Software Verification and Validation for Commercial Statistical Packages Utilized by the Statistical Consulting Section of SRTC

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Revisions Page

Revision No.	Date	Revision
1	10/31/2000	JMP Version 4 was added to the baseline software list.

ABSTRACT

The purpose of this report is to provide software verification and validation (v&v) for the statistical packages utilized by the Statistical Consulting Section (SCS) of the Savannah River Technology Center (SRTC). The need for this v&v stems from the requirements of the Quality Assurance (QA) programs that are frequently applicable to the work conducted by SCS. This document is designed to comply with software QA requirements specified in the 1Q Manual Quality Assurance Procedure 20-1, Revision 6. The SCS baseline software history covering this revision of our software QA plan is provided in the following tables

Revision 0 – SCS Baseline Software List

Computing Platform	Operating System	Software	Version	Software User's Manuals
IBM Personal Computer 300PL or IBM Personal Computer 300XL (i.e., any Pentium II processor)	Windows NT Version 4.0	JMP®	3.2.2	JMP® User's Guide, Version 3 (1995)
		Microsoft Excel®	97 SR-1	Site-licensed software; no manual distributed
		MIXSOFT™	2.3	MIXSOFT™ User's Guide Version 2.3 (1998)
		Statgraphics Plus®	4.0	Statgraphics Plus® Standard Edition (1998)
Digital AlphaServer Model 4100 5/533	VMS-AXP Open VMS V7	SAS®	6.12	SAS Procedures Guide, Ver 6, 3rd Edition (1990) SAS/STAT User's Guide Volumes 1 &2 (1990) SAS/QC Software: Reference, Ver 6, 1st Ed (1989) SAS/IML Software: Usage & Ref, Ver 6,3rd Ed (1990)

Revision – 1: SCS Baseline Software List

Computing Platform	Operating System	Software	Version	Software User's Manuals
IBM Personal Computer 300PL or IBM Personal Computer 300XL (i.e., any Pentium II processor)	Windows NT Version 4.0	JMP®	3.2.2	JMP® User's Guide, Version 3 (1995)
		JMP®	4.0	JMP® User's Guide, Version 4 (2000)
		Microsoft Excel®	97 SR-1	Site-licensed software; no manual distributed
		MIXSOFT™	2.3	MIXSOFT™ User's Guide Version 2.3 (1998)
		Statgraphics Plus®	4.0	Statgraphics Plus® Standard Edition (1998)
Digital AlphaServer Model 4100 5/533	VMS-AXP Open VMS V7	SAS®	6.12	SAS Procedures Guide, Ver 6, 3rd Edition (1990) SAS/QC Software: Reference, Ver 6, 1st Ed (1989) SAS/STAT User's Guide Volumes 1 &2 (1990) SAS/IML Software: Usage & Ref, Ver 6,3rd Ed (1990)

Revision 1 of this QA plan adds JMP Version 4 to the family of (commercially-available) statistical tools utilized by SCS. JMP Version 3.2.2 is maintained as a support option due to features unique to this version of JMP that have not as yet been incorporated into Version 4. SCS documents that include JMP output should provide a clear indication of the version or versions of JMP that were used. The IBM Personal Computer 300PL and 300XL are both Pentium II based desktops. Therefore, the software verification and validation in this report is valid interchangeably between both platforms. As new computing platforms, statistical packages, or revisions to existing packages are introduced into the Statistical Consulting Section, the appropriate problems from this report are to be re-evaluated, and this report is to be revised to address their verification and validation.

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INTRODUCTION

The mission of the Statistical Consulting Section (SCS) of the Savannah River Technology Center (SRTC) is to apply statistical thinking, methods, and computing in collaborative decision support, technology development, and continuous improvement at the Savannah River Site and to disseminate our knowledge and experience into the Federal Government complex via Department of Energy (DOE) sponsored work. Computers and computer software are essential tools utilized by the SCS statisticians in pursuit of this mission. Many of these software programs are site-licensed and general purpose while some are special-purpose statistical packages.

As a general rule, memoranda, research reports, and technical reports prepared by members of SCS in response to customer requests for assistance are technically reviewed as part of the quality assurance (QA) for the section.[1] In SRTC, calculations are frequently checked by alternate means (e.g., hand calculations) performed by an independent reviewer, but this is not always completely possible on modeling or other complicated calculations performed by some software programs. However, the technical review would certainly include an assessment of the appropriateness of the statistical approach and routines utilized in the document. In addition, validation and verification (v&v) of the software utilized for the analysis are frequently requirements of the applicable QA program directing the investigation. These requirements are typically addressed uniquely in the document or in the supporting task plan, etc. The purpose of this report is to provide a central repository for the software verification and validation (v&v) for the statistical packages utilized by SCS. This document also demonstrates the v&v of some simple statistical software such as Excel. As new computing platforms, statistical packages, or revisions to existing packages are introduced into the Statistical Consulting Section, the appropriate problems from this report or new problems are to be evaluated using these new tools, and this report is to be revised to address their v&v.

Software Classification

The software considered in this report is commercial software (some of which is site-licensed), and these packages are considered to have a Level D software classification (as defined in the WSRC 1Q Quality Assurance Manual, QAP 20-1, Revision 6) in that they are important to day to day operation of the business and analyses conducted by SCS, but their failure to perform as intended at any point in time will not affect the safety or reliability of SRS facilities.

Software Configuration Management and Control

This report specifies the SCS plan for software configuration management and control, which covers the use of off-the-shelf, commercially available software by SCS members to perform work associated with RW-0333P (or similar) tasks. The SCS section manager controls, via the purchase approval process, the introduction into the section of new software or new versions of existing software for general use. The purchase approval process, under the section manager’s direction, also controls the software available to each SCS member for his or her statistical support activities. This report is to be revised to include a new software product before the software is used by an SCS member in support of a task requiring software v&v at the RW-0333P QA level. The SCS section manager controls the revision of the report (via the document approval process).

When the QA requirements for the work being conducted by a member of SCS include software v&v (e.g., RW-0333P tasks), the SCS member must clearly identify (as part of his/her task deliverable) the commercial software package(s) used to support the analyses. This identification should include the name of the software, the version number, and the vendor. A reference to the appropriate revision of this document may also be included in the deliverable, if this is seen as beneficial.

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[1] Such reviews may be a requirement of the applicable QA program directing a particular technical task.

SCS BASELINE SOFTWARE LIST

The initial SCS baseline software list identified in Revision 0 of this report is provided in Table 1.0.

Table 1.0: SCS Baseline Software List – Revision 0

Computing Platform	Operating System	Software	Version	Software User's Manuals
IBM Personal Computer 300PL or IBM Personal Computer 300XL (i.e., any Pentium II processor)	Windows NT Version 4.0	JMP®	3.2.2	JMP® User's Guide, Version 3 (1995)
		Microsoft® Excel	97 SR-1	Site-licensed software; no manual distributed
		MIXSOFT™	2.3	MIXSOFT™ User's Guide Version 2.3 (1998)
		Statgraphics Plus®	4.0	Statgraphics Plus® Standard Edition (1998)
Digital AlphaServer Model 4100 5/533	VMS-AXP Open VMS V7	SAS®	6.12	SAS Procedures Guide, Ver 6, 3rd Edition (1990) SAS/QC Software: Reference, Ver 6, 1st Ed (1989) SAS/STAT User's Guide Volumes 1 &2 (1990) SAS/IML Software: Usage & Ref, Ver 6,3rd Ed (1990)

The current revision (Revision 1) of this report covers the software and computing platforms as identified in Table 1.1. The information in this table establishes the baseline software to be used by members of SCS, where warranted by the applicable QA requirements.

Table 1.1: SCS Baseline Software List – Revision 1

Computing Platform	Operating System	Software	Version	Software User's Manuals
IBM Personal Computer 300PL or IBM Personal Computer 300XL (i.e., any Pentium II processor)	Windows NT Version 4.0	JMP®	3.2.2	JMP® User's Guide, Version 3 (1995)
		JMP®	4.0	JMP® User's Guide, Version 4 (2000)
		Microsoft® Excel	97 SR-1	Site-licensed software; no manual distributed
		MIXSOFT™	2.3	MIXSOFT™ User's Guide Version 2.3 (1998)
		Statgraphics Plus®	4.0	Statgraphics Plus® Standard Edition (1998)
Digital AlphaServer Model 4100 5/533	VMS-AXP Open VMS V7	SAS®	6.12	SAS Procedures Guide, Ver 6, 3rd Edition (1990) SAS/QC Software: Reference, Ver 6, 1st Ed (1989) SAS/STAT User's Guide Volumes 1 &2 (1990) SAS/IML Software: Usage & Ref, Ver 6,3rd Ed (1990)

The IBM Personal Computer 300PL and 300XL are both Pentium II based desktops. Therefore, the software v&v in this report is valid interchangeably between both platforms. JMP is a product of SAS Institute, Inc. [1 and 14]. In Revision 1 of this report, Versions 3.2.2 and 4.0 are included in the software baseline list. There are no known problems in Version 3.2.2 that are corrected by Version 4.0. JMP Version 4.0 offers a different "look and feel" that is better than Version 3.2.2 in many ways. Thus, using Version 4.0 has its advantages. However, for certain problems, Version 3.2.2 provides solution capabilities that are not featured in Version 4.0. Thus, to maintain functionality, there is a need to include both versions of the JMP software in the SCS baseline list.

The SAS® system is a set of products. Those considered in this report include Base SAS [2], SAS/QC [3], SAS/STAT [4 and 5], and SAS/IML [6]. Microsoft® Excel is a site-licensed product at the Savannah River Site.[2] Mixsoft [7] is a specialized software program for mixtures and other constrained-region problems. Statgraphics [8] contains numerous statistical routines and is a product of Manugistics, Inc. Other products (such as terminal emulation and virus protection packages) are also involved in the utilization of these platforms and software. These are not deemed important to the performance of the statistical programs and are not reviewed in this report. The results from using each of the above packages to analyze the problems discussed below are organized by package as an appendix to this report.

The discussion that follows will demonstrate that the commercial software utilized by SCS will perform correctly, as designed. The SRTC approach is to take problems with known solutions from peer reviewed publications and run them on the commercial software to demonstrate that the vendor's program does indeed perform as designed. The solutions of these problems are generated using software routines that are frequently utilized at SRTC. Running these routines using SRTC platforms and systems software and generating the appropriate answers to the "textbook" problems demonstrates the v&v of the software under consideration.

DISCUSSION

In this section, problem types frequently encountered by members of SCS are identified. An example of each problem is selected from a well-established statistical textbook. The example is analyzed using a feature or features of the appropriate software described in the previous section. The results generated by the various software packages are compared to the information from the textbook and/or to each other for validation and verification. Little discussion is provided regarding the details of the problems, the underlying statistical theory, the statistical routines, or the statistical results. Information about the statistical packages, their capabilities, and details regarding their outputs can be found in their respective published documentation. These references, along with those cited as the sources of the problems, may be used to provide these details. The purpose of this report is show that the statistical packages, when used appropriately, provide reliable results.

Descriptive Statistics

The first area to be explored in this report is that of descriptive statistics, summary information about a set of data. Consider the set of data presented in Table 2, which is taken from Table 2.1 on page 40 of reference [9].

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2 Microsoft® is a registered trademark of Microsoft Corporation.

Table 2: Data on Lot Size and Number of Man-Hours

Production Run	Lot Size	Man-Hours
i	X_i	Y_i
1	30	73
2	20	50
3	60	128
4	80	170
5	40	87
6	50	108
7	60	135
8	30	69
9	70	148
10	60	132

From [9], the average of the lot size values, $\overline{X}$, is equal to 50 (see page 46), and several graphical depictions (including a Box Plot, Time Plot, and Stem-and-leaf Plot) of these lot size values are provided on page 114 of [9].

Using Excel Version 97 SR-1 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into Excel and the Excel Tools/Data Analysis/Descriptive Statistics pull-down menus were used to obtain descriptive statistics on the lot-size values that were cut and pasted into this report as Table A.1a in Appendix A. There are Excel functions that provide descriptive statistics as well. Table A.1b provides the results of applying some of these functions to the lot-size values.

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into JMP Version 3.2.2, and the descriptive statistics capability of JMP (the Distribution-of-Y platform) was used to generate Exhibit B.1 in Appendix B for the lot size values. These results were determined by JMP Version 3.2.2, saved using JMP's journal feature, and imported (electronically) directly into this report. The average of the lot size values, 50, is included in the information presented by JMP. A Box Plot, a Stem-and-leaf plot, and a time plot (a plot by production run number) are also provided; these compare very favorably to the information on page 114 of [9].

Using SAS Version 6.12 on the AlphaServer Running Open VMS V7

The data from Table 2 were included in a SAS program that used PROC MEANS, PROC SUMMARY, and PROC UNIVARIATE to generate some descriptive statistics for the lot size values. The SAS program and results were downloaded to the PC and incorporated in this report. This information is provided in Exhibit C.1 of Appendix C.

Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into Statgraphics and the numeric data one variable analysis routine of Statgraphics was used to generate Exhibit E.1 in Appendix E for the lot size values. These results were saved using Statgraphics StatReporter feature, and imported (electronically) directly into this report. The average of the lot size values, 50, is included in the information presented by Statgraphics. A Scatter Plot, a Box-and-Whisker Plot, a Histogram, a Stem-and-leaf plot, and a Normal Probability Plot are also provided. The results compare very favorably to the information on page 114 of [9] and to the JMP output in Exhibit B.1.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into JMP Version 4.0, and the descriptive statistics capability of JMP Version 4.0 (the Distribution-of-Y platform) was used to generate Exhibit F.1 in Appendix F for the lot size values. These results were determined by JMP Version 4.0, saved using JMP's journal feature, and imported (electronically) directly into this report. The average of the lot size values, 50, is included in the information presented by JMP Version 4.0. A Box Plot, a Stem-and-leaf plot, and a time plot (a plot by production run number) are also provided; these compare very favorably to the information on page 114 of [9].

Descriptive Statistics Summary Table

The critical descriptive information generated by the software packages reviewed above is summarized in Table 3.

Table 3: Summary of Descriptive Statistics for Lot-Size Values by Software Package

Source of Information/ Software Package	Mean	Standard Deviation	Standard Error
As described in [9] on page 46	50		
Excel Version 97 SR-1 on PC running Windows NT Version 4	50	19.4365	6.1464
JMP Version 3.2.2 on PC running Windows NT Version 4	50	19.4365	6.1464
SAS/STAT Version 6.12 on AlphaServer Running OpenVMS V7 PROCs MEAN, SUMMARY, and UNIVARIATE	50	19.4365	6.1464
Statgraphics Version 4.0 on PC running Windows NT Version 4.0	50	19.4365	6.1464
JMP Version 4.0 on PC running Windows NT Version 4	50	19.4365	6.1464

Table 3 summarizes what is revealed in the details of the related exhibits: a consistent set of values for the descriptive statistics from these software packages across the computer platforms for the Table 2 data. Please note, however, that the output from the different packages often includes different statistics.

Regression

The information presented in Table 2 also provides an opportunity for a look at various regression routines in fitting the simple linear model

$$Y = \beta_0 + \beta_1 X + \varepsilon \qquad (1)$$

where Y represents man-hours, X represents lot-size, the β's represent the unknown coefficients that are to be estimated, and ε represents the error term (assumed to be independently, normally distributed with zero mean and constant variance over the Y's.)

From page 44 of [9], the estimate of the y-intercept, β_0, is represented by b_0 and is determined to be 10.0, and the estimate of the slope, β_1, is represented by b_1 and is determined to be 2.0.

Using Excel Version 97 SR-1 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into Excel and used to fit the model given in equation (1). Two methods were used to analyze these data with Excel. Tools/Data Analysis/Regression pull-down menus were used to fit the data to the model given by equation (1). The results were cut and pasted into this report as Table A.2 in Appendix A.

The matrix handling capability of Excel was also used to perform the least-squares estimation of the regression parameters. The discussion of this approach to the data of Table 2 is provided in [9] on pages 207 and 208. The results from using Excel's matrix handling capability to analyze this problem were cut and pasted into this report as Table A.3 in Appendix A.

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into JMP Version 3.2.2 and used to fit the model given in equation (1). Two methods were used to analyze these data with JMP Version 3.2.2. Exhibit B.2 in Appendix B provides the results from using the Fit Y By X platform to perform this analysis.

Exhibit B.3 in Appendix B provides the results from using the Fit Model platform to perform the analysis. In both cases, the JMP Version 3.2.2 results were journaled and imported into this report, and in both cases, the estimates for the slope and y-intercept are 2 and 10, respectively.

Using SAS Version 6.12 on AlphaSever Running Open VMS V7

The SAS set of procedures provides several ways of analyzing the data from Table 2. Exhibit C.2 in Appendix C provides the SAS/STAT program that utilizes PROC REG to perform the regression. Exhibit C.3 in Appendix C provides a SAS/IML program that estimates the β's .

Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into Statgraphics and used to fit the model given in equation (1). The Simple Regression method was used. The results are included in Exhibit E.2 in Appendix E. The StatReporter routine in Statgraphics was used to import the results into this report. The estimates for the slope and y-intercept are 2 and 10, respectively.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 2 were entered into JMP Version 4.0 and used to fit the model given in equation (1). Two methods were used to analyze these data with JMP Version 4.0. Exhibit F.2 in Appendix F provides the results from using the Fit Y By X platform to perform this analysis. Exhibit F.3 in Appendix F provides the results from using the Fit Model platform to perform the analysis. In both cases, the JMP Version 4.0 results were journaled and imported into this report, and in both cases, the estimates for the slope and y-intercept are 2 and 10, respectively.

Regression Summary Table

The critical regression information generated by the software packages reviewed above is summarized in Table 4 along with the results from [9].

Table 4: Summary of Regression Statistics for Each Software Package

Source of Information/ Software Package	Estimate of Intercept	Estimate of Slope	R^2	Root Mean Square Error
As discussed in [9] on page 44	10	2		
Excel Version 97 SR-1 on a PC running Windows NT Version 4--- Regression	10	2	0.9956	2.7386
Excel Version 97 SR-1 on a PC running Windows NT Version 4--- Matrix handling capability	10	2		
JMP Version 3.2.2 on a PC running Windows NT Version 4 --- Fit Y by X	10	2	0.9956	2.7386
JMP Version 3.2.2 on a PC running Windows NT Version 4 --- Fit Model	10	2	0.9956	2.7386
SAS/STAT Version 6.12 on AlphaServer Running OpenVMS V7 PROC REG	10	2	0.9956	2.7386
SAS/IML Version 6.12 on Alphaserver Running OpenVMS V7	10	2		
Statgraphics Version 4.0 on a PC running Windows NT Version 4.0	10	2	0.9956	2.7386
JMP Version 4.0 on a PC running Windows NT Version 4 --- Fit Y by X	10	2	0.9956	2.7386
JMP Version 4.0 on a PC running Windows NT Version 4 --- Fit Y by X	10	2	0.9956	2.7386

Table 4 summarizes what is revealed in the related exhibits: a consistent set of regression results from these software packages across these computer platforms for the Table 2 data.

ANOVA

Analysis of variance (ANOVA) models are versatile statistical tools for studying the relation between a dependent variable and one or more independent variables [9]. Several of these models are investigated in this section.

One-Way ANOVA

The example provided in Table 5 is from Table 14.1 on page 533 of [9]. In this table are recorded the number of cases sold by store for each of four package designs. An ANOVA is used to investigate for differences in sales across the four package designs.

Table 5: Number of Cases Sold by Stores for Each of Four Package Designs---Kenton Food Company Example

	Cases Sold by Store		
Package		Store	
Design	1	2	3
1	12	18	
2	14	12	13
3	19	17	21
4	24	30	

The discussion in [9] leads to the ANOVA results presented in Table 6 (this information appears as Table 14.4 on page 543 in [9]).

Table 6: ANOVA for Kenton Food Company Example

Source of Variation	SS	df	MS
Between designs	258	3	86
Error	46	6	7.67
Total	304	9	

Using Excel Version 97 SR-1 on a Pentium II Processor Running Windows NT Version 4

The data from Table 5 were entered into Excel, and Tools/Data Analysis/ANOVA: Single Factor pull-down menus were used conduct the analysis of variance. The results were cut and pasted into this report as Table A.4 in Appendix A.

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

The data from Table 5 were entered into JMP Version 3.2.2, and the Fit Model platform was used to analyze these data. Exhibit B.4 in Appendix B provides the JMP Version 3.2.2 results that were journaled and imported into this report.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

Two different tools available in the SAS system were used to analyze the data from Table 5. Exhibit C.4 in Appendix C provides the input and results of PROC ANOVA, and Exhibit C.5 in Appendix C provides this information for PROC GLM.

Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 5 were entered into Statgraphics, and the One-Way ANOVA routine was used to analyze these data. Exhibit E.3 in Appendix E provides the Statgraphics results that were imported into this report using StatReporter.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 5 were entered into JMP Version 4.0, and the Fit Model platform was used to analyze these data. Exhibit F.4 in Appendix F provides the JMP Version 4.0 results that were journaled and imported into this report.

One-Way ANOVA Summary Table

Some of the critical information from the ANOVA tables generated by the software packages reviewed above is summarized in Table 7 along with the results from [9].

Table 7: One-Way ANOVA Summary Statistics for Each Software Package

Source of Information/ Software Package	Sum of Squares Between	Sum of Squares For Error	Mean Squares for Designs	F Statistic for Differences
As discussed in [9] pages 543 and 548	258	46	86	11.2
Excel Version 97 SR-1 on Windows NT Version 4--- ANOVA: Single Factor	258	46	86	11.217
JMP Version 3.2.2 on a PC running Windows NT Version 4 --- Fit Model	258	46	86	11.217
SAS/STAT Version 6.12 on Alphaserver Running OpenVMS V7 PROC ANOVA	258	46	86	11.217
SAS/STAT Version 6.12 on Alphaserver Running OpenVMS V7 PROC GLM	258	46	86	11.217
Statgraphics Version 4.0 on a PC running Windows NT Version 4	258	46	86	11.22
JMP Version 4.0 on a PC running Windows NT Version 4 --- Fit Model	258	46	86	11.217

Table 7 summarizes what is revealed in the related exhibits: a consistent set of ANOVA results from these software packages across these computer platforms for the Table 3 data.

One-Way ANOVA with Random Factor

The example provided in Table 8 is from Table 17.3 on page 654 of [9]. In this table are recorded the ratings by five (randomly selected) personnel officers of Apex Enterprises for four randomly assigned (to each officer) candidates. An ANOVA is used to estimate the variation in ratings among all personnel officers of this company.

Table 8: Ratings by Personnel Officers of Apex Enterprises [9]

Officer	Candidate (j)			
(i)	1	2	3	4
A	76	64	85	75
B	58	75	81	66
C	49	63	62	46
D	74	71	85	90
E	66	74	81	79

The ANOVA for this problem is generated as in the previous section, but the interpretation of the information in the ANOVA under the conditions of a random factor lead to some additional calculations used to estimate the variance in ratings among the personnel officers. A discussion of the details of this estimation process is provided on page 660 of [9], leading to an estimate of 73.6 for this variance. Currently, Excel does not automatically generate this estimate as part of its ANOVA: Single Factor routine.

<u>Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4</u>

The data from Table 8 were entered into JMP Version 3.2.2, and the Fit Model platform was used (with a random factor designated in the fit) to analyze these data. Exhibit B.5 in Appendix B provides the JMP Version 3.2.2 results that were journaled and imported into this report.

<u>Using SAS Version 6.12 on AlphaServer Running Open VMS V7</u>

PROC GLM and PROC VARCOMP demonstrate the capability of SAS to handle this type of problem for the data in Table 8. The inputs and results from each of these two procedures for solving this problem are provided in Exhibits C.6 and C.7 in Appendix C.

<u>Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4</u>

The data from Table 8 were entered into Statgraphics, and the ANOVA-Variance Components routine was used to analyze these data. Exhibit E.4 in Appendix E provides the Statgraphics results that were imported into this report using StatReporter

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 8 were entered into JMP Version 4.0, and the Fit Model platform was used (with a random factor designated in the fit) to analyze these data. Exhibit F.5 in Appendix F provides the JMP Version 4.0 results that were journaled and imported into this report.

One-Way ANOVA (with a Random Factor) Summary Table

Some of the critical information from the ANOVA tables generated by the software packages reviewed above is summarized in Table 9 along with the results from [9]. Note that PROC GLM provides the equation for solving for the desired estimate. Using this equation along with the ANOVA information leads to an estimate of 73.6 for the rating variance.

Table 9: One-Way ANOVA (Random Factor) Summary Statistics for Each Software Package

Source of Information/ Software Package	Sum of Squares Between	Sum of Squares For Error	Mean Squares for Offices	Estimate of Rating Variance
As discussed in [9] pages 655 and 660	1480	1134	370	73.6
JMP Version 3.2.2 on a PC running Windows NT Version 4 --- Fit Model (random)	1480	1134	370	73.6
SAS Version 6.12 on Alphaserver Running OpenVMS V7 PROC GLM	1480	1134	370	73.6
SAS Version 6.12 on Alphaserver Running OpenVMS V7 PROC VARCOMP	1480	1134	370	73.6
Statgraphics Version 4.0 on a PC running Windows NT Version 4.0	1480	1134	370	73.6
JMP Version Version 4.0 on a PC running Windows NT Version 4 --- Fit Model (random; traditional approach)	1480	1134	370	73.6

Table 9 summarizes what is revealed in the details of the exhibits covering this example: a consistent set of ANOVA results for these software packages across these computer platforms for the data of Table 8.

Two-Way ANOVA

The example provided in Table 10 is from Table 21.2 on page 787 of [9]. In this table automobile insurance premiums (in dollars) are provided for a city of small, medium, and large size in each of two regions (East and West) of the US. An ANOVA is used to investigate differences between the regions and among the cities. An assumption is made that there is no interaction between these two factors.

Table 10: Insurance Premiums [9]

Insurance Premiums in Dollars			
		Region	
		East	West
Size of City	Small	140	100
	Medium	210	180
	Large	220	200

The discussion in [9] leads to the ANOVA results presented in Table 11 (this information also appears in Table 21.2 on page 787 in [9]).

Table 11: ANOVA for Insurance Example

Source of Variation	SS	df	MS
Size of City	9,300	2	4,650
Region	1,350	1	1,350
Error	100	2	50
Total	10,750	5	

Using Excel Version 97 SR-1 on a Pentium II Processor Running Windows NT Version 4

The data from Table 10 were entered into Excel, and Tools/Data Analysis/ANOVA: Two Factors Without Replication pull-down menus were used conduct the analysis of variance. The results were cut and pasted into this report as Table A.5 in Appendix A.

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

The data from Table 10 were entered into JMP Version 3.2.2, and the Fit Model platform was used to analyze these data. Exhibit B.6 in Appendix B provides the JMP Version 3.2.2 results that were journaled and imported into this report.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

The data from Table 10 were analyzed using PROC ANOVA and PROC GLM of the SAS system. Exhibits C.8 and C.9 in Appendix C provide the inputs and results from using these two procedures to perform this analysis.

Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 10 were entered into Statgraphics, and the Multi Factor ANOVA routine was used to analyze these data. Exhibit E.5 in Appendix E provides the Statgraphics results that were imported into this report using StatReporter

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 10 were entered into JMP Version 4.0, and the Fit Model platform was used to analyze these data. Exhibit F.6 in Appendix F provides the JMP Version 4.0 results that were journaled and imported into this report.

Two-Way ANOVA Summary Table

Some of the critical information from the ANOVA tables generated by the software packages reviewed above is summarized in Table 12 along with the results from [9].

Table 12: Two-Way ANOVA Summary Statistics for Each Software Package

Source of Information/ Software Package	Sum of Squares for City Size	Sum of Squares For Region	Sum of Squares for Error	F Statistic for Region
As discussed in [9] pages 787 and 788	9300	1350	100	27
Excel Version 97 SR-1 on a PC running Windows NT Version 4--- ANOVA: Two-Factors without replication	9300	1350	100	27
JMP Version 3.2.2 on a PC running Windows NT Version 4 --- Fit Model	9300	1350	100	27
SAS Version 6.12 on Alphaserver Running OpenVMS V7 PROC ANOVA	9300	1350	100	27
SAS Version 6.12 on Alphaserver Running OpenVMS V7 PROC GLM	9300	1350	100	27
Statgraphics Version 4.0 on a PC running Windows NT Version 4	9300	1350	100	27
JMP Version 4.0 on a PC running Windows NT Version 4 --- Fit Model	9300	1350	100	27

Table 12 summarizes what is revealed in the exhibits covering this example: a consistent set of ANOVA results from these software packages across these computer platforms for the data of Table 10.

Two-Factor Nested ANOVA

A nested two-factor model differs from the previous two-factor (crossed) model in that the levels of the second factor are unique to each level of the first factor. An example of this situation is provided in Table 13 (this example is provided as Table 26.1 on page 971 of [9]).

Table 13: Sample Data for Nested Two-Factor Study
(Training School Example from [9])

Factor A (School)	Factor B (Instructor) 1	2
Atlanta	25	14
	29	11
Chicago	11	22
	6	18
San Francisco	17	5
	20	2

The discussion in [9] leads to the ANOVA results presented in Table 14 (this information appears in Table 26.5 on page 981 in [9]).

Table 14: ANOVA for Training School Example Example

Soure of Variation	SS	df	MS
Schools	156.5	2	78.25
Instructors within Schools	567.5	3	189.17
Error	42.0	6	7.00
Total	766.0	11	

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

The data from Table 13 were entered into JMP Version 3.2.2, and the Fit Model platform was used to analyze these data. Exhibit B.7 in Appendix B provides the JMP Version 3.2.2 results that were journaled and imported into this report.

If both of these factors were random instead of fixed for the data in Table 13, the questions of interest would be different (what variation in scores is due to school? and what variation in scores is due to instructor?) and the test statistics to answer these questions would be different (this is discussed on page 984 of [9]). JMP Version 3.2.2 handles this type of problem in its Fit Model platform. Using this approach leads to the results presented in Exhibit B.8 in Appendix B.

From the discussion of page 985 of [9], the test statistics for this random-effects problem are given by

$$\textbf{Test for schools}: \mathbf{F} = \mathbf{MSA}/\mathbf{MSB(A)} = 78.25/189.17 = 0.414$$

and

$$\textbf{Test for instructors}: \mathbf{F} = \mathbf{MSB(A)}/\mathbf{MSE} = 189.17/7 = 27.0$$

From Exhibit B.8, the test statistic for schools is 0.414 and for instructors is 27.0.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

The SAS system's PROC ANOVA was used to analyze the data in Table 13 and the results are presented in Exhibit C.10. Exhibit C.11 provides the results from the use of PROC GLM to analyze these same data.

If both factors are assumed to be random, there are still at least two-ways to analyze these data with SAS: PROC GLM and PROC VARCOMP. Exhibits C.12 and C.13 provide the inputs and results for these two procedures. Note that PROC VARCOMP does not compute the F statistic for schools, but the procedure does estimate this variance (-27.7) as does the JMP (both versions) procedure, by following the equation on page 985 of [9]. (A negative estimate indicates that this variance is not statistically significant for these data.)

Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 13 were entered into Statgraphics, and the Special, Advanced Regression, General Linear Model platform was used to analyze these data. Exhibit E.6 in Appendix E provides the Statgraphics results that were imported into this report using StatReporter. No option is provided for allowing both factors to be random. However, the Statgraphics results using Variance Components are presented in Exhibit E.7.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

The data from Table 13 were entered into JMP Version 4.0, and the Fit Model platform was used to analyze these data. Exhibit F.7 in Appendix F provides the JMP Version 4.0 results that were journaled and imported into this report.

If both of these factors were random instead of fixed for the data in Table 13, JMP Version 4.0 would handle this type of problem in its Fit Model platform. Using this approach leads to the results presented in Exhibit F.8 in Appendix F, with a test statistic for schools of 0.414 and for instructors of 27.0.

Two-Factor Nested ANOVA Summary Table

Some of the critical information from the ANOVA tables generated by the software packages reviewed above is summarized in Table 15 along with the results from [9].

Table 15: Two-Way Nested ANOVA Summary Statistics for Each Software Package

Source of Information/ Software Package	Sum of Squares for School	Sum of Squares For Instructor	Sum of Squares for Error	F Statistic for Schools
As discussed in [9] pages 981 - 984	156.5	567.5	42	11.2
JMP Version 3.2.2 on Windows NT Version 4 --- Fit Model	156.5	567.5	42	11.2
JMP Version 4.0 on Windows NT Version 4 --- Fit Model	156.5	567.5	42	11.2
SAS/STAT Version 6.12 on Alphaserver Running OpenVMS V7 PROC ANOVA	156.5	567.5	42	11.2
SAS/STAT Version 6.12 on Alphaserver Running OpenVMS V7 PROC GLM	156.5	567.5	42	11.2
Statgraphics for Windows Version 4.0	156.5	567.5	42	11.18

Table 15 summarizes what is revealed in the exhibits covering this example: a consistent set of ANOVA results from these software packages across these computer platforms for the data of Table 13.

Some of the critical information from the ANOVA tables generated by the software packages reviewed above for the situation in which the two factors of Table 13 are random is summarized in Table 16 along with the results from [9].

Table 16: Two-Way Nested and Random ANOVA Summary Statistics for Each Software Package

Source of Information/ Software Package	Sum of Squares for School	Sum of Squares For Instructor	Sum of Squares for Error	F Statistic for Schools
As discussed in [9] pages 981 - 984	156.5	567.5	42	0.414
JMP Version 3.2.2 on Windows NT Version 4 --- Fit Model	156.5	567.5	42	0.414
SAS/STAT Version 6.12 on Alphaserver Running OpenVMS V7 PROC GLM	156.5	567.5	42	0.414
SAS/STAT Version 6.12 on Alphaserver Running OpenVMS V7 PROC VARCOMP	156.5	567.5	42	
Statgraphics for Windows Version 4.0	156.5	567.5	42	-
JMP Version 4.0 on Windows NT Version 4 --- Fit Model	156.5	567.5	42	0.414

Table 16 summarizes what is revealed in the exhibits covering this example: a consistent set of ANOVA results from these software packages across these computer platforms for the data of Table 13 with both factors random.

Experimental Designs

Another major area of interest is that of experimental design. Two important types of problems in this area, which are addressed in this section, are fractional factorial experiments and mixture experiments. Several packages are utilized by SCS in planning these types of experiments.

Fractional Factorial

An excellent aid in the planning of these types of experiments is provided in Table 9A.1 on pages 182 and 183 of [10]. A portion of this table covering 6-factor experiments is provided in Table 17.

Table 17: Selected Fractional Factorial Experiments of the Complete Factorial Experiment for a 6-Factor Study

Number of Factors	Number of Test Runs	Fraction	Resolution	Defining Equations	Added Factors
6	8	1/8	III	I = ABD	4=12
				I=ACE	5=13
				I=BCF	6=23
	16	1/4	IV	I=ABCE	5=123

The features of this quarter fraction design for this 6-factor study of interest

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

Using the Design Experiment feature of JMP Version 3.2.2, candidate designs involving 6 factors can be explored. One option presented is a 16-run experiment (a quarter fraction of the complete factorial experiment). Exhibit B.9 in Appendix B provides the results of selecting this option from the list of JMP Version 3.2.2 candidates.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

PROC FACTEX in SAS/QC can be used to generate such designs. The input and results for this SAS procedure are provided in Exhibit C.14 of Appendix C.

Using Mixsoft Version 2.3 on a Pentium II Processor Running Windows NT Version 4

This is a specialized software program that aids in experimental designs. Exhibit D.1 in Appendix D provides the results of using this program to select a fractional factorial experiment consisting of 16 trials for a 6-factor problem.

Using Statgraphics Version 4.0 on a Pentium II Processor Running Windows NT Version 4

Using the Experimental Design platform of Statgraphics, a quarter fraction of the complete factorial experiment for a 6-factor problem was selected. The results appear in Exhibit E.8 in the Appendix.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

Using the DOE (Design of Experiment) platform of JMP Version 4.0, candidate designs involving 6 factors can be explored. One option presented is a 16-run experiment (a quarter fraction of the complete factorial experiment). Exhibit F.9 in Appendix F provides the results of selecting this option from the list of JMP Version 4.0 candidates.

Fractional Factorial Summary

Four different packages were used to generate this fractional factorial experiment, and the results are identical except that the columns for the Mixsoft results are in a different order (these can be rearranged to match results from the other packages exactly).

Mixture

Mixture experiments have been of critical importance in the support of DWPF and in other studies of the vitrification of legacy materials. In mixture experiments, the factors are ingredients of a mixture, and their levels are not independent. Extreme vertices designs are used to support these types of problems. For a full discussion, see Chapter 9 of reference [11]. An example from this reference will be used to illustrate the capabilities of the software utilized by SCS in support of mixture experiments. This example is discussed in Section 9.3.2 and involves a mixture of three components with each component being bounded as given in the equation (2)

$$0.20 \le x_1 \le 0.60 \qquad 0.10 \le x_2 \le 0.60 \qquad 0.10 \le x_3 \le 0.50 \qquad (2)$$

where the three components are represented by the x_i's. The discussion in [4] on pages 353 through 358 identifies 6 extreme vertices for the region defined by equation (2). These extremes are given in Table 18 [10].

Table 18: Extreme Vertices for Region Defined by Equation (2)

Count	x_1	x_2	x_3	Sum
1	0.6	0.3	0.1	1
2	0.3	0.6	0.1	1
3	0.2	0.6	0.2	1
4	0.2	0.3	0.5	1
5	0.4	0.1	0.5	1
6	0.6	0.1	0.3	1

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

Using the Design platform of JMP Version 3.2.2, the region defined by equation (2) was entered and the Extreme Vertices design option invoked. Exhibit B.10 in Appendix B provides the results of selecting this option under the JMP Version 3.2.2 software.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

Exhibit C.15 in Appendix C provides the input and results from using the mixture design capabilities provided in SAS/QC to generate the extreme vertices for the region defined by equation (2).

Using Mixsoft Version 2.3 on a Pentium II Processor Running Windows NT Version 4

Once again, Mixsoft is specialized software; one of its capabilities is mixture experimental design. Exhibit D.2 in Appendix D provides the inputs and outputs generated by this program to select generate the extreme vertices for the problem defined by equation (2).

Using Statgraphics, Version 4.0 on a Pentium II Processor Running Windows NT Version 4

Using the Experimental Design platform of Statgraphics, the region defined by equation (2) was entered and the Extreme Vertices design option selected. Exhibit E.9 in the Appendix provides the Statgraphics results.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

Using the DOE (Design of Experiment) platform of JMP Version 4.0, the region defined by equation (2) was entered and the Mixture Design/Extreme Vertices design options invoked. Exhibit F.10 in Appendix F provides the results of selecting this option under the JMP Version 4.0 software.

Mixture Summary

Five different packages were used to generate the set of extreme vertices for the mixture experiment described by equation (2), and the results are identical to those of Table 18 across all five packages.

Optimal Designs

Selecting an optimal design from a set of candidate points is frequently a necessity during the planning of an experiment. Computer-aided design of experiments routines utilize one or more of design optimality criteria to choose such a set of points (the design) from a candidate list of points. Almost all of these computer-aided design routines are model dependent. Once a model is chosen and a list of candidate design points is specified, a particular design (of a designated size) that minimizes or maximizes a particular criterion is selected from the candidate points. One of the more frequently selected criteria for choosing a design is

D-optimality, which seeks to minimize the determinant of $\mathbf{(X'X)^{-1}}$ where each row of the matrix **X** is a design point, i.e., a set of explanatory variables: $x_1, x_2, ..., x_p$.

This is a model-dependent criterion, and a design that is optimal for one model form, for example a first-degree model, will not necessarily be optimal for another model such as a second-degree model. The example to be considered, as part of this report, is the use of this criterion to select 8 design points from those listed in Table 19.

Table 19: Face-Centered Cube Design

Pattern	x_1	x_2	x_3	Comment
+00	1	0	0	Axial
++-	1	1	-1	FF
---	-1	-1	-1	FF
000	0	0	0	Center-FF
00-	0	0	-1	Axial
000	0	0	0	Center-FF
-00	-1	0	0	Axial
00+	0	0	1	Axial
+++	1	1	1	FF
+-+	1	-1	1	FF
000	0	0	0	Center-FF
--+	-1	-1	1	FF
-+-	-1	1	-1	FF
0-0	0	-1	0	Axial
+--	1	-1	-1	FF
0+0	0	1	0	Axial
000	0	0	0	Center-Ax
000	0	0	0	Center-Ax
000	0	0	0	Center-FF
-++	-1	1	1	FF

The design points provided in this table represent a "face-centered cube design," similar to that discussed in [10]. The optimal design for a linear model in x_1, x_2, and x_3 with an intercept term is given by the shaded rows of Table 19. These points make up the fractional factorial part of the face-centered cube design.

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

A feature of the JMP Version 3.2.2 software package is its D-Optimal Design routine to choose a set of points (the design) from a candidate list of points [1]. The data from Table 19 were entered into JMP Version 3.2.2 and the D-optimal routine evoked to select the best set of 8 points from the set of 20 points. The results from this process are provided in Exhibit B.11 in Appendix B. Values of the D-Optimality criteria, including D-efficiency, are provided as part of the output from this routine. The JMP Version 3.2.2 spreadsheet resulting from the process is also provided in Exhibit B.11, and it shows the rows selected as "optimal" for a linear model.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

Exhibit C.16 in Appendix C provides the results form using PROC OPTEX in SAS to select an optimal design.

Using Statgraphics Version 4.0 on a Pentium II Processor Running Windows NT Version 4

Exhibit E.10 in Appendix E provides the results from using the D-Optimal Design routine in Statgraphics.

Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4

This feature is not available in JMP Version 4.0. This is the primary reason for maintaining JMP Version 3.2.2 in the baseline software list.

Optimal Design Summary

Three different packages were used to generate a set of eight design points from those in Table 19 that would be D-optimal for a linear model. The two data sets resulting from the JMP Version 3.2.2 and SAS procedures were identical. Statgraphics had a mirror image design point (+--) for one of the eight points selected by JMP Version 3.2.2 (-++). However, the design efficiencies are identical. The Statgraphics design was input into JMP Version 3.2.2 and the efficiency statistics reproduced.

Control Charts

As a final area of interest in this review of software, a problem in statistical process control is explored. The construction of x-bar and s charts will be illustrated using an example from [12] (these data are provided in Table 5.1 on page 83 of [12]). These data (along with summary information) are presented in Table 20.

Table 20: Data in Subgroups Obtained at Regular Intervals (Example 5.1, Table 5.1 of [12])

Subgroup	x1	x2	x3	x4	Average	Std Dev
1	72	84	79	49	71.00	15.47
2	56	87	33	42	54.50	23.64
3	55	73	22	60	52.50	21.70
4	44	80	54	74	63.00	16.85
5	97	26	48	58	57.25	29.68
6	83	89	91	62	81.25	13.28
7	47	66	53	58	56.00	8.04
8	88	50	84	69	72.75	17.23
9	57	47	41	46	47.75	6.70
10	13	10	30	32	21.25	11.35
11	26	39	52	48	41.25	11.53
12	46	27	63	34	42.50	15.76
13	49	62	78	87	69.00	16.87
14	71	63	82	55	67.75	11.53
15	71	58	69	70	67.00	6.06
16	67	69	70	94	75.00	12.73
17	55	63	72	49	59.75	9.98
18	49	51	55	76	57.75	12.42
19	72	80	61	59	68.00	9.83
20	61	74	62	57	63.50	7.33

x-Bar and s Charts

The values were entered into Excel, and the summary statistics were computed using the AVERAGE and STDEV functions of Excel. These are the values that appear in the last two columns of Table 20, and they agree with the information in [12]. The data were also entered into JMP Version 3.2.2, and the sample means and standard deviations were computed using JMP's "grouping" feature. Table B.1 in Appendix B provides these values (which agree with Table 20). As an additional check, the data were entered into JMP Version 4.0, and the "summary" feature of this software was used to generate sample means and standard deviations. Table F.1 in Appendix F provides these values (which also agree with Table 20).

Using JMP Version 3.2.2 on a Pentium II Processor Running Windows NT Version 4

Using the Graph/Control Charts platform of JMP Version 3.2.2, the x-bar and s charts for the data of Table 20 were generated after the values were entered into JMP Version 3.2.2. These charts appear as Exhibit B.12 in Appendix B.

Using SAS Version 6.12 on AlphaServer Running Open VMS V7

Exhibit C.17 in Appendix C provides the inputs to and results from using PROC SHEWHART in SAS to generate these control charts.

Using Statgraphics Version 4.0 on a Pentium II Processor Running Windows NT Version 4

Using the Special/Quality Control/Variables Control Charts/X-bar and s option of Statgraphics, the x-bar and s charts for the data in Table 20 were generated using Statgraphics. These charts appear as Exhibit E.11 in Appendix E.

<u>Using JMP Version 4.0 on a Pentium II Processor Running Windows NT Version 4</u>

Using the Graph/Control Charts platform of JMP Version 4.0, the x-bar and s charts for the data of Table 20 were generated after the values were entered into JMP Version 4.0. These charts appear as Exhibit F.11 in Appendix F.

Control Chart Summary Table

Some of the critical information from the control charts generated by the software packages reviewed above is provided in Table 21 along with the results from [12].

Table 21: Control Chart Summary Statistics for Each Software Package

Source of Information/ Software Package	Center-line for X-bar Chart	Upper Control limit for x-bar Chart	Center- line for s Chart	Upper Control limit for s Chart
As discussed in [12] pages 83-96	59.4	82.1	13.9	31.5
JMP Version 3.2.2 on a PC running Windows NT Version 4 --- Fit Model	59.4	82.1	13.9	31.5
JMP Version 4.0 on a PC running Windows NT Version 4 --- Fit Model	59.4	82.1	13.9	31.5
SAS/QC Version 6.12 on AlphaServer Running OpenVMS V7 PROC SHEWHART	59.4	82.1	13.9	31.5
Statgraphics Version 4.0 on a PC running for Windows Version 4.0	59.4	82.1	13.9	31.5

Table 21 summarizes what is revealed in the exhibits covering this example: a consistent set of control charts from these software packages across these computer platforms for the data of Table 20.

CONCLUSIONS AND RECOMMENDATIONS

The statistical analyses completed in this study provide an important verification and validation of the statistical software and computer platforms utilized by the members of SCS. The IBM Personal Computer 300PL and 300XL are both Pentium II based desktops. Therefore, the software v&v in this report is valid interchangeably between both platforms.

Problems frequently encountered by members of SCS are identified; an example of each problem is selected from a well-established statistical textbook; the example is analyzed using a feature or features of the software (as appropriate) described in the previous section; and the results generated by the various software packages are compared to the information from the textbook and/or to each other for validation and verification. Little discussion is provided regarding the details of the problems, the underlying statistical theory, the statistical routines, or the statistical results. Information about the statistical packages, their capabilities, and details regarding their outputs can be found in their respective published documentation. These references along with those cited as the sources of the problems may be used to provide these details.

This report has shown that these statistical packages, when used appropriately, provide reliable results over a broad range of problem types. This effort is not intended to diminish the importance of the technical review process. As seen in the discussion above, selecting the appropriate statistical approach and model for the problem at hand and the appropriate feature of the available software for its solution are important issues. An important part of the technical review process is to confirm the appropriateness of these decisions.

The software considered in this report is commercial software (some of which is site-licensed), and these packages are considered to have a Level D software classification (as defined in the WSRC 1Q Quality Assurance Manual, QAP 20-1, Revision 6) in that they are important to day to day operation of the business and analyses conducted by SCS, but their failure to perform as intended at in any point in time will not affect the safety or reliability of SRS facilities.

Software configuration control for SCS is the responsibility of each member of SCS, and this document is to serve as the central repository for the software baseline list. When the QA requirements for the work being conducted include software validation and verification, the commercial software packages used to support the analyses should be clearly identified as part of the SCS deliverable. This identification should include the name of the software, the version number, and the vendor. A reference to the appropriate revision of this document may also be included in the deliverable, if this is seen as beneficial.

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APPENDICES

Appendix A: Excel Results

Appendix B: JMP Version 3.2.2 Results

Appendix C: SAS Results

APPENDICES

Appendix A: Excel Results

Table A.1a: Excel Descriptive Statistics for Lot-Size Values in Table 2

Lot Size (X_i)	
Mean	50
Standard Error	6.146362972
Median	55
Mode	60
Standard Deviation	19.43650632
Sample Variance	377.7777778
Kurtosis	-1.066608997
Skewness	-0.113491711
Range	60
Minimum	20
Maximum	80
Sum	500
Count	10
Largest(1)	80
Smallest(1)	20
Confidence Level(95.0%)	13.90404962

Table A.1b: Excel Functions for Lot-Size Values in Table 2

EXCEL Function	Value	Description
Count	10	Number of data
Average	50	Average of data
Sum	500	Sum of data
Minimum	20	Minimum of data
Maximum	80	Maximum of data
Median	55	Median of data
Mode	60	Mode of data
DEVSQ	3400	Sum of Squares of Deviations about the Mean
Std Dev	19.43650632	Standard deviation of data
Skew	-0.11349171	Skewness of data
Kurt	-1.06660900	Kurtosis of data
Geomean	46.12054471	Geometric mean of data
Harmean	41.93709436	Harmonic mean of data

Appendix A: Excel Results

Table A.2: Excel Regression of Information in Table 2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.997801
R Square	0.995608
Adjusted R Square	0.995059
Standard Error	2.738613
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	13600	13600	1813.333	1.02E-10
Residual	8	60	7.5		
Total	9	13660			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	10	2.502939	3.995302	0.003976	4.228208	15.77179	4.228208	15.77179
Lot Size (Xi)	2	0.046967	42.58325	1.02E-10	1.891694	2.108306	1.891694	2.108306

Appendix A: Excel Results

Table A.3: Excel Matrix Handling Capabilities Used to Conduct Regression Analysis for Information in Table 2

Matrix Approach:

	Y		X	
	73		1	30
	50		1	20
	128		1	60
	170		1	80
Y =	87	X =	1	40
	108		1	50
	135		1	60
	69		1	30
	148		1	70
	132		1	60

Estimates of Beta's	=	INVERSE[(X'X)]X'Y	=	10	=	estimate of intercept
				2		estimate of slope

X' =	1	1	1	1	1	1	1	1	1	1
	30	20	60	80	40	50	60	30	70	60

X'X=	10	500
	500	28400

X'Y=	1100
	61800

INVERSE(X'X)	0.835294	-0.01471
	-0.01471	0.000294

Appendix A: Excel Results

Appendix A: Excel Results

Table A.4: Excel ANOVA

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
1	2	30	15	18
2	3	39	13	1
3	3	57	19	4
4	2	54	27	18

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	258	3	86	11.21739	0.007135	4.757055
Within Groups	46	6	7.666667			
Total	304	9				

Appendix A: Excel Results

Table A.5: Excel ANOVA: Two-Factor Without Replication

Anova: Two-Factor Without Replication						
SUMMARY	*Count*	*Sum*	*Average*	*Variance*		
Small	2	240	120	800		
Medium	2	390	195	450		
Large	2	420	210	200		
East	3	570	190	1900		
West	3	480	160	2800		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	9300	2	4650	93	0.010638	19.00003
Columns	1350	1	1350	27	0.035099	18.51276
Error	100	2	50			
Total	10750	5				

Appendix B: JMP Version 3.2.2 Results

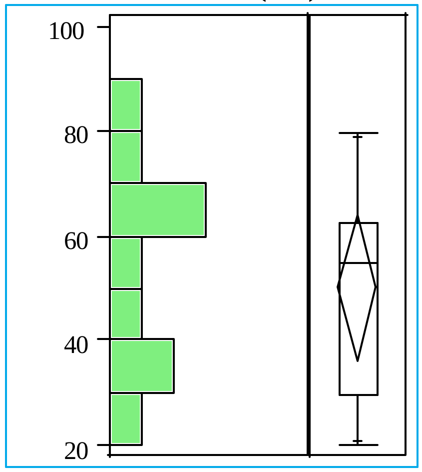
Table B.1: JMP Version 3.2.2 Sample Statistics for Data from Table 18

Subgroup	N Rows	Mean(x)	Std Dev(x)
1	4	71	15.4704
2	4	54.5	23.64318
3	4	52.5	21.70253
4	4	63	16.8523
5	4	57.25	29.68024
6	4	81.25	13.27592
7	4	56	8.041559
8	4	72.75	17.23127
9	4	47.75	6.70199
10	4	21.25	11.35415
11	4	41.25	11.52895
12	4	42.5	15.7586
13	4	69	16.87207
14	4	67.75	11.52895
15	4	67	6.055301
16	4	75	12.72792
17	4	59.75	9.979145
18	4	57.75	12.41974
19	4	68	9.831921
20	4	63.5	7.325754

Appendix B: JMP Version 3.2.2 Results

Exhibit B.1: JMP Version 3.2.2 Output for Descriptive Statistics of Lot Size Information in Table 2

Lot Size (Xi)



Quantiles

maximum	100.0%	80.000
	99.5%	80.000
	97.5%	80.000
	90.0%	79.000
quartile	75.0%	62.500
median	50.0%	55.000
quartile	25.0%	30.000
	10.0%	21.000
	2.5%	20.000
	0.5%	20.000
minimum	0.0%	20.000

Moments

Mean	50.00000
Std Dev	19.43651
Std Error Mean	6.14636
Upper 95% Mean	63.90416
Lower 95% Mean	36.09584
N	10.00000
Sum Weights	10.00000

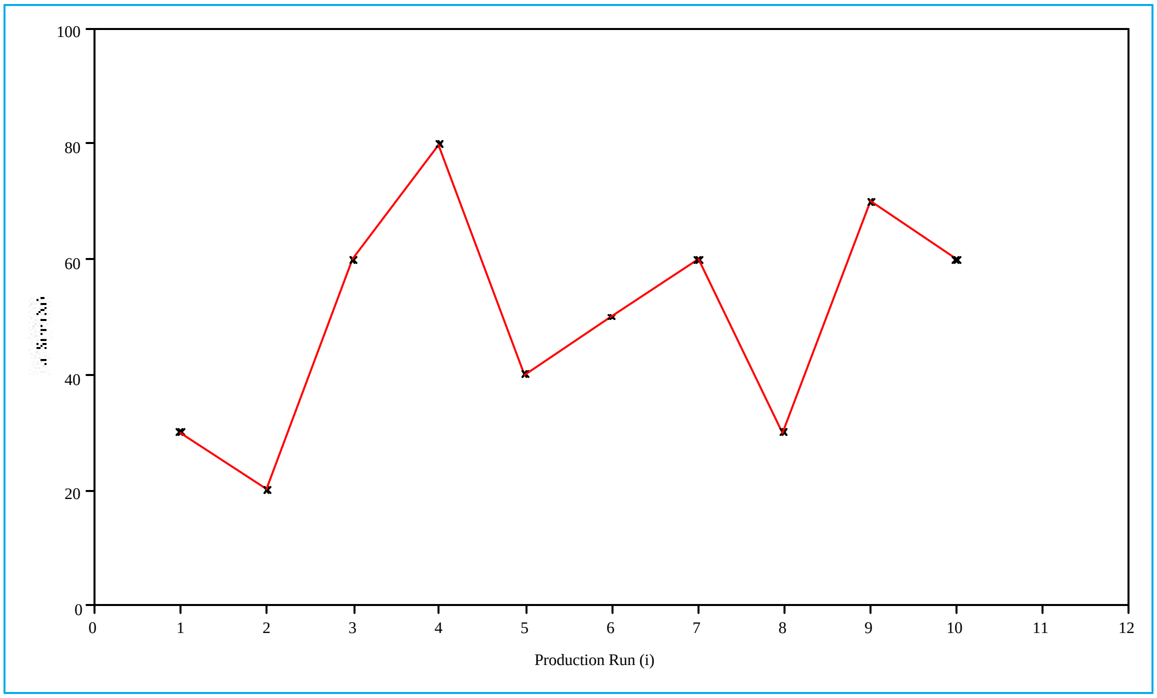
Appendix B: JMP Version 3.2.2 Results

Exhibit B.1: JMP Version 3.2.2 Output for Descriptive Statistics of Lot Size Information in Table 2 (continued)

Stem and Leaf

Stem	Leaf	Count
8	0	1
7	0	1
6	000	3
5	0	1
4	0	1
3	00	2
2	0	1

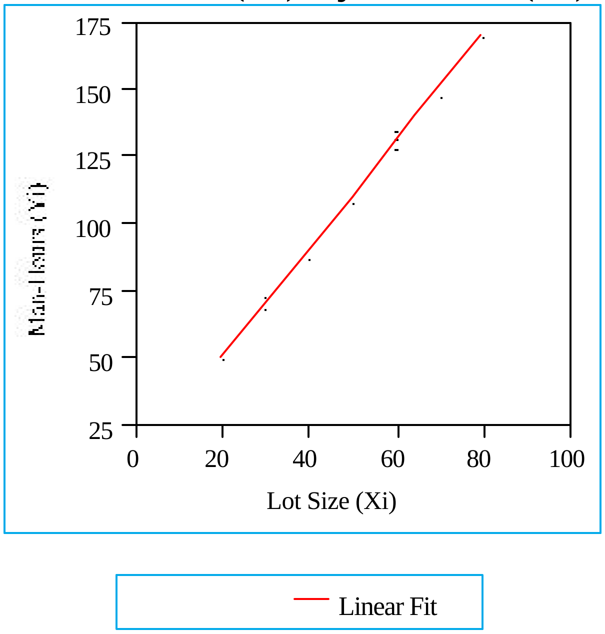
Multiply Stem.Leaf by 10



Appendix B: JMP Version 3.2.2 Results

Exhibit B.2: JMP Version 3.2.2 Output for Regression Model for Information in Table 2 Using Fit Y by X

Man-Hours (Yi) By Lot Size (Xi)



Linear Fit

Man-Hours (Yi) = 10 + 2 Lot Size (Xi)

Summary of Fit

RSquare	0.995608
RSquare Adj	0.995059
Root Mean Square Error	2.738613
Mean of Response	110
Observations (or Sum Wgts)	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	13600.000	13600.0	1813.333
Error	8	60.000	7.5	**Prob>F**
C Total	9	13660.000		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10	2.502939	4.00	0.0040
Lot Size (Xi)	2	0.046967	42.58	<.0001

Appendix B: JMP Version 3.2.2 Results

Exhibit B.3: JMP Version 3.2.2 Output for Regression Model for Information in Table 2 Using Fit Model

Response: Man-Hours (Yi)

Summary of Fit

RSquare	0.995608
RSquare Adj	0.995059
Root Mean Square Error	2.738613
Mean of Response	110
Observations (or Sum Wgts)	10

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	5	27.333333	5.4667	0.5020
Pure Error	3	32.666667	10.8889	**Prob>F**
Total Error	8	60.000000		0.7662
Max RSq				
0.9976				

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10	2.502939	4.00	0.0040
Lot Size (Xi)	2	0.046967	42.58	<.0001

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Lot Size (Xi)	1	1	13600.000	1813.333	<.0001

Appendix B: JMP Version 3.2.2 Results

Whole-Model Test

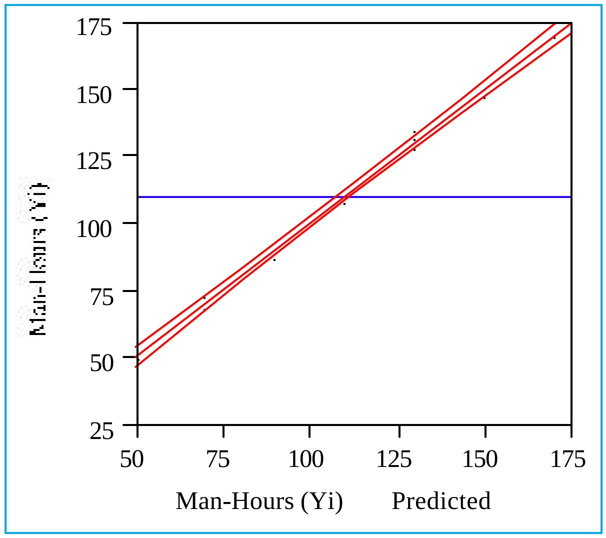
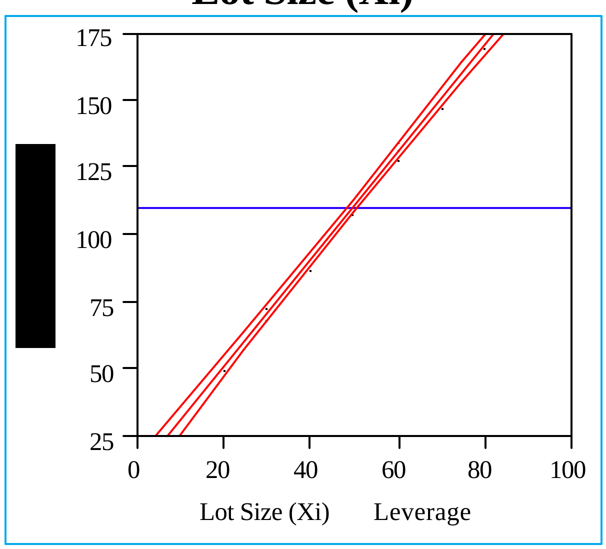


Exhibit B.3: JMP Version 3.2.2 Output for Regression Model for Information in Table 2 Using Fit Model (continued)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	13600.000	13600.0	1813.333
Error	8	60.000	7.5	**Prob>F**
C Total	9	13660.000		<.0001

Lot Size (Xi)



Effect Test

Sum of Squares	F Ratio	DF	Prob>F

13600.000	1813.333	1	<.0001

Exhibit B.4: JMP Version 3.2.2 Output for ANOVA of Information in Table 5 Using Fit Model

Response: Case Sold
Summary of Fit

RSquare	0.848684
RSquare Adj	0.773026
Root Mean Square Error	2.768875
Mean of Response	18
Observations (or Sum Wgts)	10

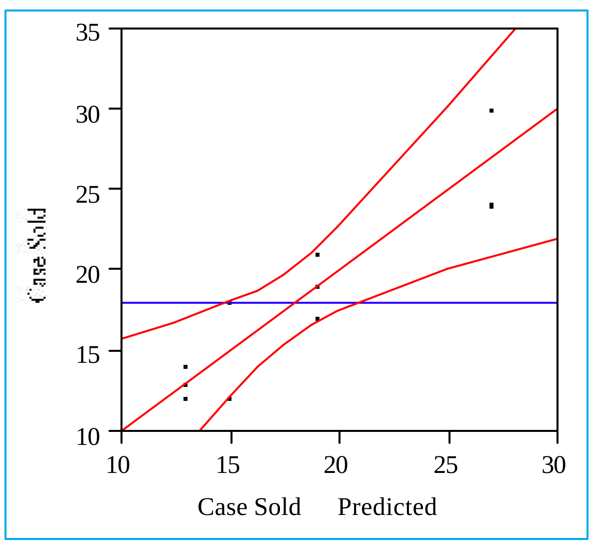
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	18.5	0.89365	20.70	<.0001
Package [1-4]	-3.5	1.64781	-2.12	0.0778
Package [2-4]	-5.5	1.440968	-3.82	0.0088
Package [3-4]	0.5	1.440968	0.35	0.7404

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Package Design	3	3	258.00000	11.2174	0.0071

Whole-Model Test

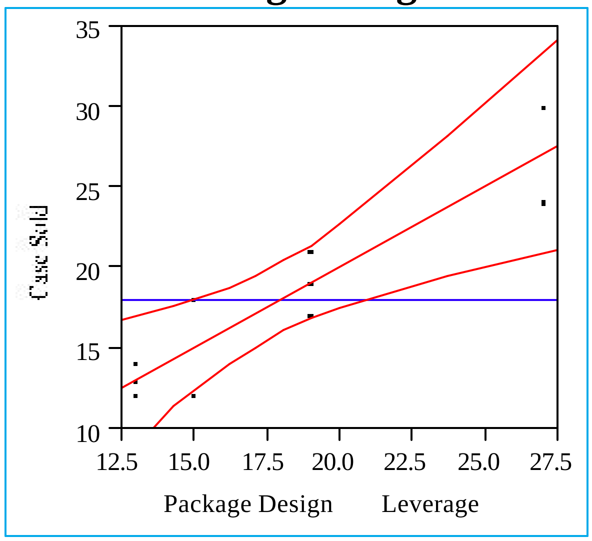


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	258.00000	86.0000	11.2174
Error	6	46.00000	7.6667	**Prob>F**
C Total	9	304.00000		0.0071

Exhibit B.4: JMP Version 3.2.2 Output for ANOVA of Information in Table 5 Using Fit Model (continued)

Package Design



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
258.00000	11.2174	3	0.0071

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
1	15.00000000	1.957890021	15.0000
2	13.00000000	1.598610508	13.0000
3	19.00000000	1.598610508	19.0000
4	27.00000000	1.957890021	27.0000

Appendix B: JMP Version 3.2.2 Results

Exhibit B.5: JMP Version 3.2.2 Output for ANOVA of Information in Table 8 Using Fit Model with Random Factor (continued)

Response: Rating
Summary of Fit

RSquare	0.566182
RSquare Adj	0.450497
Root Mean Square Error	8.694826
Mean of Response	71
Observations (or Sum Wgts)	20

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	71	1.944222	36.52	<.0001
Officer [A-E]	4	3.888444	1.03	0.3199
Officer [B-E]	-1	3.888444	-0.26	0.8005
Officer [C-E]	-16	3.888444	-4.11	0.0009
Officer [D-E]	9	3.888444	2.31	0.0352

Expected Mean Squares

The Mean Square per row by the Variance Component per column

EMS	Intercept	Officer (i)
Intercept	0	0
Officer (i)	0	4

plus 1.0 times Residual Error Variance

Variance Component Estimates

Component	Var Comp Est
Officer (i)	73.6
Residual	75.6

These estimates based on equating Mean Squares to Expected Value.

Test Denominator Synthesis

Source	MS Den	DF Den	Denom MS Synthesis
Officer (i)	75.6	15	Residual

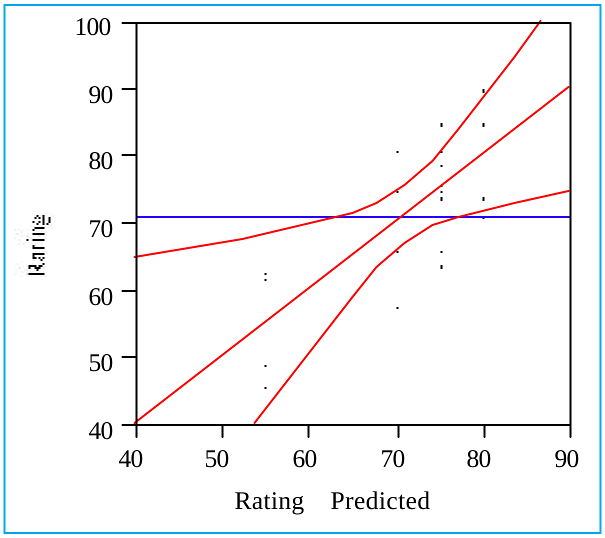
Tests wrt Random Effects

Source	SS	MS Num	DF Num	F Ratio	Prob>F
Officer (i)	1480	370	4	4.8942	0.0100

Appendix B: JMP Version 3.2.2 Results

Exhibit B.5: JMP Version 3.2.2 Output for ANOVA of Information in Table 8 Using Fit Model with Random Factor (continued)

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1480.0000	370.000	4.8942
Error	15	1134.0000	75.600	**Prob>F**
C Total	19	2614.0000		0.0100

Officer (i)

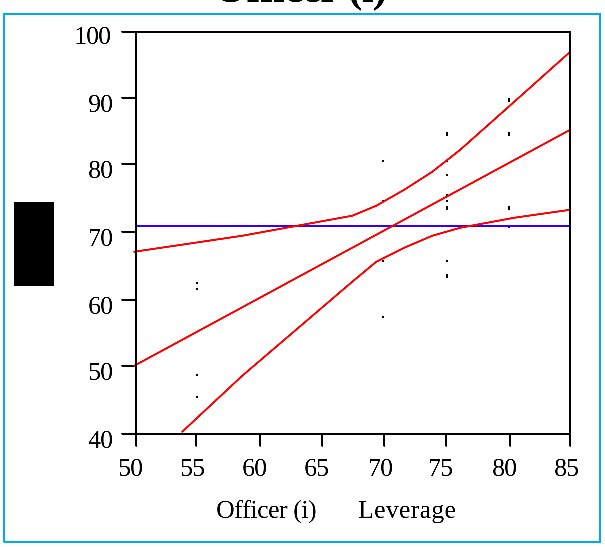


Exhibit B.5: JMP Version 3.2.2 Output for ANOVA of Information in Table 8 Using Fit Model with Random Factor (continued)

Effect Test

Sum of Squares	F Ratio	DF	Prob>F
1480.0000	4.8942	4	0.0100

Denominator MS Synthesis: Residual

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
A	75.00000000	4.347413024	75.0000
B	70.00000000	4.347413024	70.0000
C	55.00000000	4.347413024	55.0000
D	80.00000000	4.347413024	80.0000
E	75.00000000	4.347413024	75.0000

Warning: Std Err calculated with respect to Synthetic Denominator.

Exhibit B.6: JMP Version 3.2.2 Output for ANOVA of Information in Table 10 Using Fit Model with Two Factors

Response: Premium ($)

Summary of Fit

RSquare	0.990698
RSquare Adj	0.976744
Root Mean Square Error	7.071068
Mean of Response	175
Observations (or Sum Wgts)	6

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	175	2.886751	60.62	0.0003
Size of [Large-Small]	35	4.082483	8.57	0.0133
Size of [Medium-Small]	20	4.082483	4.90	0.0392
Region[East-West]	15	2.886751	5.20	0.0351

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Size of City	2	2	9300.0000	93.0000	0.0106
Region	1	1	1350.0000	27.0000	0.0351

Whole-Model Test

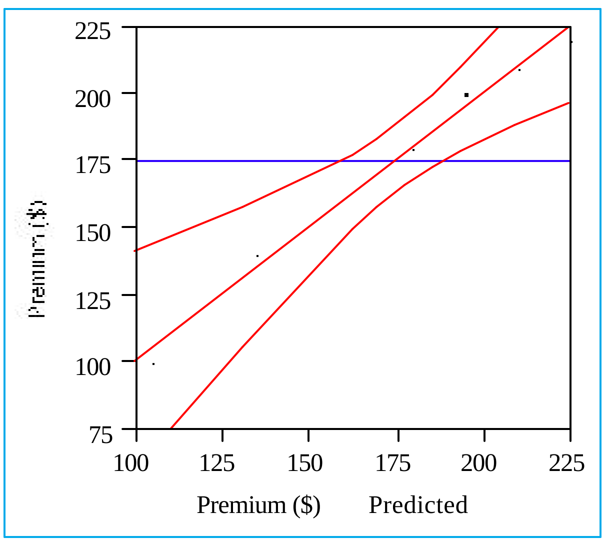
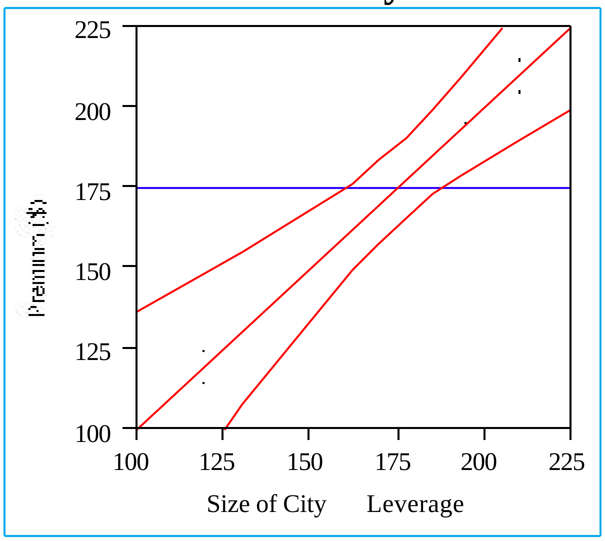


Exhibit B.6: JMP Version 3.2.2 Output for ANOVA of Information in Table 10 Using Fit Model with Two Factors (continued)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	10650.000	3550.00	71.0000
Error	2	100.000	50.00	**Prob>F**
C Total	5	10750.000		0.0139

Size of City



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
9300.0000	93.0000	2	0.0106

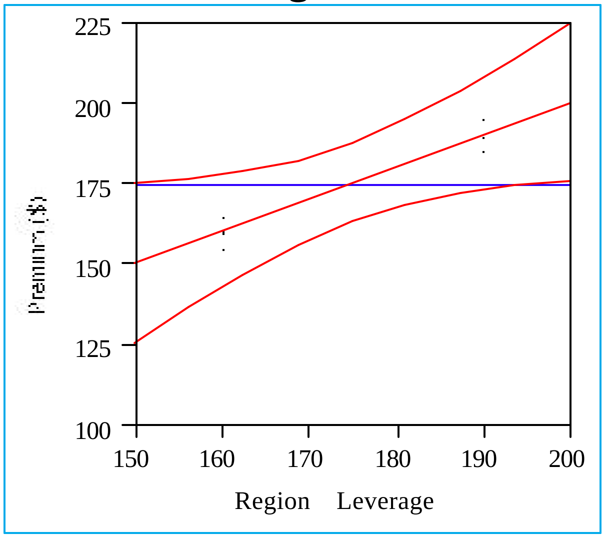
Least Squares Means

Level	Least Sq Mean	Std Error	Mean
Large	210.0000000	5.000000000	210.000
Medium	195.0000000	5.000000000	195.000
Small	120.0000000	5.000000000	120.000

Appendix B: JMP Version 3.2.2 Results

Exhibit B.6: JMP Version 3.2.2 Output for ANOVA of Information in Table 10 Using Fit Model with Two Factors (continued)

Region



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
1350.0000	27.0000	1	0.0351

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
East	190.0000000	4.082482905	190.000
West	160.0000000	4.082482905	160.000

Exhibit B.7: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with A Nested Factor

Response: Class Learning Scores (coded)
Summary of Fit

RSquare	0.94517
RSquare Adj	0.899478
Root Mean Square Error	2.645751
Mean of Response	15
Observations (or Sum Wgts)	12

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	15	0.763763	19.64	<.0001
School[Atlanta-San Fra]	4.75	1.080123	4.40	0.0046
School[Chicago-San Fra]	-0.75	1.080123	-0.69	0.5134
School[Atlanta]:Instruct[1-2]	7.25	1.322876	5.48	0.0015
School[Chicago]:Instruct[1-2]	-5.75	1.322876	-4.35	0.0048
School[San Fra]:Instruct[1-2]	7.5	1.322876	5.67	0.0013

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
School	2	2	156.50000	11.1786	0.0095
Instructor[School]	3	3	567.50000	27.0238	0.0007

Whole-Model Test

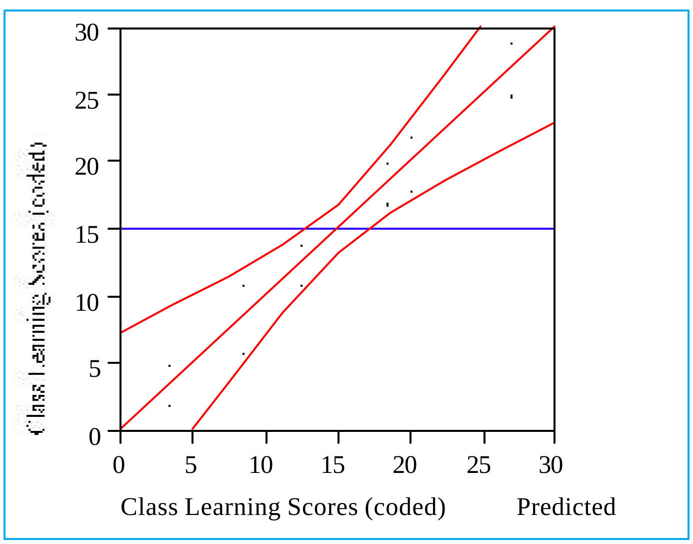
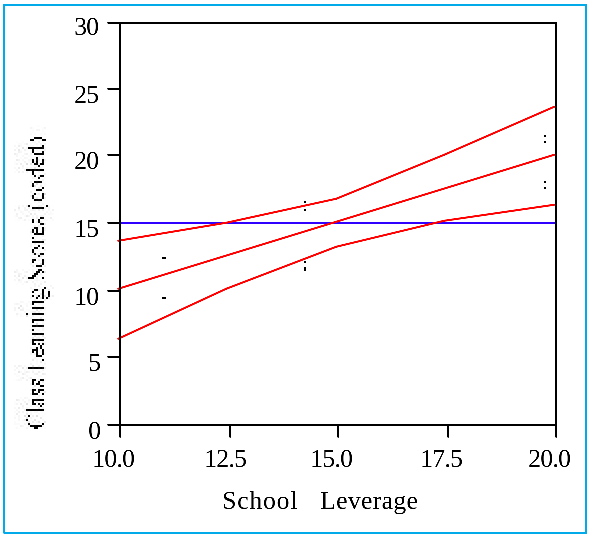


Exhibit B.7: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with A Nested Factor (continued)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	724.00000	144.800	20.6857
Error	6	42.00000	7.000	**Prob>F**
C Total	11	766.00000		0.0010

School



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
156.50000	11.1786	2	0.0095

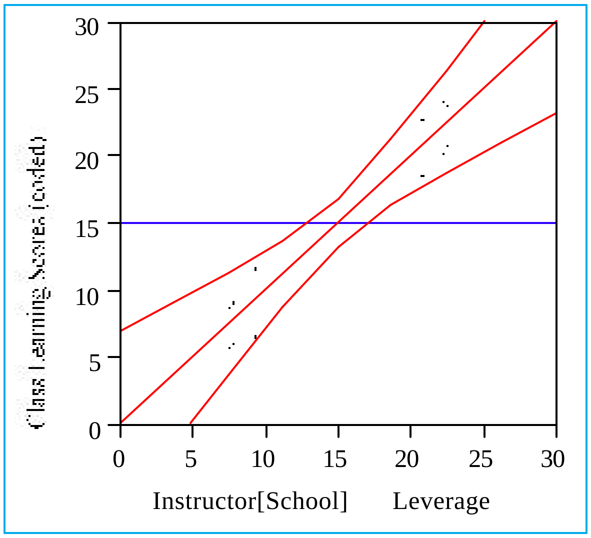
Least Squares Means

Level	Least Sq Mean	Std Error	Mean
Atlanta	19.75000000	1.322875656	19.7500
Chicago	14.25000000	1.322875656	14.2500
San Francisco	11.00000000	1.322875656	11.0000

Appendix B: JMP Version 3.2.2 Results

Exhibit B.7: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with A Nested Factor (continued)

Instructor[School]



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
567.50000	27.0238	3	0.0007

Least Squares Means

Level	Least Sq Mean	Std Error
[Atlanta]1	27.00000000	1.870828693
[Atlanta]2	12.50000000	1.870828693
[Chicago]1	8.50000000	1.870828693
[Chicago]2	20.00000000	1.870828693
[San Francisco]1	18.50000000	1.870828693
[San Francisco]2	3.50000000	1.870828693

Exhibit B.8: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors

Response: Class Learning Scores (coded)

Summary of Fit

RSquare	0.94517
RSquare Adj	0.899478
Root Mean Square Error	2.645751
Mean of Response	15
Observations (or Sum Wgts)	12

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	15	0.763763	19.64	<.0001
School[Atlanta-San Fra]	4.75	1.080123	4.40	0.0046
School[Chicago-San Fra]	-0.75	1.080123	-0.69	0.5134
School[Atlanta]:Instruct[1-2]	7.25	1.322876	5.48	0.0015
School[Chicago]:Instruct[1-2]	-5.75	1.322876	-4.35	0.0048
School[San Fra]:Instruct[1-2]	7.5	1.322876	5.67	0.0013

Expected Mean Squares

The Mean Square per row by the Variance Component per column

EMS	Intercept	School	Instructor[School]
Intercept	0	0	0
School	0	4	2
Instructor[School]	0	0	2

plus 1.0 times Residual Error Variance

Variance Component Estimates

Component	Var Comp Est
School	-27.7292
Instructor[School]	91.08333
Residual	7

These estimates based on equating Mean Squares to Expected Value.

Test Denominator Synthesis

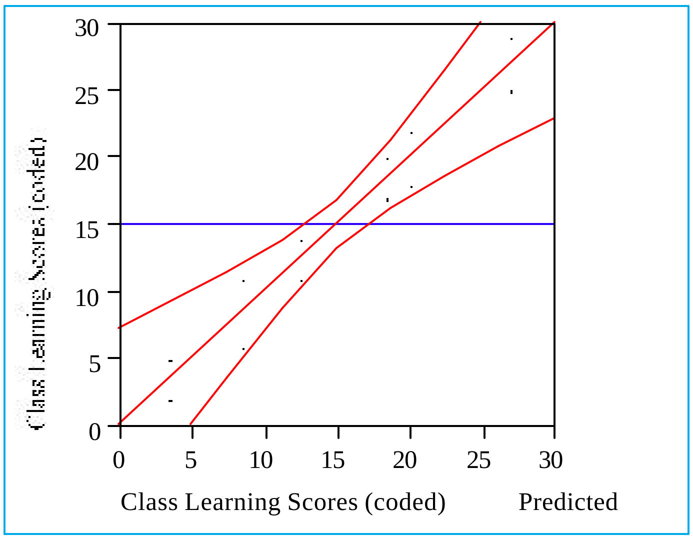
Source	MS Den	DF Den	Denom MS Synthesis
School	189.167	3	Instructor[School]
Instructor[School]	7	6	Residual

Exhibit B.8: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors (continued)

Tests wrt Random Effects

Source	SS	MS Num	DF Num	F Ratio	Prob>F
School	156.5	78.25	2	0.4137	0.6940
Instructor[School]	567.5	189.167	3	27.0238	0.0007

Whole-Model Test

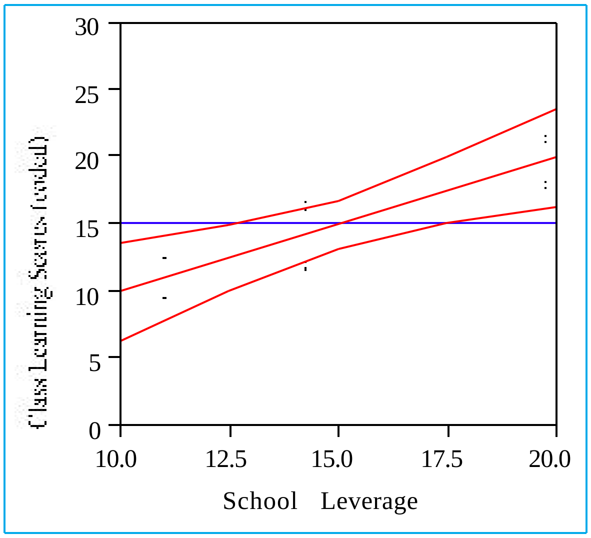


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	724.00000	144.800	20.6857
Error	6	42.00000	7.000	**Prob>F**
C Total	11	766.00000		0.0010

Exhibit B.8: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors (continued)

School



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
156.50000	0.4137	2	0.6940

Denominator MS Synthesis: Instructor[School]

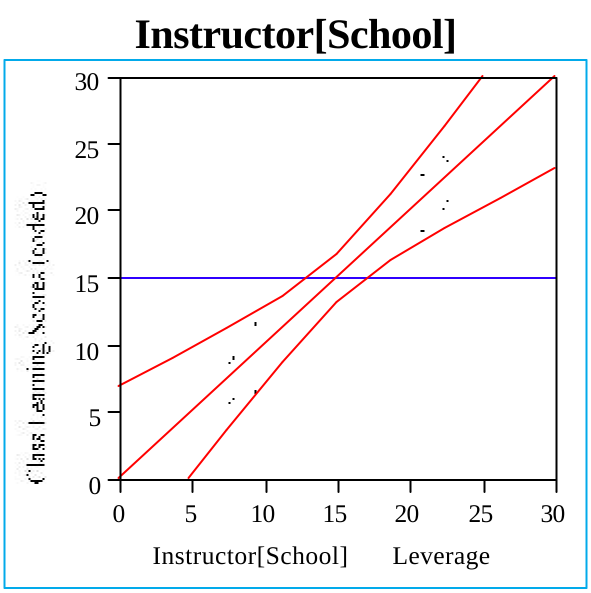
Least Squares Means

Level	Least Sq Mean	Std Error	Mean
Atlanta	19.75000000	6.876893679	19.7500
Chicago	14.25000000	6.876893679	14.2500
San Francisco	11.00000000	6.876893679	11.0000

Warning: Std Err calculated with respect to Synthetic Denominator.

Appendix B: JMP Version 3.2.2 Results

Exhibit B.8: JMP Version 3.2.2 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors (continued)



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
567.50000	27.0238	3	0.0007

Denominator MS Synthesis: Residual

Least Squares Means

Level	Least Sq Mean	Std Error
[Atlanta]1	27.00000000	1.870828693
[Atlanta]2	12.50000000	1.870828693
[Chicago]1	8.50000000	1.870828693
[Chicago]2	20.00000000	1.870828693
[San Francisco]1	18.50000000	1.870828693
[San Francisco]2	3.50000000	1.870828693

Warning: Std Err calculated with respect to Synthetic Denominator.

Appendix B: JMP Version 3.2.2 Results

Exhibit B.9: JMP Version 3.2.2 Output for a Fractional Factorial Experiment using the Design Experiment Feature

Pattern	X1	X2	X3	X4	X5	X6
------	-1	-1	-1	-1	-1	-1
---+++	-1	-1	-1	1	1	1
--+-++	-1	-1	1	-1	1	1
--++--	-1	-1	1	1	-1	-1
-+--+-	-1	1	-1	-1	1	-1
-+-+-+	-1	1	-1	1	-1	1
-++--+	-1	1	1	-1	-1	1
-++++-	-1	1	1	1	1	-1
+----+	1	-1	-1	-1	-1	1
+--++-	1	-1	-1	1	1	-1
+-+-+-	1	-1	1	-1	1	-1
+-++-+	1	-1	1	1	-1	1
++--++	1	1	-1	-1	1	1
++-+--	1	1	-1	1	-1	-1
+++---	1	1	1	-1	-1	-1
++++++	1	1	1	1	1	1

```
Fractional Factorial Structure

Factor Confounding Rules

X5 = X2*X3*X4

X6 = X1*X3*X4



Aliasing Structure

 X1  = X2*X5*X6 = X3*X4*X6 = X1*X2*X3*X4*X5

 X2  = X1*X5*X6 = X3*X4*X5 = X1*X2*X3*X4*X6
 X3  = X1*X4*X6 = X2*X4*X5 = X1*X2*X3*X5*X6
 X4  = X1*X3*X6 = X2*X3*X5 = X1*X2*X4*X5*X6
 X5  = X1*X2*X6 = X2*X3*X4 = X1*X3*X4*X5*X6
 X6  = X1*X2*X5 = X1*X3*X4 = X2*X3*X4*X5*X6
 X1*X2  = X5*X6 = X1*X3*X4*X5 = X2*X3*X4*X6
 X1*X3  = X4*X6 = X1*X2*X4*X5 = X2*X3*X5*X6
 X1*X4  = X3*X6 = X1*X2*X3*X5 = X2*X4*X5*X6
 X1*X5  = X2*X6 = X1*X2*X3*X4 = X3*X4*X5*X6
 X1*X6  = X2*X5 = X3*X4 = X1*X2*X3*X4*X5*X6
 X2*X3  = X4*X5 = X1*X2*X4*X6 = X1*X3*X5*X6
 X2*X4  = X3*X5 = X1*X2*X3*X6 = X1*X4*X5*X6
 X1*X2*X3  = X1*X4*X5 = X2*X4*X6 = X3*X5*X6
 X1*X2*X4  = X1*X3*X5 = X2*X3*X6 = X4*X5*X6
```

Appendix B: JMP Version 3.2.2 Results

Appendix B: JMP Version 3.2.2 Results

Exhibit B.10: JMP Version 3.2.2 Output for Mixture Problem Defined by Equation (2)

X_1	X_2	X_3	Dimen
0.4	0.1	0.5	0
0.6	0.1	0.3	0
0.6	0.3	0.1	0
0.2	0.3	0.5	0
0.3	0.6	0.1	0
0.2	0.6	0.2	0
0.2	0.45	0.35	1
0.6	0.2	0.2	1
0.5	0.1	0.4	1
0.25	0.6	0.15	1
0.45	0.45	0.1	1
0.3	0.2	0.5	1
0.383333	0.333333	0.283333	2

JMP Version 3.2.2 is capable of evaluating more than just the extreme vertices of this region. A value of 0 for Dimen column indicates that the row corresponds to an extreme vertex of the mixture region, a value of 1 indicates an edge of the region, and finally, a 2 value indicates the centroid of the region. This centroid is computed as part of the discussion in [1], and the value that is reported there (on page 358) is (0.384,0.333,0.283) – the same value as shown in the table above.

Appendix B: JMP Version 3.2.2 Results

Exhibit B.11: JMP Version 3.2.2's D-Optimality Results

Optimal Design Controls

N Desired	8
N Random	3
K Value	3
Trips	1

N	8	------ Ready ------
Trips	1	

Best Design

D-efficiency	100
A-efficiency	100
G-efficiency	100
AvgPredSE	0.5590
N	8.0000

Correlations

Corr	Intercept	X1	X2	X3
Intercept	1.0000	0.0000	0.0000	0.0000
X1	0.0000	1.0000	0.0000	0.0000
X2	0.0000	0.0000	1.0000	0.0000
X3	0.0000	0.0000	0.0000	1.0000

Pattern	X1	X2	X3	Comment	OptCount	OptStdPred
+00	1	0	0	Axial	0	0.5
++-	1	1	-1	FF	1	0.707107
---	-1	-1	-1	FF	1	0.707107
000	0	0	0	Center-FF	0	0.353553
00-	0	0	-1	Axial	0	0.5
000	0	0	0	Center-FF	0	0.353553
-00	-1	0	0	Axial	0	0.5
00+	0	0	1	Axial	0	0.5
+++	1	1	1	FF	1	0.707107
+-+	1	-1	1	FF	1	0.707107
000	0	0	0	Center-FF	0	0.353553
--+	-1	-1	1	FF	1	0.707107
-+-	-1	1	-1	FF	1	0.707107
0-0	0	-1	0	Axial	0	0.5
+--	1	-1	-1	FF	1	0.707107
0+0	0	1	0	Axial	0	0.5
000	0	0	0	Center-Ax	0	0.353553
000	0	0	0	Center-Ax	0	0.353553
000	0	0	0	Center-FF	0	0.353553
-++	-1	1	1	FF	1	0.707107

Appendix B: JMP Version 3.2.2 Results

Exhibit B.12: JMP Version 3.2.2 Results for x-Bar and s Charts for Data in Table 20

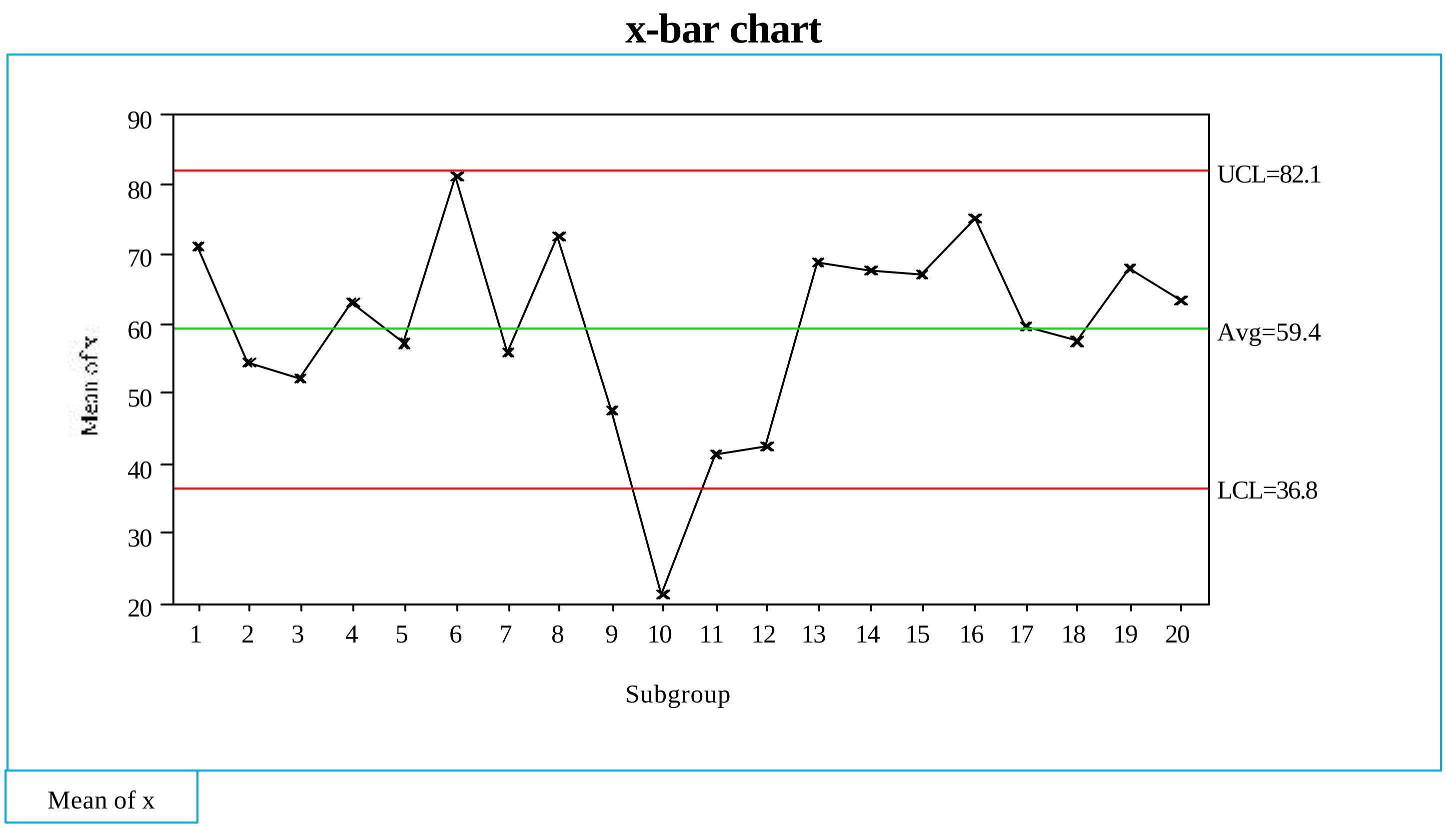
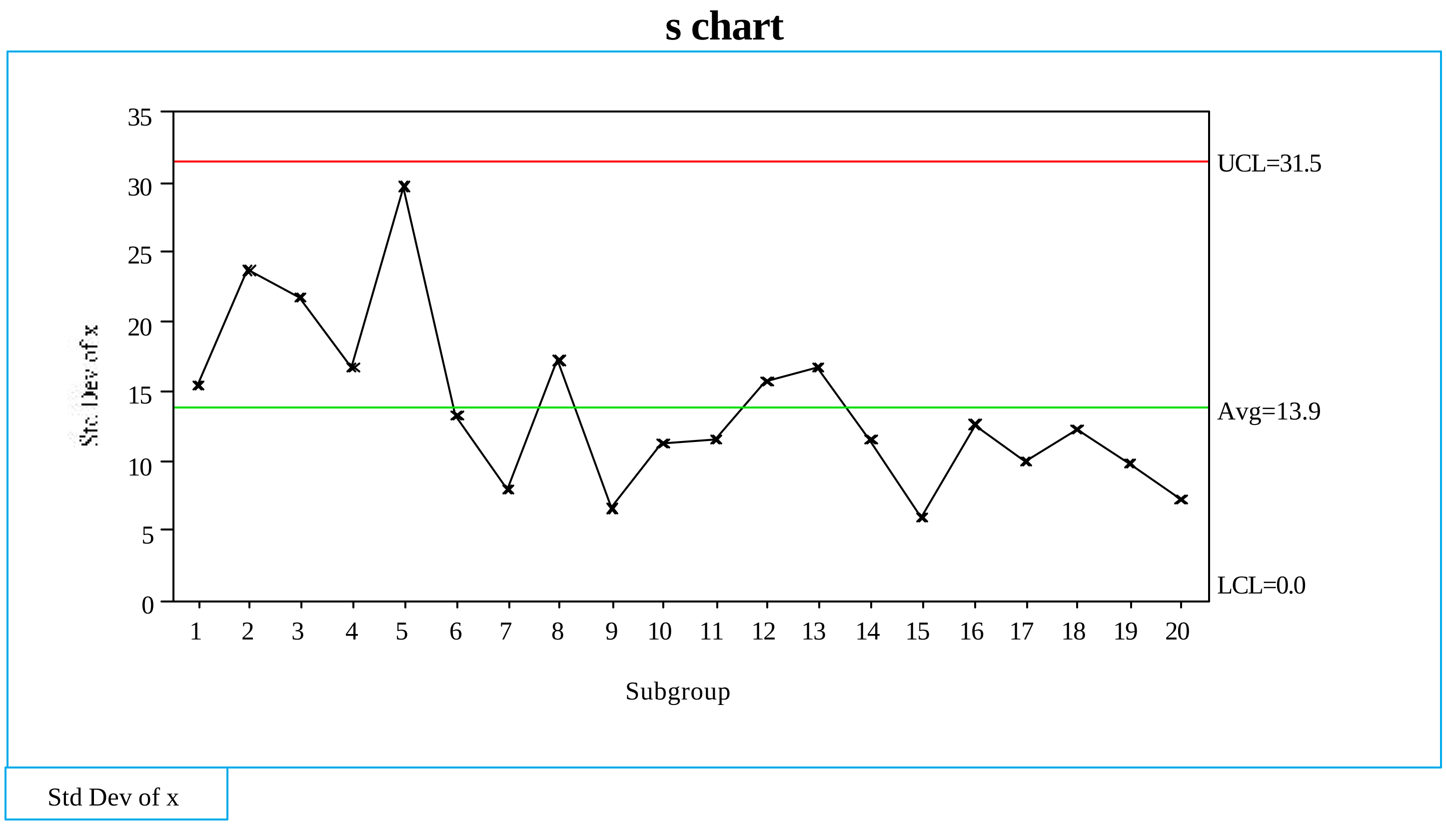


Exhibit B.12: JMP Version 3.2.2 Results for x-Bar and s Charts for Data in Table 18 (continued)



Appendix C: SAS Results

Exhibit C.1: SAS Input for and Results from Descriptive Statistics for Lot Size Values in Table 2

```
data example1;
    infile cards;
    input prod_run lot_size man_hrs;
 cards;
 1  30  73
 2  20  50
 3  60 128
 4  80 170
 5  40  87
 6  50 108
 7  60 135
 8  30  69
 9  70 148
10  60 132
;
proc summary data=example1 noprint;
   var lot_size;
   output out=outex1 n=s_size min=s_min max=s_max
              mean=s_mean std=s_std stderr=s_stderr;
proc print data=outex1;
run;
proc means data=example1 noprint;
   var lot_size;
   output out=outex2 n=s_size min=s_min max=s_max
              mean=s_mean std=s_std stderr=s_stderr;
proc print data=outex2;
run;
proc univariate data=example1 noprint;
   var lot_size;
   output out=outex3 n=s_size min=s_min max=s_max
              mean=s_mean std=s_std stdmean=s_stderr;
proc print data=outex3;
run;
```

OBS	_TYPE_	_FREQ_	S_SIZE	S_MIN	S_MAX	S_MEAN	S_STD	S_STDERR
1	0	10	10	20	80	50	19.4365	6.14636

OBS	_TYPE_	_FREQ_	S_SIZE	S_MIN	S_MAX	S_MEAN	S_STD	S_STDERR
1	0	10	10	20	80	50	19.4365	6.14636

Appendix C: SAS Results

OBS	S_SIZE	S_MEAN	S_STD	S_STDERR	S_MAX	S_MIN
1	10	50	19.4365	6.14636	80	20

Appendix C: SAS Results

Exhibit C.2: SAS Input for and Results from PROC REG for Table 2 Data

```
options ls=80 ps=66;
data example1;
    infile cards;
    input prod_run lot_size man_hrs;
 cards;
 1  30  73
 2  20  50
 3  60 128
 4  80 170
 5  40  87
 6  50 108
 7  60 135
 8  30  69
 9  70 148
10  60 132
;
proc reg data=example1;
 model man_hrs = lot_size;
 output out=outex1a;
 proc print data=outex1a;
 run;
```

```
Model: MODEL1
 Dependent Variable: MAN_HRS

                               Analysis of Variance

                                  Sum of         Mean
         Source          DF      Squares       Square      F Value       Prob>F

         Model            1  13600.00000  13600.00000     1813.333       0.0001
         Error            8     60.00000      7.50000
         C Total          9  13660.00000

             Root MSE       2.73861     R-square       0.9956
             Dep Mean     110.00000     Adj R-sq       0.9951
             C.V.           2.48965

                               Parameter Estimates

                       Parameter      Standard    T for H0:
       Variable  DF     Estimate         Error   Parameter=0    Prob > |T|

       INTERCEP   1    10.000000    2.50293945         3.995        0.0040
       LOT_SIZE   1     2.000000    0.04696682        42.583        0.0001
```

Appendix C: SAS Results

Exhibit C.3: SAS Input for and Results from SAS/IML Program for Regression of Table 2 Data

```
proc iml;
 reset noname;
 x={1 30,1 20,1 60,1 80,1 40,1 50,1 60,1 30,1 70,1 60};
 y={73, 50, 128, 170, 87, 108, 135, 69, 148, 132};
 betahat=INV(x`*x)*(x`*y);
 reset name;
 print betahat;
 quit;
 run;
```

```
BETAHAT
     10
      2
```

Appendix C: SAS Results

Exhibit C.4: SAS Input for and Results from SAS/STAT PROC ANOVA for Analyzing of Table 5 Data

```
data example3;
    infile cards;
    input design store n_cases;
 cards;
 1 1 12
 1 2 18
 2 1 14
 2 2 12
 2 3 13
 3 1 19
 3 2 17
 3 3 21
 4 1 24
 4 2 30
;

proc anova data=example3;
  class design;
  model n_cases = design;
run;
```

```
Analysis of Variance Procedure
                             Class Level Information

                            Class    Levels    Values

                            DESIGN        4    1 2 3 4


                     Number of observations in data set = 10


                          Analysis of Variance Procedure

 Dependent Variable: N_CASES
                                           Sum of             Mean
 Source                    DF            Squares           Square   F Value     Pr > F

 Model                      3       258.00000000      86.00000000     11.22     0.0071

 Error                      6        46.00000000       7.66666667

 Corrected Total            9       304.00000000

                     R-Square               C.V.         Root MSE          N_CASES Mean

                     0.848684           15.38264        2.7688746             18.000000


 Source                    DF           Anova SS      Mean Square   F Value     Pr > F
```

```
DESIGN                    3     258.00000000     86.00000000     11.22     0.0071
```

Appendix C: SAS Results

Exhibit C.5: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 5 Data

```
data example3;
    infile cards;
    input design store n_cases;
 cards;
 1 1 12
 1 2 18
 2 1 14
 2 2 12
 2 3 13
 3 1 19
 3 2 17
 3 3 21
 4 1 24
 4 2 30
;
proc glm data=example3;
  class design;
  model n_cases = design;
  output out=outex3a;
proc print data=outex3a;
run;
```

```
General Linear Models Procedure
                             Class Level Information

                            Class    Levels    Values

                            DESIGN        4    1 2 3 4


                     Number of observations in data set = 10

                          General Linear Models Procedure

 Dependent Variable: N_CASES
                                     Sum of             Mean
 Source                  DF         Squares           Square   F Value     Pr > F

 Model                    3    258.00000000      86.00000000     11.22     0.0071

 Error                    6     46.00000000       7.66666667

 Corrected Total          9    304.00000000

                   R-Square            C.V.         Root MSE           N_CASES Mean

                   0.848684        15.38264        2.7688746              18.000000


 Source                  DF       Type I SS      Mean Square   F Value     Pr > F
```

Appendix C: SAS Results

DESIGN	3	258.00000000	86.00000000	11.22	0.0071

Source	DF	Type III SS	Mean Square	F Value	Pr > F
DESIGN	3	258.00000000	86.00000000	11.22	0.0071

Appendix C: SAS Results

Exhibit C.6: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 8 Data

```
data example4;
    infile cards;
    input officer $1 cand yscore;
 cards;
A 1 76
A 2 64
A 3 85
A 4 75
B 1 58
B 2 75
B 3 81
B 4 66
C 1 49
C 2 63
C 3 62
C 4 46
D 1 74
D 2 71
D 3 85
D 4 90
E 1 66
E 2 74
E 3 81
E 4 79
;

proc glm data=example4;
  class officer;
  model yscore = officer;
  random officer/test;
  output out=outex4a;
proc print data=outex4a;
run;
```

```
General Linear Models Procedure
                             Class Level Information

                           Class     Levels    Values

                           OFFICER        5    A B C D E


                     Number of observations in data set = 20


                         General Linear Models Procedure

 Dependent Variable: YSCORE
                                     Sum of             Mean
 Source                    DF       Squares           Square   F Value     Pr > F
```

Model	4	1480.0000000	370.0000000	4.89	0.0100
Error	15	1134.0000000	75.6000000		
Corrected Total	19	2614.0000000			

Appendix C: SAS Results

Exhibit C.6: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 8 Data
(Continued)

R-Square	C.V.	Root MSE	YSCORE Mean
0.566182	12.24623	8.6948260	71.000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
OFFICER	4	1480.0000000	370.0000000	4.89	0.0100

Source	DF	Type III SS	Mean Square	F Value	Pr > F
OFFICER	4	1480.0000000	370.0000000	4.89	0.0100

General Linear Models Procedure

Source	Type III Expected Mean Square
OFFICER	Var(Error) + 4 Var(OFFICER)

General Linear Models Procedure
Tests of Hypotheses for Random Model Analysis of Variance

Dependent Variable: YSCORE

Source: OFFICER
Error: MS(Error)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
4	370	15	75.6	4.8942	0.0100

Appendix C: SAS Results

Exhibit C.7: SAS Input for and Results from SAS/STAT PROC VARCOMP for Analyzing of Table 8 Data

```
data example4;
    infile cards;
    input officer $1 cand yscore;
 cards;
A 1 76
A 2 64
A 3 85
A 4 75
B 1 58
B 2 75
B 3 81
B 4 66
C 1 49
C 2 63
C 3 62
C 4 46
D 1 74
D 2 71
D 3 85
D 4 90
E 1 66
E 2 74
E 3 81
E 4 79
;
proc varcomp data=example4 method=type1;
  class officer;
  model yscore = officer;
run;
```

```
Variance Components Estimation Procedure
                           Class Level Information

                         Class    Levels    Values

                         OFFICER       5    A B C D E

                    Number of observations in data set = 20

                   Variance Components Estimation Procedure

 Dependent Variable: YSCORE

 Source                   DF         Type I SS         Type I MS

 OFFICER                   4     1480.00000000      370.00000000

 Error                    15     1134.00000000       75.60000000

 Corrected Total          19     2614.00000000


Source                   Expected Mean Square

 OFFICER                  Var(Error) + 4 Var(OFFICER)

 Error                    Var(Error)
```

Appendix C: SAS Results

Variance Component	Estimate
Var(OFFICER)	73.60000000
Var(Error)	75.60000000

Appendix C: SAS Results

Exhibit C.8: SAS Input for and Results from SAS/STAT PROC ANOVA for Analyzing of Table 10 Data

```
data example5;
    infile cards;
    input c_size $7. region $5. premium;
 cards;
small  east 140
small  west 100
medium east 210
medium west 180
large  east 220
large  west 200
;
proc anova data=example5;
  class c_size region;
  model premium = c_size region;
run;
```

```
Analysis of Variance Procedure
                             Class Level Information

                      Class    Levels    Values

                      C_SIZE        3    large medium small

                      REGION        2    east west


                      Number of observations in data set = 6


                          Analysis of Variance Procedure

 Dependent Variable: PREMIUM
                                           Sum of            Mean
 Source                  DF               Squares          Square   F Value      Pr > F

 Model                    3      10650.000000     3550.000000     71.00      0.0139

 Error                    2        100.000000       50.000000

 Corrected Total          5      10750.000000

                   R-Square              C.V.        Root MSE            PREMIUM Mean

                   0.990698          4.040610       7.0710678               175.00000


 Source                  DF          Anova SS     Mean Square   F Value      Pr > F

 C_SIZE                   2      9300.0000000    4650.0000000     93.00      0.0106
```

```
REGION                    1      1350.0000000     1350.0000000      27.00      0.0351
```

Appendix C: SAS Results

Exhibit C.9: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 10 Data

```
data example5;
    infile cards;
    input c_size $7. region $5. premium;
 cards;
small  east 140
small  west 100
medium east 210
medium west 180
large  east 220
large  west 200
;
proc glm data=example5;
  class c_size region;
  model premium = c_size region;
  output out=outex5a;
proc print data=outex5a;
run;
```

```
General Linear Models Procedure
                             Class Level Information

                      Class    Levels    Values

                      C_SIZE        3    large medium small

                      REGION        2    east west


                      Number of observations in data set = 6

                         General Linear Models Procedure

 Dependent Variable: PREMIUM
                                          Sum of            Mean
 Source                  DF              Squares          Square   F Value      Pr > F

 Model                    3      10650.000000     3550.000000     71.00      0.0139

 Error                    2        100.000000       50.000000

 Corrected Total          5      10750.000000

                   R-Square              C.V.        Root MSE          PREMIUM Mean

                   0.990698          4.040610       7.0710678             175.00000


 Source                  DF          Type I SS     Mean Square   F Value      Pr > F

 C_SIZE                   2      9300.0000000    4650.0000000     93.00      0.0106
 REGION                   1      1350.0000000    1350.0000000     27.00      0.0351
```

Source	DF	Type III SS	Mean Square	F Value	Pr > F
C_SIZE	2	9300.0000000	4650.0000000	93.00	0.0106
REGION	1	1350.0000000	1350.0000000	27.00	0.0351

Appendix C: SAS Results

Exhibit C.10: SAS Input for and Results from SAS/STAT PROC ANOVA for Analyzing of Table 13 Data

```
data example6;
    infile cards;
    input school $14. instruct rating;
 cards;
Atlanta       1 25
Atlanta       1 29
Atlanta       2 14
Atlanta       2 11
Chicago       1 11
Chicago       1  6
Chicago       2 22
Chicago       2 18
San Francisco 1 17
San Francisco 1 20
San Francisco 2  5
San Francisco 2  2
;
proc anova data=example6;
    class school instruct;
    model rating = school instruct(school);
run;
```

```
Analysis of Variance Procedure
                             Class Level Information

                 Class    Levels    Values

                 SCHOOL        3    Atlanta Chicago San Francisco

                 INSTRUCT      2    1 2


                     Number of observations in data set = 12


                          Analysis of Variance Procedure

 Dependent Variable: RATING
                                          Sum of             Mean
 Source                   DF             Squares           Square   F Value     Pr > F

 Model                     5        724.00000000     144.80000000     20.69     0.0010

 Error                     6         42.00000000       7.00000000

 Corrected Total          11        766.00000000

                   R-Square                C.V.         Root MSE           RATING Mean

                   0.945170            17.63834        2.6457513             15.000000
```

Appendix C: SAS Results

Source	DF	Anova SS	Mean Square	F Value	Pr > F
SCHOOL	2	156.50000000	78.25000000	11.18	0.0095
INSTRUCT(SCHOOL)	3	567.50000000	189.16666667	27.02	0.0007

Appendix C: SAS Results

Exhibit C.11: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 13 Data

```
data example6;
    infile cards;
    input school $14. instruct rating;
 cards;
Atlanta       1 25
Atlanta       1 29
Atlanta       2 14
Atlanta       2 11
Chicago       1 11
Chicago       1  6
Chicago       2 22
Chicago       2 18
San Francisco 1 17
San Francisco 1 20
San Francisco 2  5
San Francisco 2  2
;
proc glm data=example6;
    class school instruct;
    model rating = school instruct(school);
    output out=outex6a;
proc print data=outex6a;
run;
```

```
General Linear Models Procedure
                             Class Level Information

                 Class     Levels    Values

                 SCHOOL         3    Atlanta Chicago San Francisco

                 INSTRUCT       2    1 2


                     Number of observations in data set = 12


                         General Linear Models Procedure

 Dependent Variable: RATING
                                       Sum of              Mean
 Source                    DF         Squares            Square   F Value     Pr > F

 Model                      5    724.00000000      144.80000000     20.69     0.0010

 Error                      6     42.00000000        7.00000000

 Corrected Total           11    766.00000000

                     R-Square            C.V.          Root MSE          RATING Mean
```

```
0.945170          17.63834       2.6457513          15.000000
```

Exhibit C.11: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 13 Data (continued)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SCHOOL	2	156.50000000	78.25000000	11.18	0.0095
INSTRUCT(SCHOOL)	3	567.50000000	189.16666667	27.02	0.0007

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SCHOOL	2	156.50000000	78.25000000	11.18	0.0095
INSTRUCT(SCHOOL)	3	567.50000000	189.16666667	27.02	0.0007

Appendix C: SAS Results

Exhibit C.12: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 13 Data

```
data example6;
    infile cards;
    input school $14. instruct rating;
 cards;
Atlanta       1 25
Atlanta       1 29
Atlanta       2 14
Atlanta       2 11
Chicago       1 11
Chicago       1  6
Chicago       2 22
Chicago       2 18
San Francisco 1 17
San Francisco 1 20
San Francisco 2  5
San Francisco 2  2
;
proc glm data=example6;
    class school instruct;
    model rating = school instruct(school);
    random school instruct(school)/test;
    output out=outex6b;
proc print data=outex6b;
run;
```

```
General Linear Models Procedure
                             Class Level Information

                 Class    Levels    Values

                 SCHOOL        3    Atlanta Chicago San Francisco

                 INSTRUCT      2    1 2


                     Number of observations in data set = 12



                         General Linear Models Procedure

 Dependent Variable: RATING
                                     Sum of             Mean
 Source                   DF        Squares           Square   F Value     Pr > F

 Model                     5     724.00000000    144.80000000     20.69     0.0010

 Error                     6      42.00000000      7.00000000

 Corrected Total          11     766.00000000
```

R-Square	C.V.	Root MSE	RATING Mean
0.945170	17.63834	2.6457513	15.000000

Exhibit C.12: SAS Input for and Results from SAS/STAT PROC GLM for Analyzing of Table 13 Data (continued)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SCHOOL	2	156.50000000	78.25000000	11.18	0.0095
INSTRUCT(SCHOOL)	3	567.50000000	189.16666667	27.02	0.0007

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SCHOOL	2	156.50000000	78.25000000	11.18	0.0095
INSTRUCT(SCHOOL)	3	567.50000000	189.16666667	27.02	0.0007

General Linear Models Procedure

Source	Type III Expected Mean Square
SCHOOL	Var(Error) + 2 Var(INSTRUCT(SCHOOL)) + 4 Var(SCHOOL)
INSTRUCT(SCHOOL)	Var(Error) + 2 Var(INSTRUCT(SCHOOL))

General Linear Models Procedure
Tests of Hypotheses for Random Model Analysis of Variance

Dependent Variable: RATING

Source: SCHOOL
Error: MS(INSTRUCT(SCHOOL))

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
2	78.25	3	189.16666667	0.4137	0.6940

Source: INSTRUCT(SCHOOL)
Error: MS(Error)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
3	189.16666667	6	7	27.0238	0.0007

Appendix C: SAS Results

Exhibit C.13: SAS Input for and Results from SAS/STAT PROC VARCOMP for Analyzing of Table 13 Data

```
data example6;
    infile cards;
    input school $14. instruct rating;
 cards;
Atlanta       1 25
Atlanta       1 29
Atlanta       2 14
Atlanta       2 11
Chicago       1 11
Chicago       1  6
Chicago       2 22
Chicago       2 18
San Francisco 1 17
San Francisco 1 20
San Francisco 2  5
San Francisco 2  2
;
proc varcomp data=example6 method=type1;
  class school instruct;
  model rating = school instruct(school);
run;
```

```
Variance Components Estimation Procedure
                             Class Level Information

                Class    Levels    Values

                SCHOOL        3    Atlanta Chicago San Francisco

                INSTRUCT      2    1 2

                    Number of observations in data set = 12

                     Variance Components Estimation Procedure

 Dependent Variable: RATING

 Source                    DF          Type I SS          Type I MS

 SCHOOL                     2      156.50000000        78.25000000

 INSTRUCT(SCHOOL)           3      567.50000000       189.16666667

 Error                      6       42.00000000         7.00000000

 Corrected Total           11      766.00000000

 Source                    Expected Mean Square

 SCHOOL                    Var(Error) + 2 Var(INSTRUCT(SCHOOL)) + 4 Var(SCHOOL)

 INSTRUCT(SCHOOL)          Var(Error) + 2 Var(INSTRUCT(SCHOOL))

 Error                     Var(Error)

 Variance Component                    Estimate

 Var(SCHOOL)                       -27.72916667

 Var(INSTRUCT(SCHOOL))              91.08333333
```

```
Var(Error)                        7.00000000
```

Appendix C: SAS Results

Exhibit C.14: SAS Input for and Results from SAS/QC PROC FACTEX for Experimental Design

```
proc factex;
   factors x1 x2 x3 x4 x5 x6;
   model res=4;
   size fraction=4;
   output out=outex7;
proc print data=outex7;
run;
```

OBS	X1	X2	X3	X4	X5	X6
1	-1	-1	-1	-1	-1	-1
2	-1	-1	-1	1	1	1
3	-1	-1	1	-1	1	1
4	-1	-1	1	1	-1	-1
5	-1	1	-1	-1	1	-1
6	-1	1	-1	1	-1	1
7	-1	1	1	-1	-1	1
8	-1	1	1	1	1	-1
9	1	-1	-1	-1	-1	1
10	1	-1	-1	1	1	-1
11	1	-1	1	-1	1	-1
12	1	-1	1	1	-1	1
13	1	1	-1	-1	1	1
14	1	1	-1	1	-1	-1
15	1	1	1	-1	-1	-1
16	1	1	1	1	1	1

Appendix C: SAS Results

Exhibit C.15: SAS Input and Output for Mixture Problem Defined by Equation (2)

```
libname new 'sys$scratch:';

    libname textbk01 xport 'sys$scratch:textbk01' cc=none;



%adxgen;

%adxmix;

%adxinit

%adxxvert(ev,x1 .2-.6/ x2 .1-.6/ x3 .1-.5,1);

   proc sort data=ev

                          out=new.ev_pts;
          by x1 x2 x3;
 proc copy in=new  out=textbk01 memtype=data;
           select ev_pts;
run;
```

Extreme Vertices (Dimen=0) and Centroid (Dimen=2)

x_1	x_2	x_3	DIMEN
0.2	0.3	0.5	0
0.2	0.6	0.2	0
0.3	0.6	0.1	0
0.383333	0.333333	0.283333	2
0.4	0.1	0.5	0
0.6	0.1	0.3	0
0.6	0.3	0.1	0

The output from this SAS run was “FTP’d” to the IBM PC using WS_FTP32 Version 3.00 by Ipswitch, Inc., 1996, as a SAS transport file. The file was then imported into JMP and copy and pasted into this document.

Appendix C: SAS Results

Exhibit C.16: SAS Input for and Results from SAS/QC PROC OPTEX for D-Optimality

```
data example2;
    infile cards;
    input x1 x2 x3;
 cards;
 1 0 0
 1 1 -1
-1 -1 -1
0 0 0
0 0 -1
0 0 0
-1 0 0
0 0 1
1 1 1
1 -1 1
0 0 0
-1 -1 1
-1 1 -1
0 -1 0
1 -1 -1
0 1 0
0 0 0
0 0 0
0 0 0
-1 1 1
;
proc optex data=example2;
   examine var;
   generate criterion=d n=8;
   model x1 x2 x3;
   output out=outex2;
proc print data=outex2;
run;
```

Design Number	D-efficiency	A-efficiency	G-efficiency	Prediction Standard Error
1	100.0000	100.0000	100.0000	0.5590
2	100.0000	100.0000	100.0000	0.5590
3	100.0000	100.0000	100.0000	0.5590
4	100.0000	100.0000	100.0000	0.5590
5	100.0000	100.0000	100.0000	0.5590
6	100.0000	100.0000	100.0000	0.5590
7	100.0000	100.0000	100.0000	0.5590
8	100.0000	100.0000	100.0000	0.5590
9	100.0000	100.0000	100.0000	0.5590
10	100.0000	100.0000	100.0000	0.5590

```
                Examining Design Number 1

      Log determinant of the information matrix = 8.3178E+00

      Maximum prediction variance over candidates =   0.5000
```

```
Average prediction variance over candidates =   0.3125
     Average variance of coefficients =   0.1250

               D-Efficiency =    100.0
               A-Efficiency =    100.0
```

Appendix C: SAS Results

Exhibit C.16: SAS Input for and Results from SAS/QC PROC OPTEX for D-Optimality (Continued)

Variance Matrix

	INTERCEPT	X1	X2	X3
INTERCEPT	0.125	0.000	0.000	0.000
X1	0.000	0.125	0.000	0.000
X2	0.000	0.000	0.125	0.000
X3	0.000	0.000	0.000	0.125

OBS	X1	X2	X3
1	-1	-1	-1
2	-1	-1	1
3	-1	1	-1
4	-1	1	1
5	1	-1	-1
6	1	-1	1
7	1	1	-1
8	1	1	1

Appendix C: SAS Results

Exhibit C.17: SAS Input and Output for Control Chart Example from Table 18

```
data example8;

    infile cards;

    input sg x1-x4;

 cards;

1 72 84 79 49
2 56 87 33 42
3 55 73 22 60
4 44 80 54 74
5 97 26 48 58
6 83 89 91 62
7 47 66 53 58
8 88 50 84 69
9 57 47 41 46
10 13 10 30 32
11 26 39 52 48
12 46 27 63 34
13 49 62 78 87
14 71 63 82 55
15 71 58 69 70
16 67 69 70 94
17 55 63 72 49
18 49 51 55 76
19 72 80 61 59
20 61 74 62 57
;
data example9;
    set example8;
    x=x1; keep sg x;
    output;
    x=x2; keep sg x;
    output;
    x=x3; keep sg x;
    output;
    x=x4; keep sg x;
    output;
run;
proc shewhart data=example9;
     xchart x*sg /
       type=estimate sigmas=3 stddeviations limitn=4;
     schart x*sg;
   run;
```

Appendix C: SAS Results

Exhibit C.17: SAS Input and Output for Control Chart Example from Table 18 (Continued)

```
3 Sigma Limits
                                                                For n=4:
           ---------------------------------------------------
      100 +                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |===============+===================================| UCL = 82.1
       80 +               +                                   |
          |               +                                   |
          |              + +                                  |
          |              + +                                  |
          |   +          + +   +                              |
          |   +          + +   +            ++    + +         |
          |   +          +  +  ++           + ++++   +     +  |
          |    +         +  + + +           +        +    + + |
          |    +     +  +   + + +          +         +    +  +|
          |    +     ++ +   + + +          +          +  +    | =
       60 +----+----+--++----++--+---------+----------++-+----| X = 59.4
    M     |     +   +   +    +   +         +            +     |
    e     |     +   +        +   +         +                  |
    a     |     ++ +             +        +                   |
    n     |       ++              +       +                   |
          |                       +       +                   |
    o     |                       +       +                   |
    f     |                       +      +                    |
          |                       +      +                    |
    X     |                       +    +++                    |
       40 +                        +   +                      |
          |                        +  +                       |
          |========================+==+=======================| LCL = 36.8
          |                        +  +                       |
          |                        +  +                       |
          |                        + +                        |
          |                         ++                        |
          |                         ++                        |
          |                         +                         |
          |                         +                         |
       20 +                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
          |                                                   |
        0 +                                                   |
```

Appendix C: SAS Results

```
                    +----+----+----+----+----+----+----+----+----+----+
                    0    2    4    6    8   10   12   14   16   18   20
                                        Subgroup Index (SG)

    Subgroup Sizes:  n=4
```

Appendix C: SAS Results

Exhibit C.17: SAS Input and Output for Control Chart Example from Table 18 (Continued)

```
      ---------------------------------------------------
  40 +                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |===================================================| UCL = 31.5
     |                                                   |
  30 +             +                                     |
     |             +                                     |
     |             +                                     |
     |            ++                                     |
     |            ++                                     |
     |            ++                                     |
     |            + +                                    |
S    |            + +                                    |
t    |     +      + +                                    |
d    |     ++    +  +                                    |
     |     + +   +  +                                    |
D    |    +   +  +  +                                    |
e    |    +   +  +  +                                    |
v 20 +    +    + +  +                                    |
     |    +    + +  +                                    |
o    |    +    ++   +                                    |
f    |    +     +   +                                    |
     |   +      +    +    +            +                 |
X    |   +           +    +          +++                 |
     |   +           +    +         +   +                |
     |               +    ++        +   +                | -
     |---------------+---+-+-------+----+----------------| S = 13.9
     |               +   + +       +    +     +          |
     |               +   + +      +      +    ++   +     |
     |                +  +  +  ++++      +    + + + +    |
     |                +  +  +  +         +   +  +  +     |
  10 +                 + +  + +           +  +   +    +  |
     |                 ++   + +           +  +         + |
     |                  +    ++            + +         + |
     |                  +    +             ++           +|
     |                       +              +            |
     |                                      +            |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
     |                                                   |
   0 +===================================================| LCL = 0
```

Appendix C: SAS Results

```
                +----+----+----+----+----+----+----+----+----+----+
                0    2    4    6    8   10   12   14   16   18   20

                               Subgroup Index (SG)

    Subgroup Sizes:  n=4
```

Appendix D: Mixsoft Results

Exhibit D.1: Mixsoft Output for a Fractional Factorial Experiment using the Design Experiment Feature

```
MIXSOFT VERSION 2.3, MARCH 1998
 TWOLEV VERSION 2.3, MARCH 1998
 COPYRIGHT (C) 1989-1998, GREGORY F. PIEPEL
 ALL RIGHTS RESERVED

  6 VARIABLES

 CODED LEVELS OF -1 AND +1 USED FOR DESIGN VARIABLES.

 FRACTIONAL FACTORIAL DESIGN,   16 POINTS
```

Run	A	B	C	D	E	F
1	-1	-1	-1	-1	-1	-1
2	1	-1	-1	-1	1	1
3	-1	1	-1	-1	1	1
4	1	1	-1	-1	-1	-1
5	-1	-1	1	-1	1	-1
6	1	-1	1	-1	-1	1
7	-1	1	1	-1	-1	1
8	1	1	1	-1	1	-1
9	-1	-1	-1	1	-1	1
10	1	-1	-1	1	1	-1
11	-1	1	-1	1	1	-1
12	1	1	-1	1	-1	1
13	-1	-1	1	1	1	1
14	1	-1	1	1	-1	-1
15	-1	1	1	1	-1	-1
16	1	1	1	1	1	1

Exhibit D.2: Mixsoft Input and Output for Mixture Problem Defined by Equation (2)

```
MIXSOFT VERSION 2.3, MARCH 1998
 VERT VERSION 2.3, MARCH 1998
 COPYRIGHT (C) 1989-1998, GREGORY F. PIEPEL
 ALL RIGHTS RESERVED

  3 COMPONENTS

 COMPONENT     LOWER BOUNDS     UPPER BOUNDS
 ---------     ------------     ------------
     1         0.200000E+00     0.600000E+00
     2         0.100000E+00     0.600000E+00
     3         0.100000E+00     0.500000E+00

 TOLERANCE VALUE = 0.1000E-05

 COMPONENT VALUE TOLERANCE VECTOR
   TOLV( 1) = 0.5000E-04
   TOLV( 2) = 0.5000E-04
   TOLV( 3) = 0.5000E-04

 THE CONSTRAINT REGION HAS      6 VERTICES.

 ALL VERTICES:    6 OBTAINED

    1  0.2000E+00  0.6000E+00  0.2000E+00
    2  0.3000E+00  0.6000E+00  0.1000E+00
    3  0.6000E+00  0.3000E+00  0.1000E+00
    4  0.2000E+00  0.3000E+00  0.5000E+00
    5  0.6000E+00  0.1000E+00  0.3000E+00
    6  0.4000E+00  0.1000E+00  0.5000E+00
```

Appendix E: Statgraphics Results

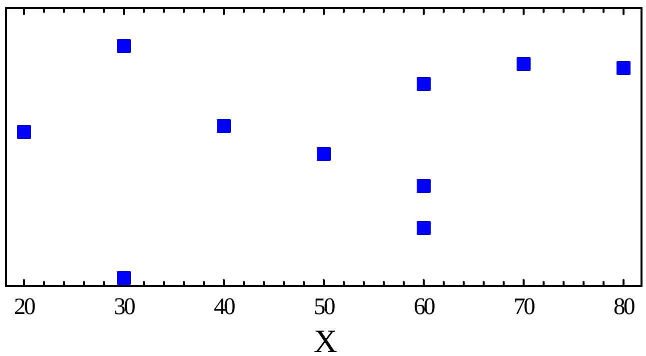
Exhibit E.1: Statgraphics Output for Statistics of Lot Size Information in Table 2

Analysis Summary

Data variable: X

10 values ranging from 20.0 to 80.0

Scatterplot for X

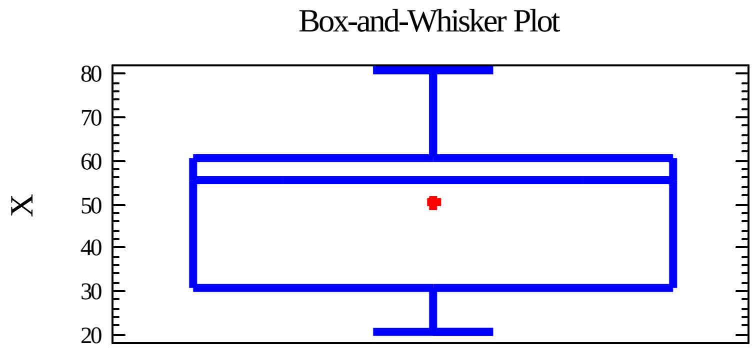


Summary Statistics for X

Count = 10
Average = 50.0
Median = 55.0
Mode = 60.0
Geometric mean = 46.1205
Variance = 377.778
Standard deviation = 19.4365
Standard error = 6.14636
Minimum = 20.0
Maximum = 80.0
Range = 60.0
Lower quartile = 30.0
Upper quartile = 60.0
Interquartile range = 30.0
Skewness = -0.113492
Stnd. skewness = -0.146517
Kurtosis = -1.06661
Stnd. kurtosis = -0.688493
Coeff. of variation = 38.873%
Sum = 500.0

Appendix E: Statgraphics Results

Exhibit E.1: Statgraphics Output for Statistics of Lot Size Information in Table 2
(continued)

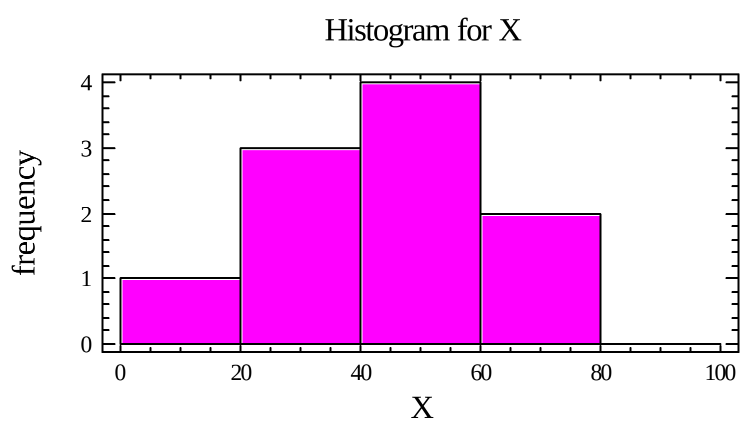


Percentiles for X

0.5% = 20.0
2.5% = 20.0
10.0% = 25.0
25.0% = 30.0
50.0% = 55.0
75.0% = 60.0
90.0% = 75.0
97.5% = 80.0
99.5% = 80.0

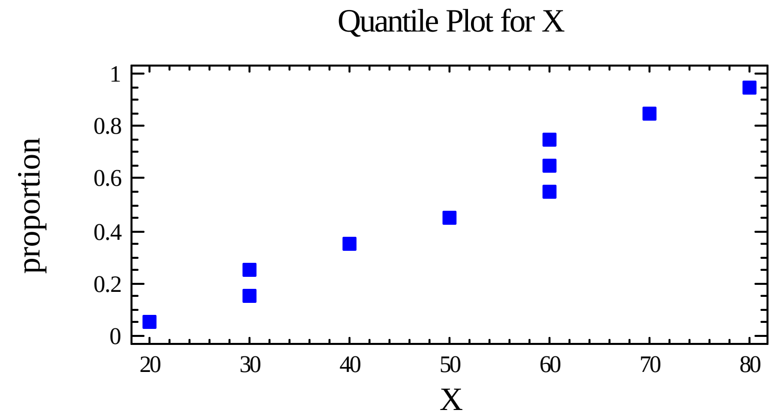
Note: There are several ways to determine estimates of quantiles. Statgraphics computes these as outlined in Hayes [13]. The Pth quantile is estimated as 100(i -0.5)/N where i is the rank. Linear interpolation is used for other quantiles.

Moments



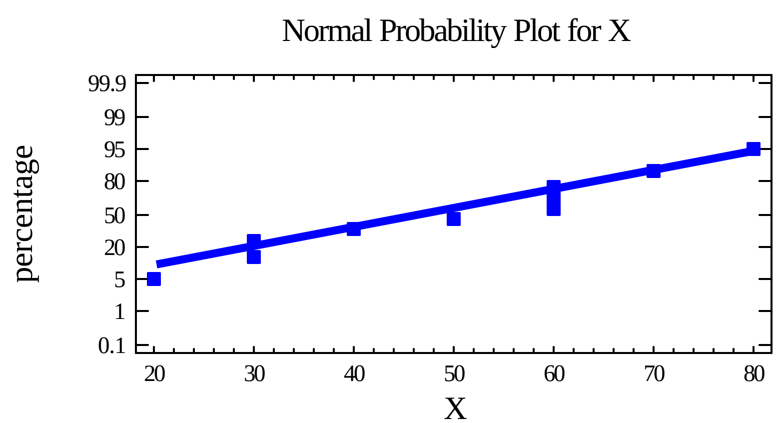
Appendix E: Statgraphics Results

Exhibit E.1: Statgraphics Output for Statistics of Lot Size Information in Table 2
(continued)



Stem-and-Leaf Display for X: unit = 1.0   1|2 represents 12.0

1	2|0
3	3|00
4	4|0
5	5|0
5	6|000
2	7|0
1	8|0



Confidence Intervals for X

95.0% confidence interval for mean: 50.0 +/- 13.9041   [36.0959,63.9041]

95.0% confidence interval for standard deviation: [13.3691,35.4835]

Appendix E: Statgraphics Results

Exhibit E.2: Statgraphics Output for Table 2 Data Using Simple Regression

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: Y
Independent variable: X

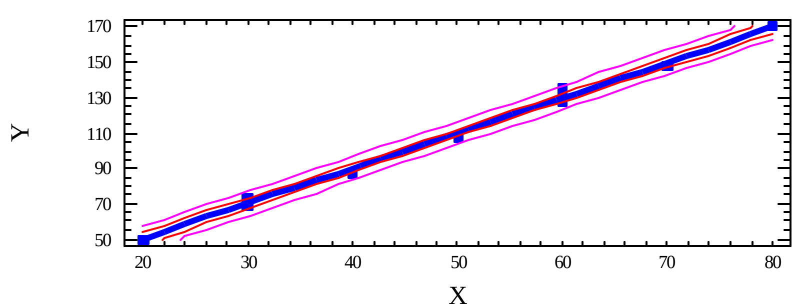
Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	10.0	2.50294	3.9953	0.0040
Slope	2.0	0.0469668	42.5833	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	13600.0	1	13600.0	1813.33	0.0000
Residual	60.0	8	7.5		
Total (Corr.)	13660.0	9			

Correlation Coefficient = 0.997801
R-squared = 99.5608 percent
Standard Error of Est. = 2.73861

Plot of Fitted Model



Analysis of Variance with Lack-of-Fit

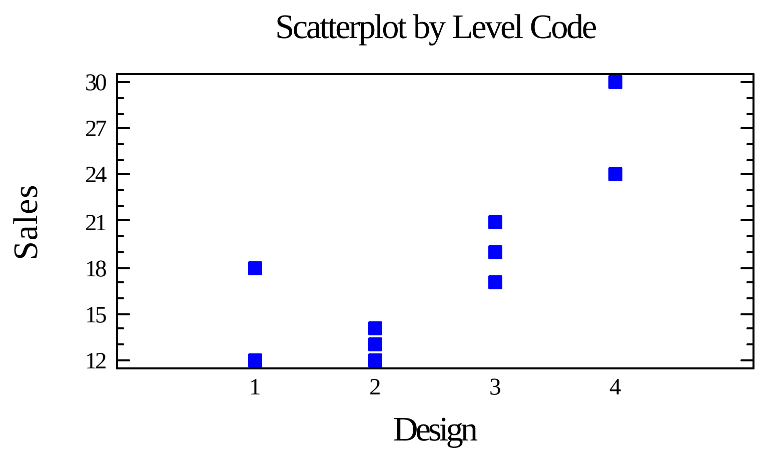
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	13600.0	1	13600.0	1813.33	0.0000
Residual	60.0	8	7.5		
Lack-of-Fit	27.3333	5	5.46667	0.50	0.7662
Pure Error	32.6667	3	10.8889		
Total (Corr.)	13660.0	9			

Appendix E: Statgraphics Results

Exhibit E.3: Statgraphics Output for Table 5 Data Using One-Way ANOVA

Dependent variable: Sales
Factor: Design

Number of observations: 10
Number of levels: 4



Summary Statistics for Sales

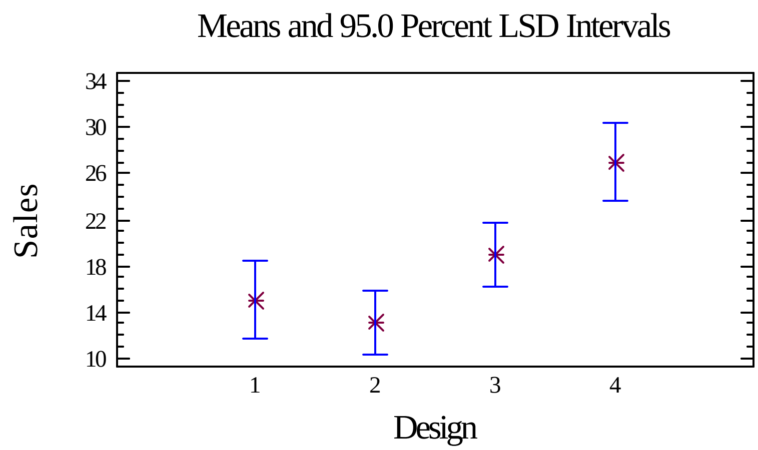
Design	Count	Average	Variance
1	2	15.0	18.0
2	3	13.0	1.0
3	3	19.0	4.0
4	2	27.0	18.0
Total	10	18.0	33.7778

Design	Standard deviation	Minimum	Maximum
1	4.24264	12.0	18.0
2	1.0	12.0	14.0
3	2.0	17.0	21.0
4	4.24264	24.0	30.0
Total	5.81187	12.0	30.0

Design	Range	Stnd. skewness	Stnd. kurtosis
1	6.0		
2	2.0	0.0	
3	4.0	0.0	
4	6.0		
Total	18.0	1.23305	0.358593

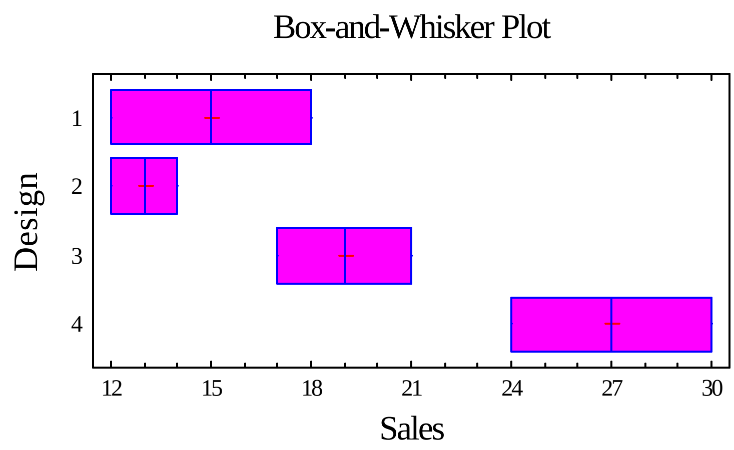
Appendix E: Statgraphics Results

Exhibit E.3: Statgraphics Output for Table 5 Data Using One-Way ANOVA
(continued)



ANOVA Table for Sales by Design

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	258.0	3	86.0	11.22	0.0071
Within groups	46.0	6	7.66667		
Total (Corr.)	304.0	9			



Appendix E: Statgraphics Results

Exhibit E.3: Statgraphics Output for Table 5 Data Using One-Way ANOVA
(continued)

Table of Means for Sales by Design with 95.0 percent LSD intervals

Design	Count	Mean	Stnd. error (pooled s)	Lower limit	Upper limit
1	2	15.0	1.95789	11.6124	18.3876
2	3	13.0	1.59861	10.234	15.766
3	3	19.0	1.59861	16.234	21.766
4	2	27.0	1.95789	23.6124	30.3876
Total	10	18.0			

Appendix E: Statgraphics Results

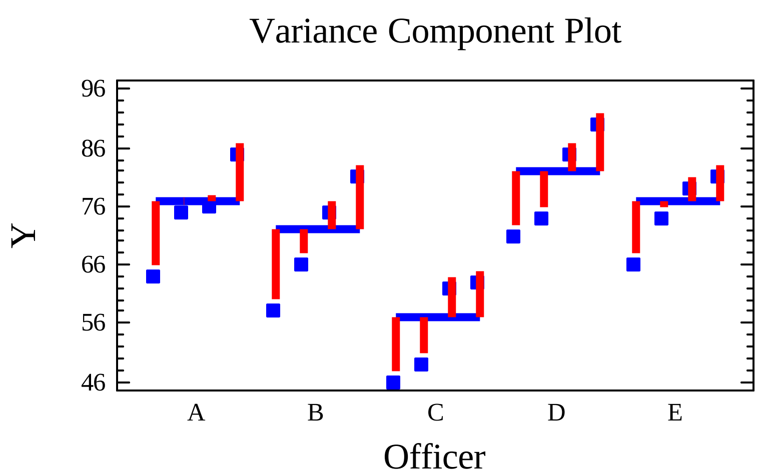
Exhibit E.4: Statgraphics Output for Table 8 Data using Variance Components Analysis

Dependent variable: Y
Factors: Officer

Number of complete cases: 20

Analysis of Variance for Y

Source	Sum of Squares	Df	Mean Square	Var. Comp.	Percent
TOTAL (CORRECTED)	2614.0	19			
Officer	1480.0	4	370.0	73.6	49.33
ERROR	1134.0	15	75.6	75.6	50.67



Y

Level	Count	Mean	Standard Deviation
GRAND MEAN	20	71.0	11.7294
Officer			
A	4	75.0	8.60233
B	4	70.0	10.0995
C	4	55.0	8.75595
D	4	80.0	8.98146
E	4	75.0	6.68331

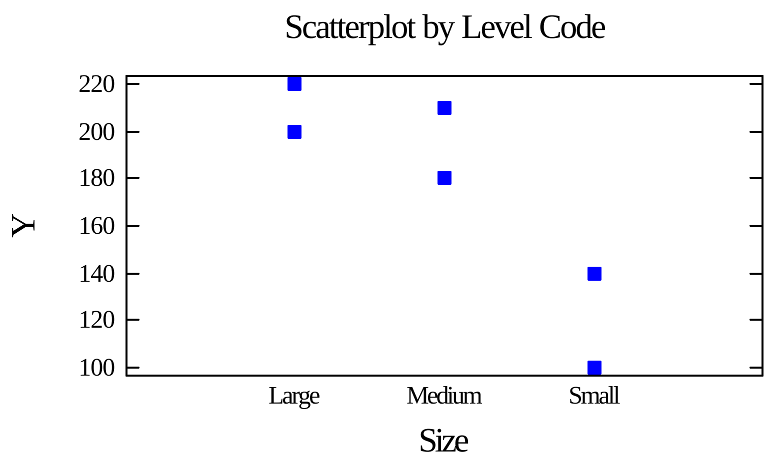
Appendix E: Statgraphics Results

Exhibit E.5: Statgraphics Output for Table 10 Data using Two Factor ANOVA

Multifactor ANOVA - Y

Dependent variable: Y
Factors:
    Size
    Region

Number of complete cases: 6



Analysis of Variance for Y

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Size	9300.0	2	4650.0	93.00	0.0106
B:Region	1350.0	1	1350.0	27.00	0.0351
RESIDUAL	100.0	2	50.0		
TOTAL (CORRECTED)	10750.0	5			

All F-ratios are based on the residual mean square error.

Appendix E: Statgraphics Results

Exhibit E.5: Statgraphics Output for Table 10 Data using Two Factor ANOVA
(continued)

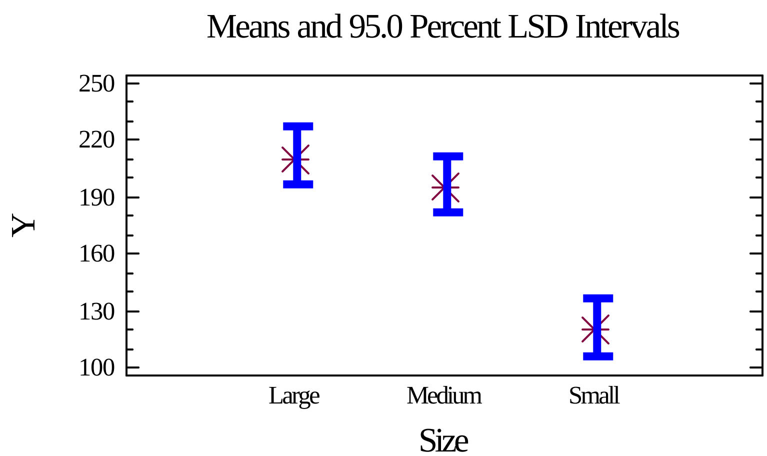


Table of Least Squares Means for Y with 95.0 Percent Confidence Intervals

Level	Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN	6	175.0			
Size					
Large	2	210.0	5.0	188.487	231.513
Medium	2	195.0	5.0	173.487	216.513
Small	2	120.0	5.0	98.4867	141.513
Region					
East	3	190.0	4.08248	172.434	207.566
West	3	160.0	4.08248	142.434	177.566

Multiple Range Tests for Y by Size

Method: 95.0 percent LSD

Size	Count	LS Mean	Homogeneous Groups
Small	2	120.0	X
Medium	2	195.0	X
Large	2	210.0	X

Contrast	Difference	+/- Limits
Large - Medium	15.0	30.4243
Large - Small	*90.0	30.4243
Medium - Small	*75.0	30.4243

* denotes a statistically significant difference.

Appendix E: Statgraphics Results

Exhibit E.6: Statgraphics Output for Table 13 Data using a Nested Model

General Linear Models

Number of dependent variables: 1
Number of categorical factors: 2
Number of quantitative factors: 0

Analysis of Variance for Y

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	724.0	5	144.8	20.69	0.0010
Residual	42.0	6	7.0		
Total (Corr.)	766.0	11			

Type III Sums of Squares

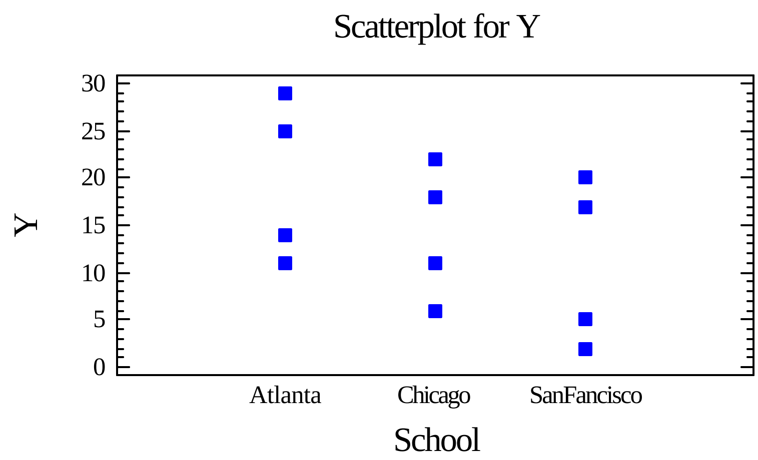
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
School	156.5	2	78.25	11.18	0.0095
Instructor(School)	567.5	3	189.167	27.02	0.0007
Residual	42.0	6	7.0		
Total (corrected)	766.0	11			

All F-ratios are based on the residual mean square error.

R-Squared = 94.517 percent
R-Squared (adjusted for d.f.) = 89.9478 percent
Standard Error of Est. = 2.64575
Mean absolute error = 1.83333
Durbin-Watson statistic = 1.89881

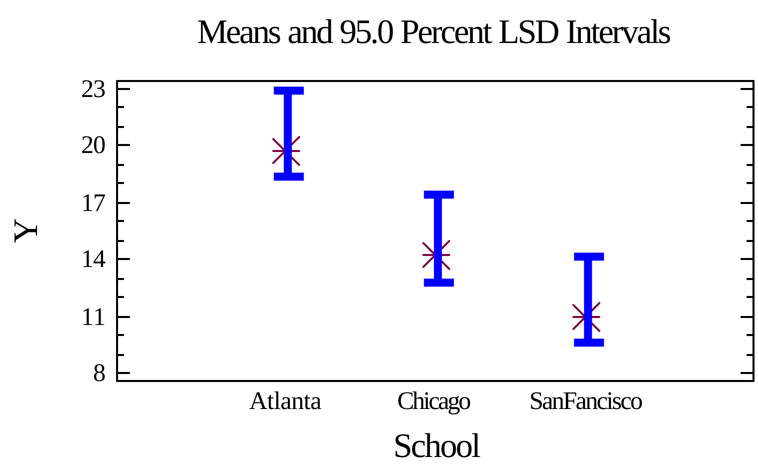
Appendix E: Statgraphics Results

Exhibit E.6: Statgraphics Output for Table 13 Data using a Nested Model
(continued)



95.0% confidence intervals for coefficient estimates (Y)

Parameter	Estimate	Standard Error	Lower Limit	Upper Limit	V.I.F.
CONSTANT	15.0	0.763763	13.1311	16.8689	
School	4.75	1.08012	2.10703	7.39297	1.33333
School	-0.75	1.08012	-3.39297	1.89297	1.33333
Instructor(School)	7.25	1.32288	4.01303	10.487	1.0
Instructor(School)	-5.75	1.32288	-8.98697	-2.51303	1.0
Instructor(School)	7.5	1.32288	4.26303	10.737	1.0



Appendix E: Statgraphics Results

Exhibit E.6: Statgraphics Output for Table 13 Data using a Nested Model
(continued)

Table of Least Squares Means for Y with 95.0 Percent Confidence Intervals

Level		Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN		12	15.0	0.763763	13.1311	16.8689
School						
Atlanta		4	19.75	1.32288	16.513	22.987
Chicago		4	14.25	1.32288	11.013	17.487
SanFancisco		4	11.0	1.32288	7.76303	14.237
Instructor within School						
1	Atlanta	2	27.0	1.87083	22.4222	31.5778
1	Chicago	2	8.5	1.87083	3.92224	13.0778
1	SanFancisc	2	18.5	1.87083	13.9222	23.0778
2	Atlanta	2	12.5	1.87083	7.92224	17.0778
2	Chicago	2	20.0	1.87083	15.4222	24.5778
2	SanFancisc	2	3.5	1.87083	-1.07776	8.07776

Multiple Comparisons for Y by School

Method: 95.0 percent LSD

School	Count	LS Mean	Homogeneous Groups
SanFancisco	4	11.0	X
Chicago	4	14.25	X
Atlanta	4	19.75	X

Contrast	Difference	+/- Limits
Atlanta - Chicago	*5.5	4.57776
Atlanta - SanFancisco	*8.75	4.57776
Chicago - SanFancisco	3.25	4.57776

* denotes a statistically significant difference.

Appendix E: Statgraphics Results

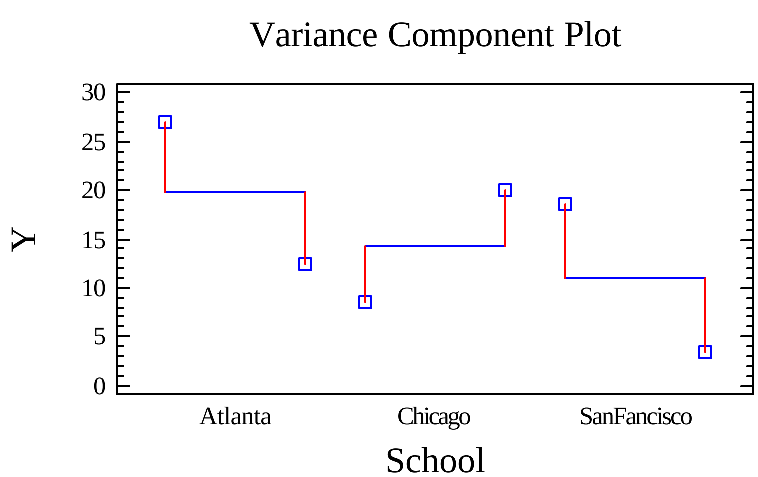
Exhibit E.7: Statgraphics Output for Table 13 Data using Variance Component Analysis

Dependent variable: Y
Factors:
School
Instructor

Number of complete cases: 12

Analysis of Variance for Y

Source	Sum of Squares	Df	Mean Square	Var. Comp.	Percent
TOTAL (CORRECTED)	766.0	11			
School	156.5	2	78.25	0.0	0.00
Instructor	567.5	3	189.167	91.0833	92.86
ERROR	42.0	6	7.0	7.0	7.14



Y

Level	**Count**	**Mean**	**Standard Deviation**
GRAND MEAN	12	15.0	8.34484
School			
Atlanta	4	19.75	8.61684
Chicago	4	14.25	7.13559
SanFancisco	4	11.0	8.83176

Appendix E: Statgraphics Results

Exhibit E.7: Statgraphics Output for Table 13 Data using Variance Component Analysis
(continued)

Instructor

1	2	27.0	2.82843
2	2	12.5	2.12132
1	2	8.5	3.53553
2	2	20.0	2.82843
1	2	18.5	2.12132
2	2	3.5	2.12132

Appendix E: Statgraphics Results

Exhibit E.8: Statgraphics Output for Fractional Factorial Design

Screening Design Attributes

Design Summary

Design class: Screening
Design name: Quarter fraction 2^6-2

Base Design

Number of experimental factors: 6 Number of blocks: 1
Number of responses: 1
Number of runs: 16 Error degrees of freedom: 2
Randomized: No

Factors	Low	High	Continuous
X1	-1.0	1.0	Yes
X4	-1.0	1.0	Yes
X3	-1.0	1.0	Yes
X2	-1.0	1.0	Yes
X6	-1.0	1.0	Yes
X5	-1.0	1.0	Yes

Run	X1	X2	X3	X4	X5	X6
1	-1	-1	-1	-1	-1	-1
2	-1	-1	-1	1	1	1
3	-1	-1	1	-1	1	1
4	-1	-1	1	1	-1	-1
5	-1	1	-1	-1	1	-1
6	-1	1	-1	1	-1	1
7	-1	1	1	-1	-1	1
8	-1	1	1	1	1	-1
9	1	-1	-1	-1	-1	1
10	1	-1	-1	1	1	-1
11	1	-1	1	-1	1	-1
12	1	-1	1	1	-1	1
13	1	1	-1	-1	1	1
14	1	1	-1	1	-1	-1
15	1	1	1	-1	-1	-1
16	1	1	1	1	1	1

Exhibit E.8: Statgraphics Output for Fractional Factorial Design

(continued)

Alias Structure

Contrast	Estimates
1	A
2	B
3	C
4	D
5	E
6	F
7	AB+CE
8	AC+BE
9	AD+EF
10	AE+BC+DF
11	AF+DE
12	BD+CF
13	BF+CD

Appendix E: Statgraphics Results

Exhibit E.9: Statgraphics Output for Extreme Vertices

Design Summary

Design class: Mixture
Design name: Extreme vertices

Base Design

Number of components: 3
Number of responses: 1
Number of runs: 6
Model type: Linear
Randomized: Yes

Components	Low	High	Units
X1	0.2	0.6	
X2	0.1	0.6	
X3	0.1	0.5	

Mixture total = 1.0

Run	X1	X2	X3
1	0.6	0.3	0.1
2	0.6	0.1	0.3
3	0.3	0.6	0.1
4	0.2	0.6	0.2
5	0.4	0.1	0.5
6	0.2	0.3	0.5

Appendix E: Statgraphics Results

Exhibit E.10: Statgraphics D-Optimality Results

Optimize Experiment

Selection criterion: D-optimality
Desired number of runs: 8
Selection method: Forward
Model order: 1

Number of runs already completed: 0
Additional candidate runs: 20

D-optimal Design

Design has been reduced to 8 runs.
D-efficiency = 100.0%
A-efficiency = 100.0%
G-efficiency = 100.0%

Select	Condition	X1	X2	X3
*	1	-1	-1	1
	2	0	0	0
*	3	1	-1	1
	4	0	1	0
*	5	1	1	1
	6	0	0	0
	7	0	0	0
*	8	1	-1	-1
*	9	-1	1	1
	10	0	0	-1
*	11	-1	1	-1
	12	-1	0	0
	13	0	0	1
	14	0	0	0
	15	0	0	0
	16	0	-1	0
*	17	-1	-1	-1
	18	0	0	0
	19	1	0	0
*	20	1	1	-1

*** indicates a run selected to achieve D-optimality**

Appendix E: Statgraphics Results

Exhibit E.11: Statgraphics X-bar and S Charts - X

Initial Study for X

Number of subgroups = 20
Average subgroup size = 4.0
0 subgroups excluded

X-bar Chart

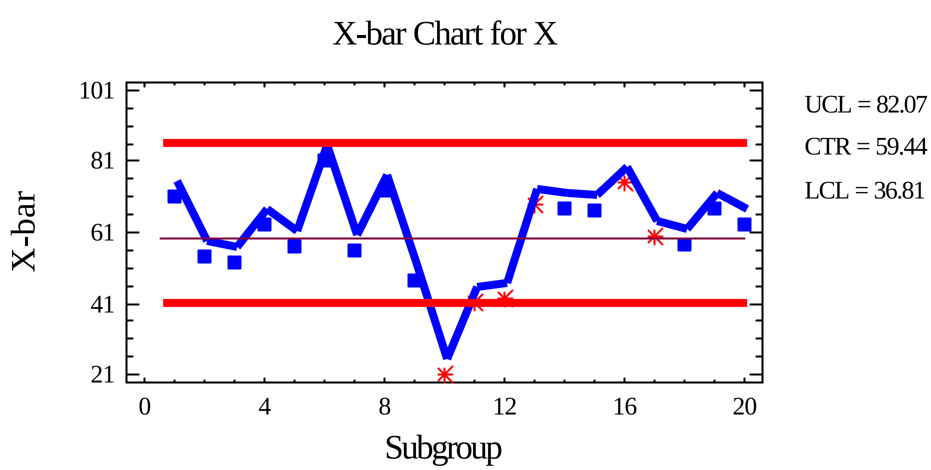
UCL: +3.0 sigma = 82.0667
Centerline = 59.4375
LCL: -3.0 sigma = 36.8083

S Chart

UCL: +3.0 sigma = 31.496
Centerline = 13.8991
LCL: -3.0 sigma = 0.0

Estimates

Process mean = 59.4375
Process sigma = 15.0861
Mean sigma = 13.8991



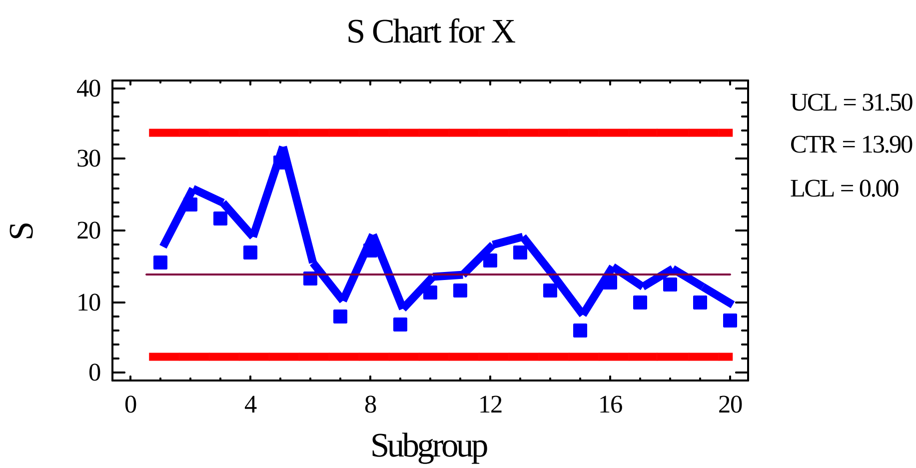
Appendix E: Statgraphics Results

Exhibit E.11: Statgraphics X-bar and S Charts - X
(continued)

Subgroup Reports

All Subgroups
X = Excluded * = Beyond Limits

Subgroup	Size	X-bar	S
1	4	71.0	15.4704
2	4	54.5	23.6432
3	4	52.5	21.7025
4	4	63.0	16.8523
5	4	57.25	29.6802
6	4	81.25	13.2759
7	4	56.0	8.04156
8	4	72.75	17.2313
9	4	47.75	6.70199
10	4	* 21.25	11.3541
11	4	41.25	11.5289
12	4	42.5	15.7586
13	4	69.0	16.8721
14	4	67.75	11.5289
15	4	67.0	6.0553
16	4	75.0	12.7279
17	4	59.75	9.97914
18	4	57.75	12.4197
19	4	68.0	9.83192
20	4	63.5	7.32575



Appendix F: JMP Version 4.0 Results

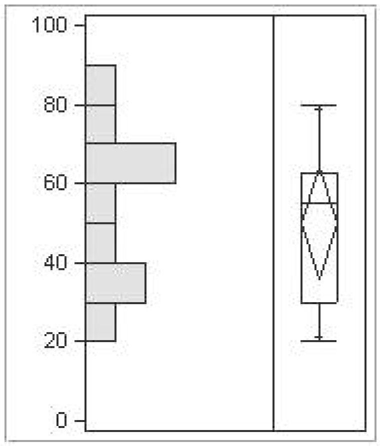
Table F.1: JMP Version 4.0 Sample Statistics for Data from Table 20

Subgroup	N Rows	Mean(x)	Std Dev(x)
1	4	71	15.4704
2	4	54.5	23.64318
3	4	52.5	21.70253
4	4	63	16.8523
5	4	57.25	29.68024
6	4	81.25	13.27592
7	4	56	8.041559
8	4	72.75	17.23127
9	4	47.75	6.70199
10	4	21.25	11.35415
11	4	41.25	11.52895
12	4	42.5	15.7586
13	4	69	16.87207
14	4	67.75	11.52895
15	4	67	6.055301
16	4	75	12.72792
17	4	59.75	9.979145
18	4	57.75	12.41974
19	4	68	9.831921
20	4	63.5	7.325754

Appendix F: JMP Version 4.0 Results

Exhibit F.1: JMP Version 4.0 Output for Descriptive Statistics of Lot Size Information in Table 2

Distributions
Lot Size (Xi)



Moments

Mean	50.00000
Std Dev	19.43651
Std Err Mean	6.14636
upper 95% Mean	63.90416
lower 95% Mean	36.09584
N	10.00000

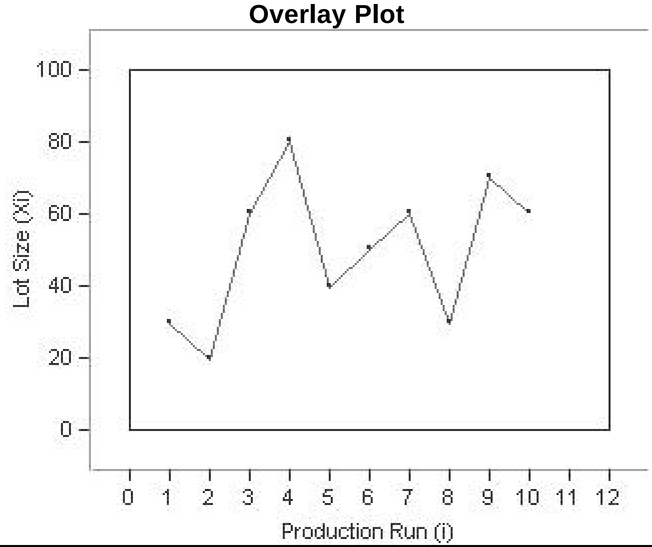
Stem and Leaf

Stem	Leaf	Count
8		
8	0	1
7		
7	0	1
6		
6	000	3
5		
5	0	1
4		
4	0	1
3		
3	00	2
2		
2	0	1

Quantiles

100.0%	maximum	80.000
99.5%		80.000
97.5%		80.000
90.0%		79.000
75.0%	quartile	62.500
50.0%	median	55.000
25.0%	quartile	30.000
10.0%		21.000
2.5%		20.000
0.5%		20.000
0.0%	minimum	20.000

Overlay Plot



Note: There are several ways to determine estimates of quantiles. JMP computes them as follows [14]
"To compute the Pth quantile of N nonmissing values in a column, arrange the N values in ascending order and call these column values $y_1, y_2, \dots y_N$. Compute the rank number for the Pth quantile as $\frac{P}{100}(N+1)$

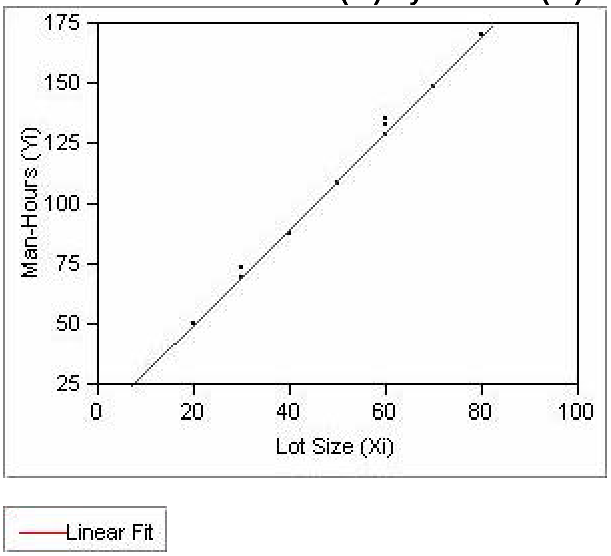
If the result is an integer, the Pth quantile is that rank's corresponding value. If the result is not an integer, the Pth quantile is found by interpolation. Denote the integer portion of the computed rank number as I and the fractional portion as f. The Pth quantile, denoted q_P, is computed $q_P = (1-f)y_I + (f)y_{I+1}$

If I=N, then y_N is taken as the quantile."

Appendix F: JMP Version 4.0 Results

Exhibit F.2: JMP Version 4.0 Output for Regression Model for Information in Table 2 Using Fit Y by X

Bivariate Fit of Man-Hours (Yi) By Lot Size (Xi)



Linear Fit

Man-Hours (Yi) = 10 + 2 Lot Size (Xi)

Summary of Fit

RSquare	0.995608
RSquare Adj	0.995059
Root Mean Square Error	2.738613
Mean of Response	110
Observations (or Sum Wgts)	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	13600.000	13600.0	1813.333
Error	8	60.000	7.5	Prob > F
C. Total	9	13660.000		<.0001

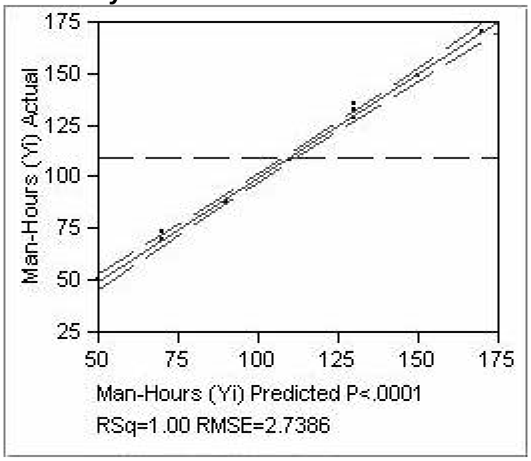
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10	2.502939	4.00	0.0040
Lot Size (Xi)	2	0.046967	42.58	<.0001

Appendix F: JMP Version 4.0 Results

Exhibit F.3: JMP Version 4.0 Output for Regression Model for Information in Table 2 Using Fit Model

Response Man-Hours (Yi)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.995608
RSquare Adj	0.995059
Root Mean Square Error	2.738613
Mean of Response	110
Observations (or Sum Wgts)	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	13600.000	13600.0	1813.333
Error	8	60.000	7.5	Prob > F
C. Total	9	13660.000		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	5	27.333333	5.4667	0.5020
Pure Error	3	32.666667	10.8889	Prob > F
Total Error	8	60.000000		0.7662
				Max RSq
				0.9976

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10	2.502939	4.00	0.0040
Lot Size (Xi)	2	0.046967	42.58	<.0001

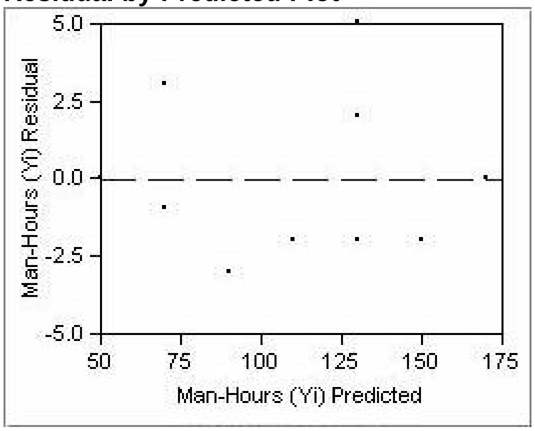
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Lot Size (Xi)	1	1	13600.000	1813.333	<.0001

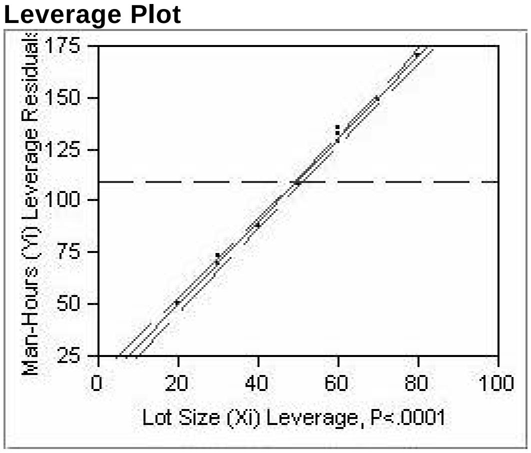
Appendix F: JMP Version 4.0 Results

Exhibit F.3: JMP Version 4.0 Output for Regression Model for Information in Table 2 Using Fit Model (continued)

Residual by Predicted Plot



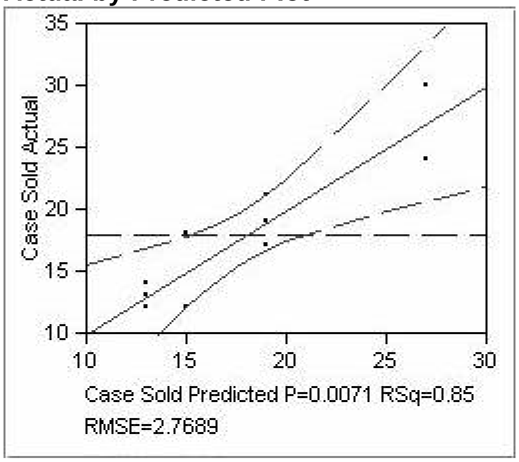
Lot Size (Xi)
Leverage Plot



Appendix F: JMP Version 4.0 Results

Exhibit F.4: JMP Version 4.0 Output for ANOVA of Information in Table 5 Using Fit Model

Response Case Sold
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.848684
RSquare Adj	0.773026
Root Mean Square Error	2.768875
Mean of Response	18
Observations (or Sum Wgts)	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	258.00000	86.0000	11.2174
Error	6	46.00000	7.6667	Prob > F
C. Total	9	304.00000		0.0071

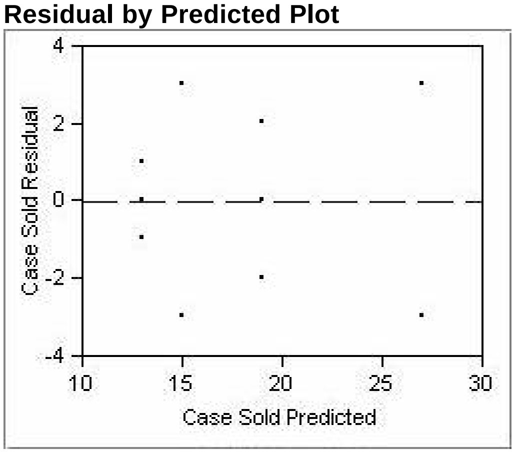
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	18.5	0.89365	20.70	<.0001
Package Design[1]	-3.5	1.64781	-2.12	0.0778
Package Design[2]	-5.5	1.440968	-3.82	0.0088
Package Design[3]	0.5	1.440968	0.35	0.7404

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Package Design	3	3	258.00000	11.2174	0.0071

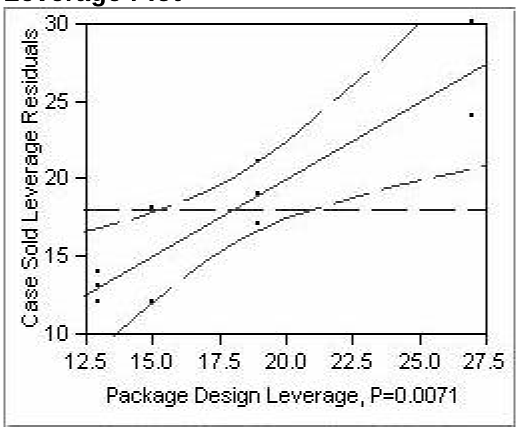
Residual by Predicted Plot



Appendix F: JMP Version 4.0 Results

Exhibit F.4: JMP Version 4.0 Output for ANOVA of Information in Table 5 Using Fit Model (continued)

Package Design
Leverage Plot



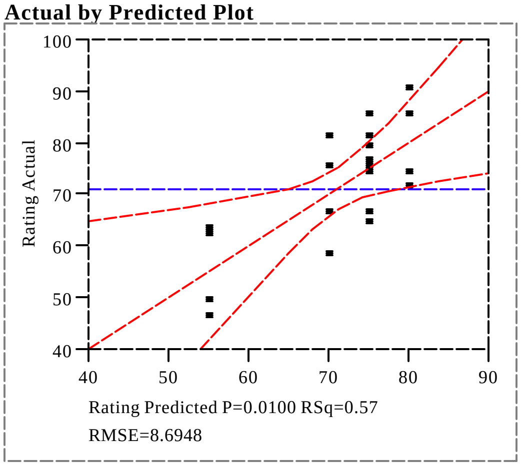
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1	15.000000	1.9578900	15.0000
2	13.000000	1.5986105	13.0000
3	19.000000	1.5986105	19.0000
4	27.000000	1.9578900	27.0000

Appendix F: JMP Version 4.0 Results

Exhibit F.5: JMP Version 4.0 Output for ANOVA of Information in Table 8 Using Fit Model with Random Factor

Response Rating
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.566182
RSquare Adj	0.450497
Root Mean Square Error	8.694826
Mean of Response	71
Observations (or Sum Wgts)	20

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1480.0000	370.000	4.8942
Error	15	1134.0000	75.600	Prob > F
C. Total	19	2614.0000		0.0100

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	71	1.944222	36.52	<.0001
Officer (i)[A]	4	3.888444	1.03	0.3199
Officer (i)[B]	-1	3.888444	-0.26	0.8005
Officer (i)[C]	-16	3.888444	-4.11	0.0009
Officer (i)[D]	9	3.888444	2.31	0.0352

Expected Mean Squares

The Mean Square per row by the Variance Component per column

EMS	Intercept	Officer (i)&Random
Intercept	0	0
Officer (i)&Random	0	4

plus 1.0 times Residual Error Variance

Variance Component Estimates

Component	Var Comp Est	Percent of Total
Officer (i)&Random	73.6	49.330
Residual	75.6	50.670
Total	149.2	100.000

These estimates based on equating Mean Squares to Expected Value.

Test Denominator Synthesis

Source	MS Den	DF Den	Denom MS Synthesis
Officer (i)&Random	75.6	15	Residual

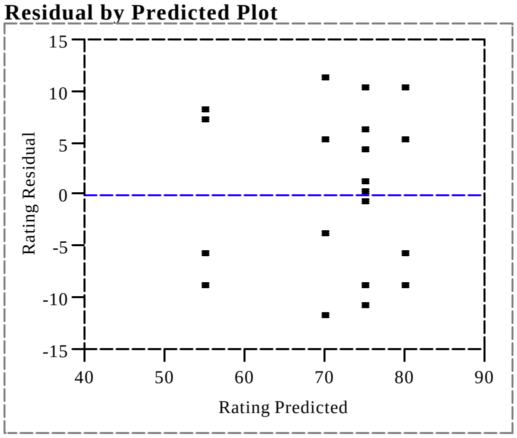
Tests wrt Random Effects

Source	SS	MS Num	DF Num	F Ratio	Prob > F
Officer (i)&Random	1480	370	4	4.8942	0.0100

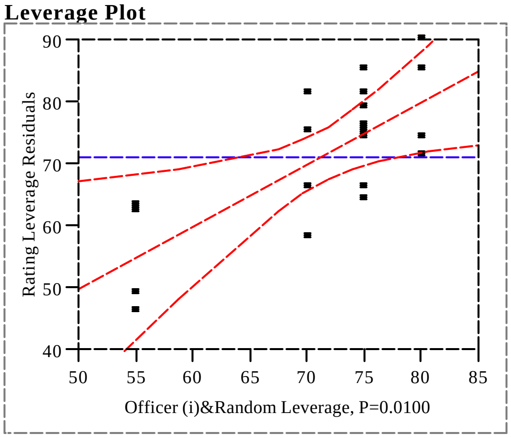
Appendix F: JMP Version 4.0 Results

Exhibit F.5: JMP Version 4.0 Output for ANOVA of Information in Table 8 Using Fit Model with Random Factor (continued)

Residual by Predicted Plot



Officer (i)&Random
Leverage Plot



Effect Test

Sum of Squares	F Ratio	DF	Prob > F
1480.0000	4.8942	4	0.0100

Denominator MS Synthesis:
Residual

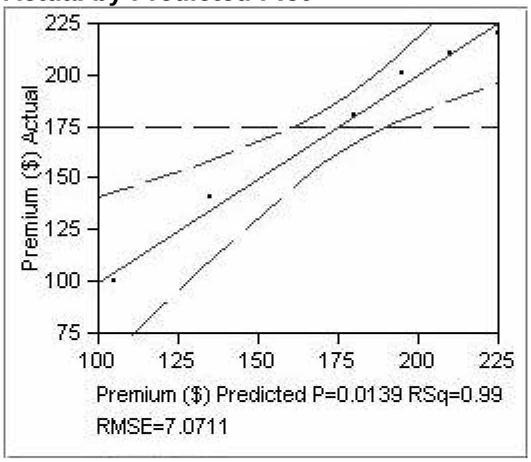
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	75.000000	4.3474130	75.0000
B	70.000000	4.3474130	70.0000
C	55.000000	4.3474130	55.0000
D	80.000000	4.3474130	80.0000
E	75.000000	4.3474130	75.0000

Appendix F: JMP Version 4.0 Results

Exhibit F.6: JMP Version 4.0 Output for ANOVA of Information in Table 10 Using Fit Model with Two Factors

Response Premium ($)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.990698
RSquare Adj	0.976744
Root Mean Square Error	7.071068
Mean of Response	175
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	10650.000	3550.00	71.0000
Error	2	100.000	50.00	Prob > F
C. Total	5	10750.000		0.0139

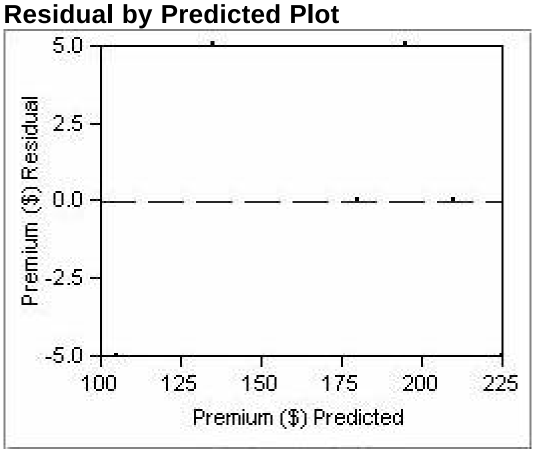
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	175	2.886751	60.62	0.0003
Size of City[Large]	35	4.082483	8.57	0.0133
Size of City[Medium]	20	4.082483	4.90	0.0392
Region[East]	15	2.886751	5.20	0.0351

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Size of City	2	2	9300.0000	93.0000	0.0106
Region	1	1	1350.0000	27.0000	0.0351

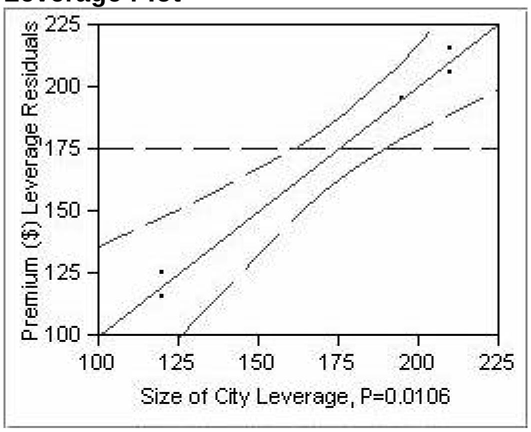
Residual by Predicted Plot



Appendix F: JMP Version 4.0 Results

Exhibit F.6: JMP Version 4.0 Output for ANOVA of Information in Table 10 Using Fit Model with Two Factors (continued)

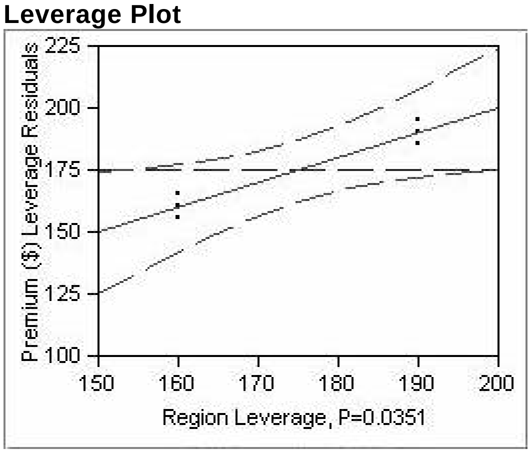
Size of City
Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Large	210.00000	5.0000000	210.000
Medium	195.00000	5.0000000	195.000
Small	120.00000	5.0000000	120.000

Region
Leverage Plot



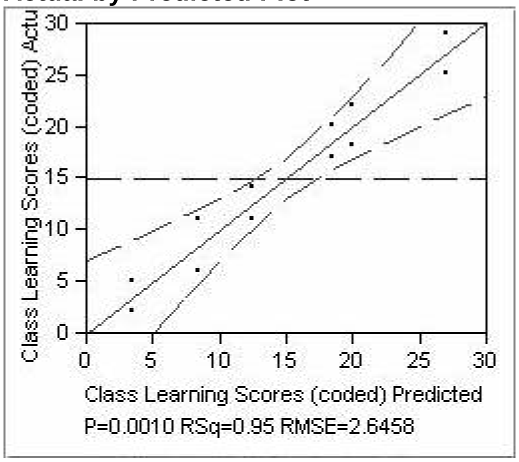
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
East	190.00000	4.0824829	190.000
West	160.00000	4.0824829	160.000

Appendix F: JMP Version 4.0 Results

Exhibit F.7: JMP Version 4.0 Output for Nested ANOVA of Information in Table 13 Using Fit Model with A Nested Factor

Response Class Learning Scores (coded)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.94517
RSquare Adj	0.899478
Root Mean Square Error	2.645751
Mean of Response	15
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	724.00000	144.800	20.6857
Error	6	42.00000	7.000	Prob > F
C. Total	11	766.00000		0.0010

Parameter Estimates

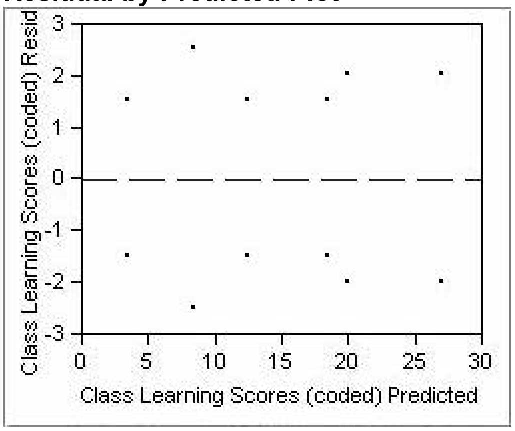
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	15	0.763763	19.64	<.0001
School[Atlanta]	4.75	1.080123	4.40	0.0046
School[Chicago]	-0.75	1.080123	-0.69	0.5134
School[Atlanta]:Instructor[1]	7.25	1.322876	5.48	0.0015
School[Chicago]:Instructor[1]	-5.75	1.322876	-4.35	0.0048
School[San Francisco]:Instructor[1]	7.5	1.322876	5.67	0.0013

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
School	2	2	156.50000	11.1786	0.0095
Instructor[School]	3	3	567.50000	27.0238	0.0007

Appendix F: JMP Version 4.0 Results

Residual by Predicted Plot

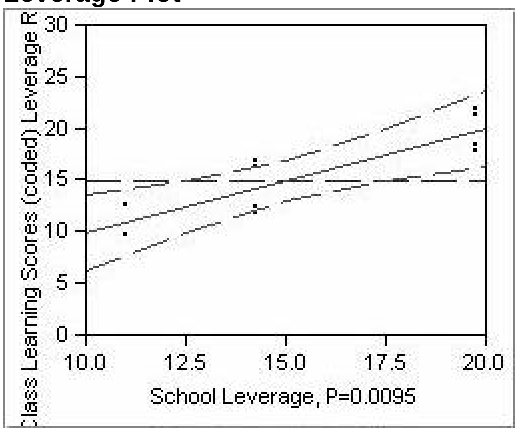


Appendix F: JMP Version 4.0 Results

Exhibit F.7: JMP Version 4.0 Output for Nested ANOVA of Information in Table 13 Using Fit Model with A Nested Factor (continued)

School

Leverage Plot

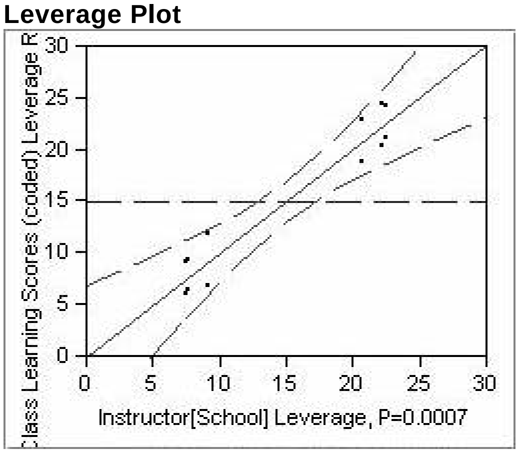


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Atlanta	19.750000	1.3228757	19.7500
Chicago	14.250000	1.3228757	14.2500
San Francisco	11.000000	1.3228757	11.0000

Instructor[School]

Leverage Plot



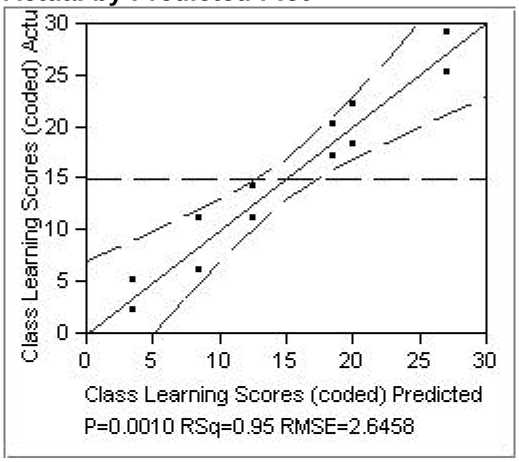
Least Squares Means Table

Level	Least Sq Mean	Std Error
[Atlanta]1	27.000000	1.8708287
[Atlanta]2	12.500000	1.8708287
[Chicago]1	8.500000	1.8708287
[Chicago]2	20.000000	1.8708287
[San Francisco]1	18.500000	1.8708287
[San Francisco]2	3.500000	1.8708287

Appendix F: JMP Version 4.0 Results

Exhibit F.8: JMP Version 4.0 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors

Response Class Learning Scores (coded)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.94517
RSquare Adj	0.899478
Root Mean Square Error	2.645751
Mean of Response	15
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	724.00000	144.800	20.6857
Error	6	42.00000	7.000	Prob > F
C. Total	11	766.00000		0.0010

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	15	0.763763	19.64	<.0001
School[Atlanta]	4.75	1.080123	4.40	0.0046
School[Chicago]	-0.75	1.080123	-0.69	0.5134
School[Atlanta]:Instructor[1]	7.25	1.322876	5.48	0.0015
School[Chicago]:Instructor[1]	-5.75	1.322876	-4.35	0.0048
School[San Francisco]:Instructor[1]	7.5	1.322876	5.67	0.0013

Expected Mean Squares

The Mean Square per row by the Variance Component per column

EMS	Intercept	School&Random	Instructor[School]& Random
Intercept	0	0	0
School&Random	0	4	2
Instructor[School]& Random	0	0	2

plus 1.0 times Residual Error Variance

Variance Component Estimates

Component	Var Comp Est	Percent of Total
School&Random	-27.7292	-39.414
Instructor[School]&Random	91.08333	129.464
Residual	7	9.950
Total	70.35417	100.000

These estimates based on equating Mean Squares to Expected Value.

Test Denominator Synthesis

Source	MS Den	DF Den	Denom MS Synthesis
School&Random	189.167	3	Instructor[School]&Random
Instructor[School]&Random	7	6	Residual

Tests wrt Random Effects

Source	SS	MS Num	DF Num	F Ratio	Prob > F
School&Random	156.5	78.25	2	0.4137	0.6940

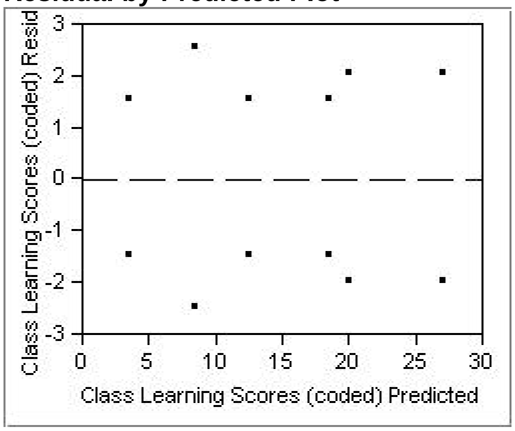
Appendix F: JMP Version 4.0 Results

Source	SS	MS Num	DF Num	F Ratio	Prob > F
Instructor[School]&Random	567.5	189.167	3	27.0238	0.0007

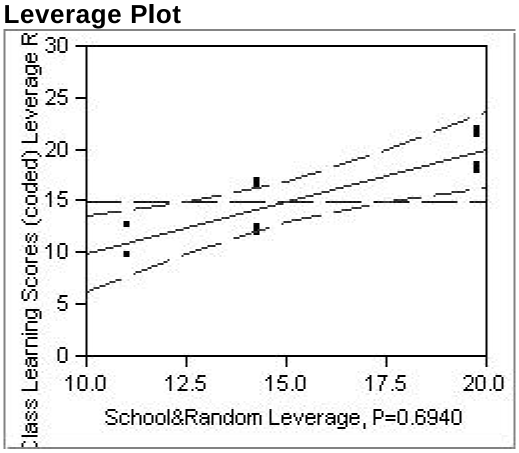
Appendix F: JMP Version 4.0 Results

Exhibit F.8: JMP Version 4.0 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors

Residual by Predicted Plot



School&Random
Leverage Plot



Effect Test

Sum of Squares	F Ratio	DF	Prob > F
156.50000	0.4137	2	0.6940

Denominator MS Synthesis:
Instructor[School]&Random

Least Squares Means Table

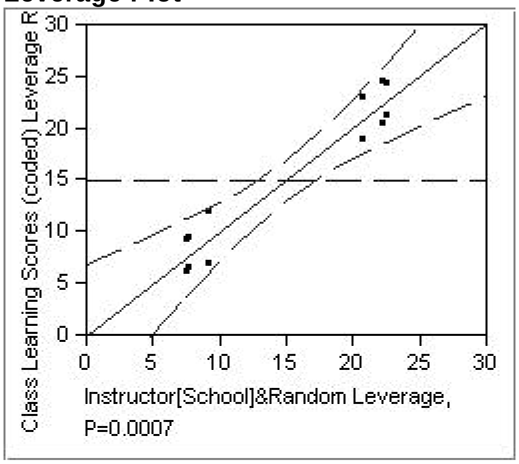
Level	Least Sq Mean	Std Error	Mean
Atlanta	19.750000	6.8768937	19.7500
Chicago	14.250000	6.8768937	14.2500
San Francisco	11.000000	6.8768937	11.0000

Appendix F: JMP Version 4.0 Results

Exhibit F.8: JMP Version 4.0 Output for Nested ANOVA of Information in Table 13 Using Fit Model with Random Factors (continued)

Instructor[School]&Random

Leverage Plot



Effect Test

Sum of Squares	F Ratio	DF	Prob > F
567.50000	27.0238	3	0.0007

Denominator MS Synthesis:
Residual

Least Squares Means Table

Level	Least Sq Mean	Std Error
[Atlanta]1	27.000000	1.8708287
[Atlanta]2	12.500000	1.8708287
[Chicago]1	8.500000	1.8708287
[Chicago]2	20.000000	1.8708287
[San Francisco]1	18.500000	1.8708287
[San Francisco]2	3.500000	1.8708287

Appendix F: JMP Version 4.0 Results

Exhibit F.9: JMP Version 4.0 Output for a Fractional Factorial Experiment using the Design Experiment Feature

Screening Design
Aliasing of Effects

Effects	Aliases
X1*X2	= X5*X6
X1*X3	= X4*X6
X1*X4	= X3*X6
X1*X5	= X2*X6
X1*X6	= X2*X5 = X3*X4
X2*X3	= X4*X5
X2*X4	= X3*X5

Output Options

Run Order
Number of Center Points
0
Replicates
0

Pattern	X1	X2	X3	X4	X5	X6
-++--+	-1	1	1	-1	-1	1
---+++	-1	-1	-1	1	1	1
+--++-	1	-1	-1	1	1	-1
+-++-+	1	-1	1	1	-1	1
--++--	-1	-1	1	1	-1	-1
++--++	1	1	-1	-1	1	1
++-+--	1	1	-1	1	-1	-1
-++++-	-1	1	1	1	1	-1
-+-+-+	-1	1	-1	1	-1	1
-+--+-	-1	1	-1	-1	1	-1
+-+-+-	1	-1	1	-1	1	-1
------	-1	-1	-1	-1	-1	-1
--+-++	-1	-1	1	-1	1	1
++++++	1	1	1	1	1	1
+++---	1	1	1	-1	-1	-1
+----+	1	-1	-1	-1	-1	1

Appendix F: JMP Version 4.0 Results

Exhibit F.10: JMP Version 4.0 Output for Mixture Problem Defined by Equation (2)

Mixture Design
3 Factors
Factor Settings

Run	X1	X2	X3
1	0.40000	0.10000	0.50000
2	0.60000	0.10000	0.30000
3	0.60000	0.30000	0.10000
4	0.20000	0.30000	0.50000
5	0.30000	0.60000	0.10000
6	0.20000	0.60000	0.20000

Output Options
Run Order
Replicates
0

X1	X2	X3
0.2	0.6	0.2
0.6	0.3	0.1
0.4	0.1	0.5
0.6	0.1	0.3
0.2	0.3	0.5
0.3	0.6	0.1

JMP Version 4.0 is capable of evaluating more than just the extreme vertices of this region. The table below provides the extreme vertices , center points along an edge of the region, and finally, the centroid of the entire region. This centroid is computed as part of the discussion in [see SAS Institute, Inc.'s "JMP® Design of Experiments," Version 4, 2000], and the value reported there (on page 358) is (0.384,0.333,0.283) the same value as shown in the table below.

Mixture Design
3 Factors
Factor Settings

Run	X1	X2	X3
1	0.40000	0.10000	0.50000
2	0.60000	0.10000	0.30000
3	0.60000	0.30000	0.10000
4	0.20000	0.30000	0.50000
5	0.30000	0.60000	0.10000
6	0.20000	0.60000	0.20000
7	0.20000	0.45000	0.35000
8	0.60000	0.20000	0.20000
9	0.50000	0.10000	0.40000
10	0.25000	0.60000	0.15000
11	0.45000	0.45000	0.10000
12	0.30000	0.20000	0.50000
13	0.38333	0.33333	0.28333

Output Options
Run Order
Replicates
0

X1	X2	X3
0.3	0.2	0.5
0.6	0.2	0.2
0.38333333	0.33333333	0.28333333
0.2	0.3	0.5
0.6	0.1	0.3
0.25	0.6	0.15

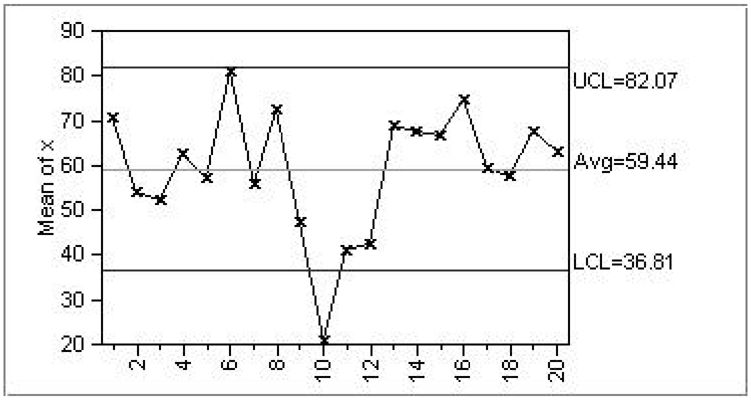
Appendix F: JMP Version 4.0 Results

X1	X2	X3
0.4	0.1	0.5
0.45	0.45	0.1
0.3	0.6	0.1
0.6	0.3	0.1
0.2	0.6	0.2
0.2	0.45	0.35
0.5	0.1	0.4

Appendix F: JMP Version 4.0 Results

Exhibit F.11: JMP Version 4.0 Results for x-Bar and s Charts for Data in Table 20

Variable Control Chart
XBar of x



Note: Sigma used for limits based on standard deviation.

S of x