_L and T_U for the Wilcoxon Rank Sum Test: Independent Samples	985
Table 16	Critical Values of T_0 in the Wilcoxon Matched-Pairs Signed Ranks Test	986
Table 17	Critical Values of Spearman's Rank Correlation Coefficient	987
Table 18	Factors Used When Constructing Control Charts	988
Table 19	Values of K for Tolerance Limits for Normal Distributions	989
Table 20	Sample Size n for Nonparametric Tolerance Limits	990
Table 21	Sample Size Code Letters: MIL-STD-105D	990
Table 22	A Portion of the Master Table for Normal Inspection (Single Sampling): MIL-STD-105D	991
APPENDIX III	DDT ANALYSES ON FISH SAMPLES, TENNESSEE RIVER, ALABAMA	993
APPENDIX IV	CENTRAL PROCESSING UNIT (CPU) TIMES OF 1,000 COMPUTER JOBS	997
APPENDIX V	PERCENTAGE IRON CONTENT FOR 390 IRON ORE SPECIMENS	1001
	Answers to Selected Exercises	1005
	Index	1031