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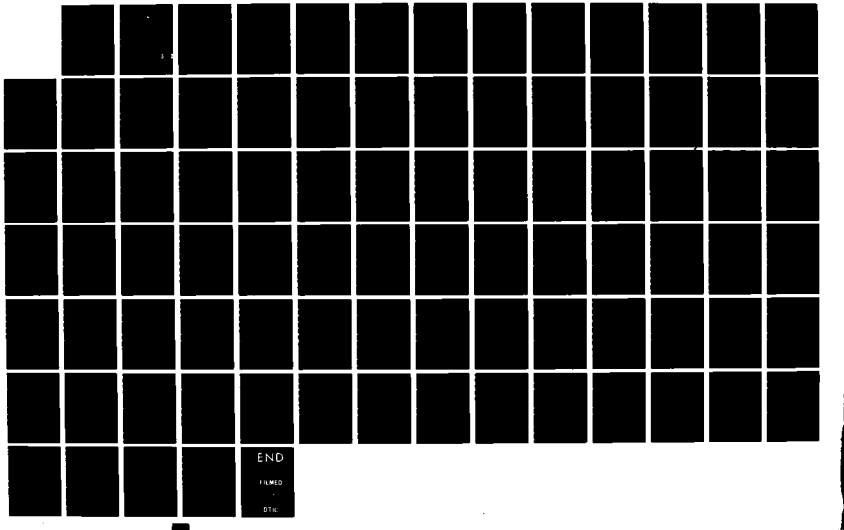

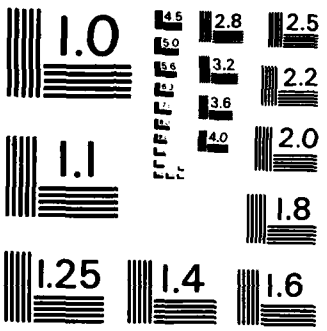

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AN INVESTIGATION OF PAYBACK PERIODS OF EQUIPMENT PURCHASED THROUGH THE FAST PAYBACK CAPITAL INVESTMENT PROGRAM (FASCAP)

THESIS

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AN INVESTIGATION OF PAYBACK PERIODS OF EQUIPMENT PURCHASED THROUGH THE FAST PAYBACK CAPITAL INVESTMENT PROGRAM (FASCAP)

THESIS

Presented to the Faculty of the School of
Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Systems Management

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GS-12

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Preface

The purpose of this study was to determine if any type of equipment purchased with Fast Payback Capital Investment Program (FASCAP) funds had a payback period that was significantly different from the average payback period computed for all FASCAP projects. The maximum time allowed for payback is 24 months and the average usually is about one year.

Before attending the Air Force Institute of Technology, I reviewed cost data in requests for FASCAP funds in my job as a cost analyst at Headquarters Air Force Logistics Command, Wright-Patterson AFB OH. Informally, I noted a wide disparity in the projected payback periods. This thesis was a formalized study to see if payback periods varied according to equipment type.

This research was accomplished only through the cooperation and support of many others. Specifically, I would like to thank my thesis advisor, Mr. Virgil Rehg, for his guidance and judgment. Also, I wish to thank my thesis readers, Mr. Mike Suttles and Mr. Mike Waker of HQ AFLC, for their technical advice and their time spent reviewing this document. My deepest gratitude is extended to my sister, Judy Damewood, for her time and superior

skill in typing this document. And finally, I wish to express my sincerest appreciation to my husband, Dan, and son, Jack, for their patience and encouragement while I researched and wrote this thesis.

Janice L. Burke

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Abstract

This thesis was an investigation of payback periods of equipment purchased through the Fast Payback Capital Investment Program (FASCAP). The average payback period for all FASCAP projects was about one year at the time this research was accomplished. The purpose of this thesis was to identify any equipment type that amortized significantly faster or slower than the one year average.

Projects approved in 1980, 1981, and 1982 that amortized within two years were included in the analysis. These projects were grouped into eleven equipment types based on Federal Supply Classification. Average payback periods for each group were statistically analyzed for significant differences. The data was not normally distributed so nonparametric methods were used. The Kruskal-Wallis test indicated that there were significant differences among the averages of the groups. The Wilcoxon rank-sum test was then performed to identify which pairs of average payback periods differed significantly.

AN INVESTIGATION OF PAYBACK PERIODS OF EQUIPMENT PURCHASED THROUGH THE FAST PAYBACK CAPITAL INVESTMENT PROGRAM (FASCAP)

I. Introduction

General Issue

In 1975, The Department of Defense (DoD) established the Defense Productivity Program to reverse the trend of declining productivity in the DoD workforce (1:20,21). As part of this program money was set aside in the budget specifically for projects that increased productivity and recovered the original investment cost through savings. The DoD's program for funding such projects is Productivity Enhancing Capital Investment (PECI). Each service has programs under the PECI, but only the Air Force (AF) will be considered in this research. The AF's three programs that make up the PECI are Fast Payback Capital Investment Program (FASCAP), Component Sponsored Investment Program (CSIP), and Productivity Investment Fund (PIF). This thesis will focus on the FASCAP program which is designed to fund off-the-shelf items costing between $3,000 and $100,000 that pay back the original investment within two years.

The savings that result from these FASCAP projects and their amortization periods are monitored closely and reported to Congress to substantiate the validity of this branch of the Defense Productivity Program.

Problem Statement

As of April 1985, the average payback period for all FASCAP projects was about one year (12:2). It is not known if any type or types of equipment have a payback period that is significantly different from the average. The purpose of this research is to identify any equipment type which amortized significantly faster or slower than the average.

Background

Previous Research. To locate previous research on this subject, recent volumes of the Business Periodicals Index, the Air University Library Index to Military Periodicals, and the Social Sciences Index were consulted as well as technical report summaries (search control number DKK19J) provided by the Defense Technical Information Center (DTIC). A review of published articles pertaining to productivity provided general information on the FASCAP program, but did not reveal any previous research on the behavior of payback periods of various

equipment types. Telephone conferences with FASCAP representatives at the Air Force Management Engineering Agency (AFMEA) (3; 17) and at Headquarters United States Air Force Productivity Programs (2) also indicated that no research had been accomplished in this area. The majority of this background section, then, will provide general information on FASCAP's inception, operation, and evaluation.

Need for FASCAP.

Funding Low Priority Items. In an article written by Robert K. Ackard, an illustration was given of the need for a program such as the Fast Payback Capital Investment Program (FASCAP) (1:18). An air base used hand tampers and ready-mix compounds for repairing potholes in a runway. A paving machine to replace the hand tampers could be purchased for only $5,800. This investment would save approximately $5,000 annually. Even considering costs for supplies and maintenance for the paving machine, it is obvious that substantial savings would accrue if the paving machine was purchased. However, funds for such low priority items usually were denied when the budget was being written. It was the highly visible projects that had the backing necessary to be included in the budget. Now, with the FASCAP program, these smaller, less visible programs like the paving machine are being funded.

Through the FASCAP program DoD sets aside funds that are designated for purchasing small off-the-shelf equipment that aids productivity (1:18,19). Productivity is used here as a "measure of an organization's performance" (6:2). This measure includes both "'efficiency' (the ratio of inputs to outputs)" and "'effectiveness' (to what extent the output satisfies mission objectives)". So, the quantity produced as well as the "quality, timeliness, responsiveness, and readiness" of the product is important when measuring productivity (6:2).

Speeding Up the Funding Process. In addition to providing funding for low priority projects, the FASCAP program is also important because it has speeded up the funding process in areas where technology is rapidly changing. Recent advances in computer aided processes have increased automation in office and administrative functions, but attempts to equip government offices with state-of-the-art equipment failed because the customary form of funding was too slow. By the time this equipment underwent the usual multiyear planning, programming, and budgeting cycle, the equipment was out of date. As a result, the federal workforce has been more labor intensive than is effective (1:20). Aside from the office functions, FASCAP is also useful for funding medical equipment, maintenance equipment, food service equipment, and many other types of equipment.

Regulations Governing FASCAP Projects. The primary regulation governing FASCAP projects is the Air Force Productivity Enhancement Program (PEP), AFR 25-3. The following sections include some highlights from the regulation.

Criteria to Qualify for FASCAP Funds. There are certain qualifying criteria that a prospective FASCAP project must meet. The equipment to be purchased must be of existing design or "off-the-shelf" and must provide "reduced operating and support (O&S) costs by improving methods, processes or procedures" (7:13). The equipment may be obtained commercially or through government sources. The cost of the proposed equipment must be greater than $3,000 and less than $100,000. This ceiling is for any one project and does not preclude buying several to receive quantity discounts. The amount invested for the equipment must be paid back through savings within two years of the equipment operational date. FASCAP funds can only be used for the acquisition costs of the equipment. Funds for other costs such as transportation, installation and O&S are provided by the organization that will be using the equipment. The proposed equipment must provide services or functions more economically than the equipment it will be replacing (7:13).

Criteria that Disallow FASCAP Funding. There are also some criteria that can disqualify a project from being funded by FASCAP. Some of these criteria include restrictions depending on whether the proposed equipment is under lease from commercial or governmental sources. The funds also cannot be used for buying spare parts. If the same equipment is already in the budget or was proposed to Congress but specifically denied, it cannot be funded through FASCAP. One last disqualifying criteria mentioned in this document concerns comparison with a commercial contract. The proposed FASCAP equipment must be more economical than a commercial contract to accomplish the activity (7:13).

Process of the FASCAP Program. The Secretary of Defense gives annual directions on the level of funds available based on the goals and investment plans presented. The Air Force budgets a certain amount for FASCAP funds. Congress then reviews this budget which is really a request for money to support the program in that same year. This allows for funds to be available almost immediately instead of following the normal long budgetary cycle. Sixty days is the usual time that lapses between submission and approval (1:23). Reports that include project cost and savings data are required every 180 days until the project has been fully amortized (7:13).

Computation of Payback Period. The payback period for a FASCAP project is computed using the following equation:

$$\frac{\text{Total Investment Costs}}{\text{Two Year Total Savings}} \times 24 = \text{Payback Period in Months} \quad (1)$$

The numerator, total investment costs, includes the cost of acquisition, transportation, installation and other one-time incidental costs that occur within twenty-four months of the equipment operational date (FASCAP funds are only used for acquisition costs). The denominator, two-year total savings, includes savings of manpower, material/energy, supply credit for equipment, maintenance, and other specified savings over the initial twenty-four months of operation.

Project Selection. Projects are reviewed in the order received unless a limitation of funds has caused a backlog. If this occurs, the projects are processed according to pre-established priorities. The highest priority is the length of the payback period. The next priority is savings in terms of whole manpower slots. Next is savings as a result of reduced civilian overtime, then savings of consumables, e.g. energy. The last priority is other 'hard' dollar savings, i.e.,

benefits that can be precisely measured, quantified, and placed under management control at the time of realization (7:13; 8:9).

Compensation for Reductions in Manpower. When manpower authorizations are forfeited through a FASCAP project, those spaces can be used elsewhere in the command providing the requirements have been validated by Management Engineering Teams (MET) but previously unfunded (7:14).

Status of FASCAP. Savings and payback periods are monitored closely to provide feedback on the progress of the program. As of April 1985, the typical FASCAP project amortized in about one year (12:2). From the time the program originated in fiscal year 77, until March 1984, about 1,000 projects had been approved (14:4). The majority of FASCAP projects have been office automation equipment (12:2), but overall the projects range from word processing equipment, copy equipment, and mini-computers to asphalt recycling machines, water sandblasters, flake ice makers, and blood plasma freezers (15:25).

Possible Program Changes. The FASCAP program is dynamic with several specific changes being considered. One of these changes would involve the order in which projects are approved. At present, the projects are approved based on order of submission until the funds

are depleted. The alternate method being considered is a ranking system giving priority to projects based on the amount of their payback (13:13).

Reporting of FASCAP Program Results. To ensure the continued funding support of Congress, the FASCAP program results are examined regularly to determine the success/validity of the program. One measure of success is the computation of the average payback period for all types of equipment funded through FASCAP funds. As was mentioned in the Status section, the current overall average payback period is about 1 year (12:2).

Research Objective

The general objective of this research is to determine which equipment types, if any, have payback periods that are significantly different from the average payback period of FASCAP projects.

Research Questions

1. What method is currently used to compute the average payback period for FASCAP projects?

2. What data base is used to store data for FASCAP projects?

3. What FASCAP projects can be reviewed for this research and what is the procedure to obtain data on these projects?

4. What classification can be used to categorize the projects by equipment type?

5. What statistical methods can be used to determine if the average payback periods differ significantly among equipment types?

6. Do significant differences exist among the average payback periods for equipment types?

7. If significant differences exist among any of the average payback periods (Question 6), which equipment types are responsible?

II. Methodology

Research Question 1 Answered

Question: What method is currently used to compute the average payback period for FASCAP projects?

Answer: The average payback period computed by HQ USAF/MPME incorporates all approved FASCAP projects. Projected payback periods are used in the computation until the project amortizes. Then the actual payback period is used to update the figures (2).

Research Question 2 Answered

Question: What data base is used to store data for FASCAP projects?

Answer: The Reacquisition of Files (REACQ) is a system located at Randolph AFB, Texas. The FASCAP data base was entered on REACQ in March 1984 (3). The REACQ system stores data on FASCAP projects approved in 1980 through the present. Projects from the initial year, 1977, through 1979 are not included in the REACQ data base (17). The REACQ system can be accessed through a local telephone number with appropriate identification and password entries (18).

Research Question 3 Answered

Question: What FASCAP projects can be reviewed for this research and what is the procedure to obtain data on these projects?

Answer: For this research, the population of FASCAP projects approved in 1980, 1981, and 1982 that amortized within two years (Code A1 on REACQ as of April 1985) and which belonged to Federal Supply Groups with five or more projects were analyzed. Projects approved in the first three years of FASCAP (1977, 1978, and 1979) were not included in the analysis because data for those years is not stored in the REACQ system. Projects approved in 1983 or later also were not included because many had not amortized at the time of this research. The total number of projects analyzed was 334. There were no constraints or requirements imposed on the 1980, 1981, and 1982 projects that made those years' projects unique.

Details of Collection. The first phase of data collection was obtaining a list of all FASCAP projects in the years under review. After entering the FASCAP system (selection FSCP), the desired fiscal year was chosen (80, 81 or 82). Next was the selection from the Main Menu--for this situation, the selection was Display Data (selection 1). The program inquired whether the job was Local or Batch (in this case Local: selection 1) and then offered a

Display Menu. To list all projects in the fiscal year entered, File Display (selection 3) was chosen. Finally, the program inquired whether Projected Data or Actual Data was required (Actual Data was used for this analysis: selection 2). This sequence of steps resulted in an alphabetical listing by major command of all projects in the given fiscal year including the project number, location (base), work center, item description, acquisition cost, total investment cost, two-year savings, life cycle savings, manpower authorization and status code. The information from this listing that was pertinent to this study was the project number, the item description, and the status code. The project number was necessary to retrieve the associated payback period. The item description was critical for categorizing according to equipment type and the status code was necessary to determine which projects were included in the analysis. The code A1 identified projects that amortized within two years, A2 indicated amortization but in more than 2 years, D1 was used for disapproved projects, and W1 indicated withdrawn prior to approval. Code N1 meant not yet amortized, but projected to amortize on course (not applicable for years 1980, 1981 and 1982--only 1983 and later), and N0 meant not yet operational (11; 17). Only those projects that were coded A1 were analyzed in this study.

The next phase of the data collection was retrieving payback periods for the projects coded A1. Again the FASCAP system was selected, the fiscal year entered, Display Data was chosen from the Main Menu, and the Local selection was chosen. To obtain the payback period, the Project Display (selection 1) was selected, after which the program queried the project number. Once the specific project number had been entered, the program presented a Detail Menu from which Dollar Data was chosen. Only To-Date data was required and the system then provided the costs of the project, the specific types of savings (manpower, maintenance, materials, supply credit, and other), the payback period, the return on investment and the life cycle savings. The procedure for subsequent projects repeated part of these steps. The Detail Menu was offered from which New Project Number (selection 5) was chosen. The project number was requested and the steps detailed above were repeated. This procedure was used for each of the 89 projects in 1980, 127 projects in 1981, and the 133 projects in 1982 (some of these were later eliminated from the analysis because their Federal Supply Group contained less than five projects--see answer to question 4).

Research Question 4 Answered

Question: What classification can be used to categorize the projects by equipment type?

Answer: The FASCAP projects studied were categorized by equipment type using Federal Supply Groups (FSG). This classification was based on homogeneous areas of commodities. Items were grouped according to similarities in physical and performance characteristics or because the items were usually requisitioned or issued together. There were 78 of these Federal Supply Classification (FSC) groups in which to categorize projects (5:iii).

The first step in classifying FASCAP projects by group was reviewing item descriptions on each of the 349 original projects (15 projects were later removed because of sample sizes less than five for several FSGs). Repetitions were noted as well as items that were unique. Next the FSC Cataloging Handbook H2-1 which includes descriptions and examples for each group was searched for groups that obviously would be included or excluded. For example, the Weapons Group, the Nuclear Ordnance Group, the Guided Missiles Group,and others were eliminated as possible categories because the review of item descriptions indicated that these groups were not represented. Other groups, such as the Medical, Dental, and Veterinary

Equipment and Supplies Group and the Office Machines, Text Processing Systems and Visible Record Equipment Group were included because the item description review had identified equipment of these types. An iterative process followed with reviews of the item descriptions and the group descriptions until most of the 349 items were matched with a group. For the remaining items another document was consulted. This was the Cataloging Handbook H6 which contains an alphabetical index of item names with the associated FSC (4). The immense volume of the H6 Handbook restricted its use only to the exceptional items not classified using the H2-1. A list of projects with item descriptions and their FSG is located in Appendix A.

The Federal Supply Groups that were represented in this study (excludes those with less than five projects) and their number of projects are shown in Table I.

TABLE I

Federal Supply Groups Represented in This Study

Federal Supply Group	Title	Number of Projects
36	Special Industry Machinery	32
37	Agricultural Machinery and Equipment	7
38	Construction, Mining, Excavating, and Highway Maintenance Equipment	8
41	Refrigeration, Air Conditioning, and Air Circulating Equipment	7
49	Maintenance and Repair Shop Equipment*	12
58	Communication, Detection, and Coherent Radiation Equipment	5
65	Medical, Dental, and Veterinary Equipment and Supplies	46
66	Instruments and Laboratory Equipment	11
67	Photographic Equipment	9
70	General Purpose Automatic Data Processing Equipment (Including Firmware), Software, Supplies and Support Equipment	9
74	Office Machines, Text Processing Systems and Visible Record Equipment	188

* Depot Maintenance Industrially Funded Equipment is not eligible for FASCAP funds.

The accuracy of classification of projects according to FSG was limited because the National Stock Number (NSN) for each project was not available. The grouping was accomplished based on the judgment of the researcher after consulting the H2-1 Cataloging Handbook and the H6 Cataloging Handbook.

Research Question 5 Answered

Question: What statistical methods can be used to determine if the average payback periods differ significantly among equipment types?

Answer: To identify significant differences among average payback periods, the projects must first be classified by equipment type (answer to question 4). Following this classification according to Federal Supply Group (FSG), the groups must be checked for normality. Frequency charts for groups would provide a visual check for normality and the Chi^2 Goodness of Fit test would confirm or deny the visual conclusion (10:250-252). If the groups exhibit normal distributions, parametric methods are appropriate and a traditional single-factor Analysis of Variance (ANOVA) would be used (9:344-353). If the groups are not normally distributed, non-parametric methods are necessary (9:566). The method to use in this non-normal or distribution-free situation is the Kruskal-Wallis test (9:596-598).

If the results of the appropriate test (ANOVA or Kruskal-Wallis) indicate that the null hypothesis of equal means cannot be rejected, no further analysis is necessary. If, however, the hypothesis of equal means is rejected, it is of interest to identify which means are different. If the assumption of normality is accepted, Tukey's or Scheffé's tests (9:355; 16:169-175) could be applied to determine which pairs of means differ significantly. For the non-normal case, the Wilcoxon rank-sum test (also called the Mann-Whitney test) would be used (9:582-587; 16:205,206). All tests on means in this research were conducted at the .05 level of confidence.

III. Analysis

Research Question 6 Answered

Question: Do significant differences exist among the average payback periods for equipment types?

Answer: As was described in the answer to question 5, the method used to test for significant differences among the average payback periods was dependent on whether the groups were normally distributed. To check for normality, frequency bar charts were plotted using the Statistical Analysis System (SAS). These charts are shown in Appendix B. The charts suggested that the groups were not normally distributed. As a further test of normality, the Chi^2 Goodness of Fit test was used (10:250-252). In this test

$$x^2 = \sum_{i=1}^{k} \frac{(Y_i - E_i)^2}{E_i} \qquad (2)$$

where

Y_i = the actual number of observations (payback periods) in class i within the FSG

E_i = the expected number of observations in class i within the FSG

If this computed χ^2 value was less than the table value for χ^2 with k-3 degrees of freedom then the hypothesis that the data would fit a normal curve was not rejected (k was the number of classes and one additional degree of freedom was subtracted for each estimated parameter, i.e., the mean and standard deviation). For much of the data analyzed in this thesis, the hypothesis that the data would fit a normal curve at the .1 level of significance was rejected. Sample calculations are included in Appendix C.

Because of this non-normal or distribution-free data set, the Kruskal-Wallis test was used to test for equality of means. The null hypothesis for this test was $H_0: \mu_i = \mu_{i+1} = \ldots = \mu_I$ where $i = 1,2,3,\ldots 11$ $(I=11)$ with each μ_i being the average payback period for Federal Supply Group (FSG) i. Table II is a list of each FSG with the corresponding average payback period and the number of projects included.

TABLE II

Average Payback Periods in Decreasing Order

FSG	TITLE	NUMBER OF PROJECTS	AVERAGE PAY-BACK PERIOD
36	Special Industry Machinery	32	13.88
74	Office Machines, Text Processing Systems and Visible Record Equipment	188	12.08
37	Agricultural Machinery and Equipment	7	10.99
41	Refrigeration, Air Conditioning, and Air Circulating Equipment	7	10.10
58	Communication, Detection, and Coherent Radiation Equipment	5	9.80
67	Photographic Equipment	9	9.26
70	General Purpose Automatic Data Processing Equipment (Including Firmware), Software, Supplies and Support Equipment	9	8.81
38	Construction, Mining, Excavating, and Highway Maintenance Equipment	8	8.36
65	Medical, Dental, and Veterinary Equipment and Supplies	46	8.12
49	Maintenance and Repair Shop Equipment	12	6.76
66	Instruments and Laboratory Equipment	11	5.75

The Kruskal-Wallis test required that all observations were ranked from smallest to largest payback period (ties in rank will be addressed later). Then the projects were regrouped into their original FSGs, retaining the rank established within the whole data set (see Appendix D). These ranks were then used in computing the Kruskal-Wallis test statistic K. The calculating formula for the test statistic K was

$$K = \frac{12}{N(N+1)} \sum_{i=1}^{I} \frac{R_i^2}{n_i} - 3(N+1) \qquad (9:596) \qquad (3)$$

where

N = the total number of observations or projects (334)

R_i^2 = the sum of the ranks of projects in FSG i, squared

n_i = the number of observations or projects in FSG i

Because ties resulted in the ranking, an adjustment factor was applied to the test statistic K. The adjustment factor can be expressed as

$$1 - \frac{\sum (\tau_i - 1)(\tau_i)(\tau_i + 1)}{(N^3 - N)} \qquad (4)$$

where "τ_i is the number of ties in the i^{th} group of ties and the sum is over all groups of ties" (9:598). The K statistic was divided by this adjustment factor.

The details of the computations for these formulas are included in Appendix E. The Kruskal-Wallis statistic K was 37.37 after the adjustment factor was applied. According to this test, the null hypothesis of equal means must be rejected if $K \geq \chi^2_{\alpha, I-1}$ (where I=the number of FSGs). At the .05 level, the χ^2 value for ten degrees of freedom (I=11, degrees of freedom = I-1) was 18.307. The K value of 37.37 exceeded this, so the null hypothesis that the means or average payback periods were equal was rejected. Described in another way, the rejection of this hypothesis implied that the payback periods of the 334 observations were not randomly distributed in the ranking as would be expected if the payback periods had come from the same distribution (9:596).

Research Question 7 Answered

Question: If significant differences exist among any of the average payback periods (Question 6), which equipment types are responsible?

Answer: The results of the Kruskal-Wallis test indicated that the means of the FSGs or the average payback periods were not all from the same distribution.

Based on that conclusion, further tests were completed to identify which means differed significantly. Because the data was not normal, the Wilcoxon rank-sum test was used to compare the 55 possible pairings among the eleven groups. The null hypothesis was $H_0: \mu_i - \mu_j = 0$ where i = 1,2,3...11, j = 1,2,3...11 and $i \neq j$. When the sample sizes, in this case the number of projects in FSGs i and j, are eight or more, the test statistic was

$$Z = \frac{W - [m(m + n + 1)]/2}{\sqrt{[mn(m + n + 1)]/12}} \qquad (9:585) \qquad (5)$$

where

W = the sum of the ranks of the observations (payback periods) of the smaller group

m = the number of observations (payback periods) in the smaller group

n = the number of observations (payback periods) in the larger group

If ties occurred, as did in many of the comparisons, the denominator of the Z statistic changed to

$$\left[\frac{mn(m+n+1)}{12} - \frac{mn}{12(m+n)(m+n-1)} \cdot \sum (\tau_i-1)(\tau_i)(\tau_i+1)\right]^{1/2} \quad (6)$$

"where τ_i is the number of tied observations in the i^{th} set of ties and the sum is over all sets of ties" (9:586). An example of this calculation is shown in

Appendix F. This test statistic Z was compared to the two-tailed z value at the .05 level of significance. The null hypothesis was rejected if the calculated Z was ≥ 1.96 or ≤ -1.96. Rejection of the hypothesis implied that there was a significant difference between the two means under consideration.

When both groups being compared contained less than eight observations, the W was determined just as was the W for the larger sample, but the critical value, c, was value obtained from a table called The Upper-Tail Critical Values and Probabilities for the Null Distribution of the Wilcoxon Signed-Rank Statistic W (9:629). The c value was dependent on the sizes of the two samples and the level of significance desired. The null hypothesis was rejected if $W \geq c$ or if $W \leq m(m + n + 1) - c$ (9:584).

The 55 comparisons of means was accomplished using the Wilcoxin procedure on the Statistical Analysis System (SAS) which provided the W statistic and the corresponding Z statistic which was compared to the z value of ± 1.96. A summarization of the results of the 55 comparisons is shown in Appendix G.

The following table shows the ten pairs of means that were rejected using the Wilcoxon rank-sum test. These pairs were rejected as belonging to the same distribution at the .05 level of significance. Also shown are the average payback periods for each FSG.

TABLE III

Pairs of Means Rejected Using Wilcoxon Rank-Sum Test
(Average payback periods for each FSG are in parentheses)

FSG 36:	Special Industry Machinery (13.88 months)	FSG 66:	Instruments and Laboratory Equipment (5.75 months)
FSG 36:	Special Industry Machinery (13.88 months)	FSG 49:	Maintenance and Repair Shop Equipment (6.76 months)
FSG 36:	Special Industry Machinery (13.88 months)	FSG 65:	Medical, Dental, and Veterinary Equipment and Supplies (8.12 months)
FSG 36:	Special Industry Machinery (13.88 months)	FSG 38:	Construction, Mining, Excavating, and Highway Maintenance Equipment (8.36 months)
FSG 36:	Special Industry Machinery (13.88 months)	FSG 70:	General Purpose Automatic Data Processing Equipment (Including Firmware), Software, Supplies and Support Equipment (8.81 months)
FSG 36:	Special Industry Machinery (13.88 months)	FSG 67:	Photographic Equipment (9.26 months)
FSG 74:	Office Machines, Text Processing Systems and Visible Record Equipment (12.08 months)	FSG 66:	Instruments and Laboratory Equipment (5.75 months)
FSG 74:	Office Machines, Text Processing Systems and Visible Record Equipment (12.08 months)	FSG 49:	Maintenance and Repair Shop Equipment (6.76 months)
FSG 74:	Office Machines, Text Systems and Visible Record Equipment (12.08 months)	FSG 65:	Medical, Dental, and Veterinary Equipment and Supplies (8.12 months)
FSG 41:	Refrigeration, Air Conditioning, and Air Circulating Equipment (10.10 months)	FSG 66:	Instruments and Laboratory Equipment (5.57 months)

FSG 36: Special Industry Machinery, with the highest average payback period of 13.88 months, differed significantly from the six FSGs with the lowest payback periods (ranging from 5.75 months to 9.26 months). These were FSG 66: Instruments and Laboratory Equipment; FSG 49: Maintenance and Repair Shop Equipment; FSG 65: Medical, Dental and Veterinary Equipment and Supplies; FSG 38: Construction, Mining, Excavating, and Highway Maintenance Equipment; FSG 70: General Purpose Automatic Data Processing Equipment (Including Firmware), Software, Supplies and Support Equipment; and FSG 67: Photographic Equipment. FSG 36 was not significantly different from the FSGs with payback periods ranging from 9.80 months to 12.08 months.

The second highest average payback period (12.08 months) was for FSG 74: Office Machines, Text Processing Systems and Visible Record Equipment. This FSG was shown to differ significantly from some but not all of the same FSGs rejected in comparisons with FSG 36. The FSGs that had significantly different payback periods from FSG 74 were FSG 66, FSG 49, and FSG 65 (with payback periods ranging from 5.75 months to 8.12 months).

The last pair that was shown to have significantly different payback periods was FSG 41: Refrigeration, Air Conditioning, and Air Circulating Equipment and FSG 66: Instruments and Laboratory Equipment.

Another way of presenting the results of the Wilcoxon test is shown in Figure 1.

FSG										
36										
74	A									
37	A	A								
41	A	A	A							
58	A	A	A	A						
67	**	A	A	A	A					
70	**	A	A	A	A	A				
38	**	A	A	A	A	A	A			
65	**	**	A	A	A	A	A	A		
49	**	**	A	A	A	A	A	A	A	
66	**	**	A	**	A	A	A	A	A	A
FSG	36	74	37	41	58	67	70	38	65	49

A: Do not reject the null hypothesis that $\mu_1 - \mu_2 = 0$

**: Reject the null hypothesis that $\mu_1 - \mu_2 = 0$

Figure 1. Results of Wilcoxon Rank-Sum Test for All 55 Combinations

Statistically, these results and those in Table III seem to indicate some regrouping by combining FSGs would be possible (36 with 74; 49 with 66; or 49, 66 and 65; the remaining FSGs together). However, further analysis was not accomplished because no logical regrouping could be established that corresponded to the apparent statistical grouping. For example, FSG 36: Special Industry Machinery was not logically related to FSG 74: Office Machines, Text Processing Systems and Visible Record Equipment. Also FSG 49: Maintenance and Repair Shop Equipment could not be logically related to FSG 66: Instruments and Laboratory Equipment.

IV. Conclusions

Summary of Results

The general objective of determining which equipment types, if any, have payback periods that are significantly different from the average payback period was met using the Kruskal-Wallis test and the Wilcoxon rank-sum test. The Kruskal-Wallis test showed that the average payback periods were not all equal, i.e. they did not belong to the same distribution. With the inequality of means established, the Wilcoxon rank-sum test was used to identify those FSGs whose average payback period differed significantly from other FSG's average payback period.

Implications

Benefit to Reviewers. Air Force personnel involved in reviewing FASCAP projects before approval can benefit from findings of this research. The distribution of payback periods that were obtained for each FSG can be used as a test of reasonableness of projected payback periods. The project under review would be classified by FSG and then its payback period would be compared to the distribution for that FSG. If the proposed payback period differed from the distribution of payback periods for that FSG, the reviewer would be alerted to scrutinize the projected savings and costs.

Benefit to Submitters. Another use for the findings in this research would exist if the emphasis for ranking FASCAP projects was placed more on payback period. Submitting major commands could use the results of this study to judge which projects to submit for FASCAP funds and for which projects to seek out other sources of funding. If the majority of projects being approved for FASCAP funds have low projected payback periods, the command could promote submission of projects that have similarly low payback periods. For example, if an organization needed both office machines (FSG 74, average payback of 12.08 months) and Instruments and Laboratory Equipment (FSG 66, average payback of 5.75 months), the Instruments project would stand a much better chance of being approved for FASCAP funding. The command could maximize its total requests funded by requesting FASCAP funds for projects with competitively low payback periods (instruments) and request other funds for projects with higher payback periods (office machines).

Benefit to FASCAP. To better utilize the funds available through FASCAP, publicity could be given to those types of projects that have low average payback periods. Organizations needing those particular types of equipment would be encouraged through this publicity to submit requests for funds.

Recommendations

Analysis Using Different Classification of Equipment Type. The grouping of FASCAP projects into equipment types was not attempted prior to this research. Additional research could be accomplished using a different classification of projects. Classification by some method other than by Federal Supply Group may show different results and may be useful in different ways (e.g. classify by inherent mechanical process). Also, modification of this research by grouping according to the less aggregate Federal Supply Class may yield different results.

Analysis Using Different Projects. The data used for this study was limited to those projects that amortized within the required twenty-four months. Inclusion of projects that exceeded the allowable payback period might also provide results that differ from those found in this study.

Appendix A: List of Projects

(Includes those projects coded A1 as of 26 Apr 1985)
(FSGs with less than five projects are not included)

Federal Supply Group	Title	Number of Projects
36	Special Industry Machinery	32
37	Agricultural Machinery and Equipment	7
38	Construction, Mining, Excavating, and Highway Maintenance Equipment	8
41	Refrigeration, Air Conditioning, and Air Circulating Equipment	7
49	Maintenance and Repair Shop Equipment*	12
58	Communication, Detection, and Coherent Radiation Equipment	5
65	Medical, Dental, and Veterinary Equipment and Supplies	46
66	Instruments and Laboratory Equipment	11
67	Photographic Equipment	9
70	General Purpose Automatic Data Processing Equipment (Including Firmware), Software, Supplies and Support Equipment	9
74	Office Machines, Text Processing Systems and Visible Record Equipment	188

* Depot Maintenance Industrially Funded Equipment is not eligible for FASCAP funds.

Appendix A (continued):

1980

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
1	80	1	17.6	36	Print Plant Equipment
2	80	2	10.7	37	Tree Spade
3	80	3	4.0	74	5 Postal Metering Systems
4	80	4	5.9	49	Modular Paint Booth
5	80	5	4.3	37	Leaf Vacuum
6	80	6	5.8	36	Display Phototypesetter
7	80	7	6.5	49	Hydro-Blaster
8	80	8	11.3	74	Information Processor
9	80	11	10.5	74	Edit Writer Composing System
10	80	12	7.7	36	Phototypesetting System
11	80	14	4.9	74	Desktop Calculator
12	80	18	17.1	74	Word Processing System
13	80	19	7.7	41	Ice Machine
14	80	20	15.3	49	Letter Machine
15	80	21	12.1	65	Ultrasound Scanner
16	80	22	20.7	37	Stump Cutter
17	80	24	8.4	74	Administrative System
18	80	26	7.9	65	Ultrasound Scanner
19	80	27	18.3	74	Word Processing Equipment
20	80	30	5.0	66	Radio Service Monitor
21	80	33	18.4	74	Automated Document Storage & Retrieval
22	80	34	19.5	74	Word Processing system
23	80	35	12.9	41	Ice Maker
24	80	36	11.0	41	Ice Machine
25	80	37	17.4	74	Publications Storage & Retrieval System
26	80	38	2.7	67	Photo Processor
27	80	39	6.0	65	Gastroscope System
28	80	40	21.8	36	Copier
29	80	41	6.4	49	Engine Analyzer
30	80	42	6.9	70	Tape Evaluator Cleaner System
31	80	44	16.8	74	Two CRT Typing Systems
32	80	45	14.7	74	Word Processor
33	80	47	11.0	36	Paper Pulverizing Machine
34	80	49	5.5	41	Ice Maker Machine
35	80	50	18.4	58	Telephone System

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
36	80	51	5.8	74	Advanced Administrative System
37	80	52	6.3	70	Tape Evaluator/Cleaner
38	80	53	4.7	67	Photographic Print Processor
39	80	54	7.4	65	Ultrasound System
40	80	56	18.1	41	Three Ice Machines
41	80	57	11.2	36	5 Transceivers & 2 Memeograph Printers
42	80	58	10.1	49	Wheel Alignment System
43	80	60	7.8	36	Copier
44	80	61	9.6	65	Colposcope
45	80	62	17.0	74	Advanced Administrative System
46	80	63	11.3	74	Word Processing System
47	80	64	7.1	65	Ultrasound Equipment
48	80	67	18.3	74	Word Processing System
49	80	68	9.2	74	Mini Computer System
50	80	69	17.9	74	Word Processing System
51	80	72	4.7	36	Print Plant Equipment
52	80	73	10.5	36	Copier
53	80	76	16.0	74	Document Retrieval System
54	80	78	3.9	65	Peripheral Vascular Changer
55	80	79	18.0	74	2 Word Processing Systems
56	80	81	23.0	74	2 Word Processing Systems
57	80	83	6.8	66	Infrared Scanner
58	80	84	9.9	67	Micrographic Production Equipment
59	80	85	18.0	74	Word Processing System
60	80	86	18.0	74	Word Processing System
61	80	87	16.1	74	Word Processing System
62	80	88	23.2	74	Document Storage & Retrieval System
63	80	89	9.2	38	Ice Control Spreader
64	80	90	14.0	74	Word Processing System
65	80	92	16.1	67	Micrographic Production Equipment
66	80	93	6.5	74	2 Printers
67	80	94	9.0	65	Gas Supply System
68	80	95	9.3	65	Ultrasound System

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
69	80	97	5.7	37	Traveling Gun Sprinkler System
70	80	98	19.6	67	Reader-Printer/Viewing Screen
71	80	101	13.0	74	Word Processing System
72	80	102	12.4	74	Word Processing System
73	80	105	0.7	66	Electrical Test Equipment
74	80	108	5.8	65	Middle Ear Analyzer
75	80	109	6.3	65	Ultrasound Scanner
76	80	113	14.8	74	Mini Computer System
77	80	115	5.0	66	Blood Chemistry Analysis System
78	80	120	10.6	65	Drug Dispensing System
79	80	121	17.6	65	Cardiac Ultrasound System
80	80	122	3.2	49	Spray Paint Unit
81	80	124	4.9	38	Ice Control Spreader
82	80	125	12.5	36	10 Copiers

Appendix A (continued):

1981

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
1	81	1	15.3	74	Word Processing System
2	81	2	13.9	36	4 copiers
3	81	3	2.8	74	Postal Metering System
4	81	4	17.1	36	Offset Press
5	81	5	5.5	74	Word Processing System
6	81	7	16.6	36	Photocomposing Equipment
7	81	8	13.9	74	Word Processing System
8	81	9	17.2	74	Word Processing System
9	81	12	18.0	36	Reproduction Equipment
10	81	13	23.4	74	2 Word Processing Systems
11	81	14	3.3	49	Front End Alignment Machine
12	81	15	6.7	58	Closed Circuit TV Surveillance System
13	81	16	3.0	67	Microfilm Enlarger Printer
14	81	17	18.1	36	Duplicator (Xerox 9400)
15	81	18	16.0	49	Paint Spray Booth
16	81	19	6.0	66	Chemical Analyzer System
17	81	20	5.2	36	Color Copier
18	81	21	7.5	70	Computer Communication System
19	81	22	16.9	65	Gas Chromatograph System
20	81	23	11.3	74	4 Electronic Postal Metering Systems
21	81	24	6.4	74	2 Printers
22	81	27	6.9	74	Electronic Mailing System
23	81	28	5.5	74	2 Electronic Mailing Systems
24	81	29	10.0	70	Video Cassette Tape Cleaner & Evaluator
25	81	30	5.0	74	Word Processing System
26	81	31	18.4	74	Word Processing System
27	81	33	6.5	74	Word Processing System
28	81	34	13.9	74	Word Processing System
29	81	35	17.9	66	Optical Mark Scanner System
30	81	36	2.7	66	Portable Infrared Scanner
31	81	37	1.6	74	Electronic Mailing System
32	81	38	11.3	74	Electronic Mailing System
33	81	39	3.2	74	2 Electronic Mailing Systems

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
34	81	40	5.2	74	6 Electronic Postal Metering Systems
35	81	41	7.3	58	Central Pager System
36	81	42	5.7	74	6 Electronic Postal Metering Systems
37	81	43	5.7	74	6 Electronic Postal Metering Systems
38	81	44	3.8	74	2 Electronic Cash Registers
39	81	45	15.9	74	6 Data/Word Processing Systems
40	81	46	18.0	74	6 Data/Word Processing Systems
41	81	47	11.4	36	Color Copier
42	81	48	4.0	38	Ice Control Spreader
43	81	50	7.0	65	Ultrasound Scanner
44	81	53	19.8	74	2 Word Processing Systems
45	81	54	21.8	38	Backhoe
46	81	55	18.5	74	Mini Computer System
47	81	56	20.1	74	Word Processing System
48	81	57	3.7	49	Automotive Front End Alignment System
49	81	58	11.1	65	Electrocardiograph Machine w/Treadmill
50	81	60	11.5	38	Ice Control Spreader
51	81	61	15.1	74	Keyboard Training System
52	81	62	15.3	74	Word Processing System
53	81	64	15.2	74	Word Processing System
54	81	65	4.6	74	5 Electronic Postal Metering Systems
55	81	66	17.8	74	Technical Administrative Support System
56	81	67	18.6	74	Word Processing System
57	81	68	13.6	74	Mini Computer System
58	81	69	10.5	74	2 Word Processing Systems
59	81	70	2.5	74	Microprocessor System
60	81	71	4.7	74	3 Electronic Mailing Systems
61	81	73	4.7	74	Electronic Mailing System
62	81	74	2.2	66	Filter Scavenger System
63	81	75	14.4	74	Printer System
64	81	77	12.5	74	Microcomputer System

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
65	81	80	17.9	74	3 Word Processing Systems
66	81	81	11.9	74	Automated Document Storage & Retrieval
67	81	82	1.6	65	Spirometric Computer w/Digital Plotter
68	81	83	3.1	49	Water Sandblaster
69	81	84	4.4	65	Gastroscope
70	81	86	12.4	65	Ultrasound Scanner
71	81	87	0.7	66	Roof Moisture Meter
72	81	88	12.9	37	Limb Chipper
73	81	89	10.5	74	Electronic Mailing System
74	81	90	8.3	74	Word Processing System
75	81	92	0.3	74	Autoticketer Machine
76	81	93	19.7	74	Word Processing System
77	81	94	4.7	70	Tape Cleaner/Evaluator
78	81	96	1.9	74	Electronic Mailing System
79	81	97	15.8	74	Electronic Mailing System
80	81	98	10.5	74	Electronic Mailing System
81	81	99	13.0	74	4 Word Processing Systems
82	81	100	14.8	74	Information Processing System
83	81	101	14.8	74	Word Processing System
84	81	104	9.0	65	Ultrasound System
85	81	105	18.5	70	Tape Evaluator/Cleaner
86	81	106	9.2	65	Ultrasound Scanner
87	81	110	17.1	74	Document Storage & Retrieval System
88	81	111	3.7	49	Engine Analyzer
89	81	113	0.6	74	10 Auto Ticketer Machines
90	81	114	11.1	74	Edit Writer
91	81	115	3.9	49	Engine Analyzer
92	81	116	19.9	74	Word Processing System
93	81	117	17.6	74	Word Processing System
94	81	121	10.1	36	Copier
95	81	122	0.2	38	25 Ft. Screed
96	81	126	0.4	74	Auto Ticketer Machine
97	81	127	0.3	74	Auto Ticketer Machine
98	81	128	15.3	74	Word Processing System
99	81	129	10.7	74	Mini Computer System
100	81	132	20.1	74	2 Electronic Mailing Systems

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
101	81	134	20.8	74	2 Programmable Calculators
102	81	136	4.1	74	2 Electronic Mailing Systems
103	81	137	5.3	74	2 Electronic Mailing Systems
104	81	138	13.6	74	2 Electronic Mailing Systems
105	81	139	6.8	74	2 Electronic Mailing Systems
106	81	140	12.5	74	Electronic Typewriter
107	81	141	0.4	74	Auto Ticketer Machine
108	81	142	14.2	74	Electronic Mailing Systems
109	81	143	20.6	74	2 Electronic Mailing Systems
110	81	144	18.1	74	2 Electronic Mailing Systems
111	81	145	21.8	74	2 Electronic Mailing Systems
112	81	146	16.7	74	2 Electronic Mailing Systems
113	81	147	13.1	74	Word Processing Equipment
114	81	148	4.8	70	2 Tape Evaluator/Cleaners
115	81	150	0.9	74	Auto Ticketer Machine
116	81	151	8.6	41	2 Ice Machines
117	81	152	17.1	74	2 Electronic Mailing Systems
118	81	167	15.1	74	6 Information Processing Systems
119	81	168	14.7	74	6 Information Processing Systems
120	81	169	17.5	74	6 Information Processing Systems
121	81	170	16.6	74	2 Information Processing Systems
122	81	171	18.1	74	2 Information Processing Systems
123	81	185	0.5	74	Teleticketer
124	81	187	13.6	74	Word Processing System

Appendix A (continued):

1982

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
1	82	1	2.5	65	Medical X-ray Unit
2	82	2	14.8	36	Offset Printing System
3	82	3	11.6	65	Ultrasound Scanner
4	82	6	16.2	74	Printer System
5	82	7	7.9	70	2 Tape Evaluator/Cleaners
6	82	9	17.4	67	Microform Equipment
7	82	10	5.1	65	Ultrasound Scanner
8	82	11	8.0	74	Word Processing System
9	82	12	15.2	74	2 Word Processing Systems
10	82	13	4.9	65	Adult Endoscope
11	82	15	13.5	74	Word Processing System
12	82	17	5.9	36	Printing Equipment
13	82	20	8.2	36	Printing Plant Equipment
14	82	21	21.7	74	3 Word Processing Systems
15	82	22	5.0	74	Microprocessor Development System
16	82	23	21.9	74	Programmable Calculators
17	82	24	15.5	65	Electrocardiographic Exercise Stress System
18	82	25	22.5	74	Electric Mailing Equipment
19	82	28	23.3	74	Word Processing Equipment
20	82	29	14.9	74	Word Processing Equipment
21	82	30	14.5	74	Word Processor
22	82	31	20.2	74	2 Electronic Mailing Systems
23	82	32	3.7	65	Dual Format Video Imager
24	82	33	4.7	65	Ocular Pneumoplethysmograph
25	82	34	16.1	74	Word Processing System
26	82	36	14.8	74	Word Processing Equipment
27	82	38	9.7	74	Rotary File Systems
28	82	39	18.0	74	2 Word Processing Systems
29	82	40	17.8	74	2 Word Processing Systems
30	82	41	8.5	74	Word Processing System
31	82	42	1.4	67	Microfiche Duplicator
32	82	43	15.3	74	4 Word Processing Systems
33	82	45	14.0	37	2 Hydraulic Rotary Mowers
34	82	46	17.4	36	Copier/Duplicator
35	82	48	9.5	74	Word Processing Systems
36	82	50	20.9	65	Electrocardiograph

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
37	82	51	9.3	36	5 Copy Machines
38	82	53	9.2	65	Neonatal Monitor
39	82	54	9.7	36	Phototypesetter & Processor
40	82	55	14.7	74	2 Word Processing Systems
41	82	57	15.6	74	Rotary Filing Cabinet
42	82	59	16.8	74	Document Data Processing Set
43	82	60	20.2	36	Copier
44	82	62	19.9	74	Word Processing System
45	82	65	14.3	74	Word Processing System
46	82	67	3.6	65	Fluoricon Compact Video Image
47	82	69	12.7	74	Word Processing Systems
48	82	71	12.6	74	Word Processing Systems
49	82	72	16.2	58	Radio Pager System
50	82	73	16.2	74	Document Storage & Retrieval System
51	82	75	14.0	74	Word Processing System
52	82	76	4.8	66	Electronic Distance Measuring Device
53	82	78	6.9	41	Ice Machine
54	82	79	5.8	65	Densitometer
55	82	80	8.5	67	Camera System
56	82	82	16.2	74	Word Processing System
57	82	83	1.7	65	Colonfiberscope
58	82	84	23.0	74	Automatic Mail-Inserting Machine
59	82	85	2.4	74	Ribbon Re-Inker
60	82	88	4.8	65	Ultrasound
61	82	89	9.7	74	Microcomputer
62	82	90	2.3	65	Electrosurgical Unit
63	82	91	17.4	74	Word Processing System
64	82	92	19.8	74	Word Processing Equipment
65	82	94	12.0	74	Word Processing Center
66	82	96	3.6	65	Therapeutic Drug Assay System
67	82	98	3.6	74	Electronic Mail Equipment
68	82	99	17.0	36	Copier/Duplicator
69	82	100	21.6	36	Reprographic Equipment
70	82	102	18.5	74	Word Processing System
71	82	104	21.1	36	Copier/Duplicator

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
72	82	105	8.6	37	Large Capacity Mower
73	82	106	11.5	66	Gas Leak Detection Equipment
74	82	107	19.5	74	3 Word Processing Systems
75	82	108	21.7	36	Copier/Duplicator
76	82	109	19.8	36	Copier/Duplicator
77	82	112	0.7	74	Autoticketer
78	82	113	0.9	74	Airline Autoticketer
79	82	114	0.6	74	Airline Autoticketer
80	82	115	0.5	74	Airline Autoticketer
81	82	116	0.2	74	Airline Autoticketer
82	82	117	4.0	65	Ultrasound System
83	82	118	4.5	65	Ultrasound Unit
84	82	119	9.4	74	Word Processing System
85	82	120	10.6	74	Word Processor
86	82	121	19.1	74	8 Word Processors
87	82	122	19.8	74	4 Word Processors
88	82	123	18.8	74	6 Word Processors
89	82	124	19.0	74	6 Word Processors
90	82	125	17.3	74	Word Processing System
91	82	126	16.2	74	Word Processing System
92	82	127	11.3	65	Holter Scanner System
93	82	130	20.3	74	Base Level Microcomputers
94	82	133	9.4	65	Electrolyte Analyzer
95	82	135	3.6	74	Word Processor
96	82	138	12.7	70	Tape Evaluator/Cleaner
97	82	139	16.9	74	Word Processing System
98	82	140	6.3	74	Word Processors
99	82	141	11.9	38	Asphalt Recycling Plant
100	82	142	10.6	65	Drug Detection System
101	82	143	4.2	65	Gastroscope
102	82	145	1.6	74	Electronic Cash Registers
103	82	146	2.1	74	Electronic Cash Registers
104	82	147	2.6	74	Electronic Cash Registers
105	82	148	2.9	74	Electronic Cash Registers
106	82	151	2.8	74	Electronic Cash Registers
107	82	153	2.1	74	Electronic Cash Registers
108	82	154	1.9	74	Electronic Cash Registers
109	82	155	1.9	74	Electronic Cash Registers
110	82	158	2.0	74	Electronic Cash Registers
111	82	159	16.3	74	Displaywriters

Appendix A (continued):

OBS	YEAR	PROJECT NUMBER	PAYBACK PERIOD	FSG	ITEM DESCRIPTION
112	82	161	16.3	74	Displaywriters
113	82	162	19.2	36	Tandem Duplicator
114	82	164	15.7	65	Ultrasound System
115	82	165	7.3	74	Word Processing System
116	82	167	9.5	65	Ultrasound
117	82	169	5.8	65	Colonscope
118	82	171	11.4	74	Word Processing System
119	82	172	1.6	74	Word Processing System
120	82	192	17.4	36	Reprographic Equipment
121	82	199	3.4	38	Mobile Asphalt Recycler
122	82	200	5.1	74	Word Processing System
123	82	202	3.6	74	Word Processor
124	82	203	5.5	74	Microcomputer
125	82	212	8.5	74	Word Processing System
126	82	217	14.3	65	Ultrasound System
127	82	220	0.4	58	Space Comsec Test System
128	82	222	11.4	74	Electronic Cash Registers

Appendix B: Frequency Bar Charts for Normality Check

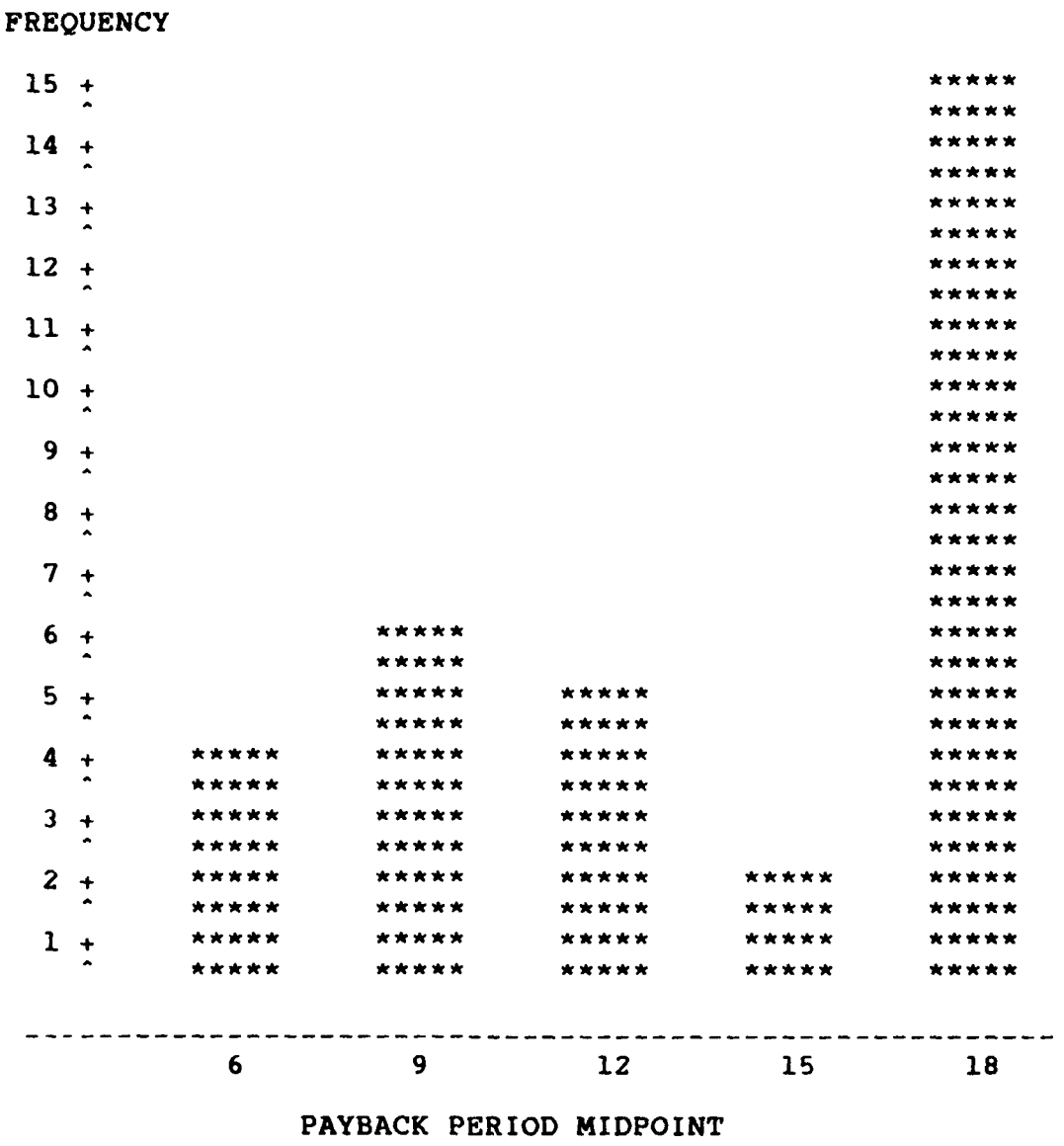

Figure 2. Frequency Bar Chart for FSG 36

Appendix B (continued):

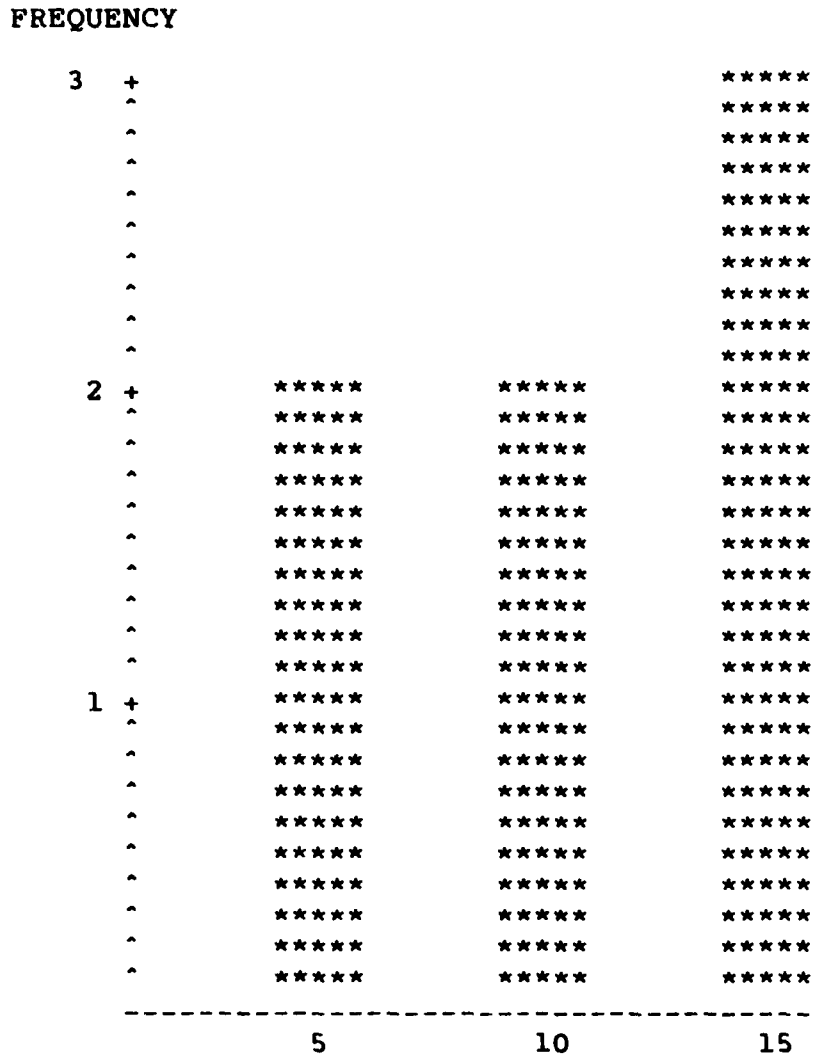

Figure 3. Frequency Bar Chart for FSG 37

Appendix B (continued):

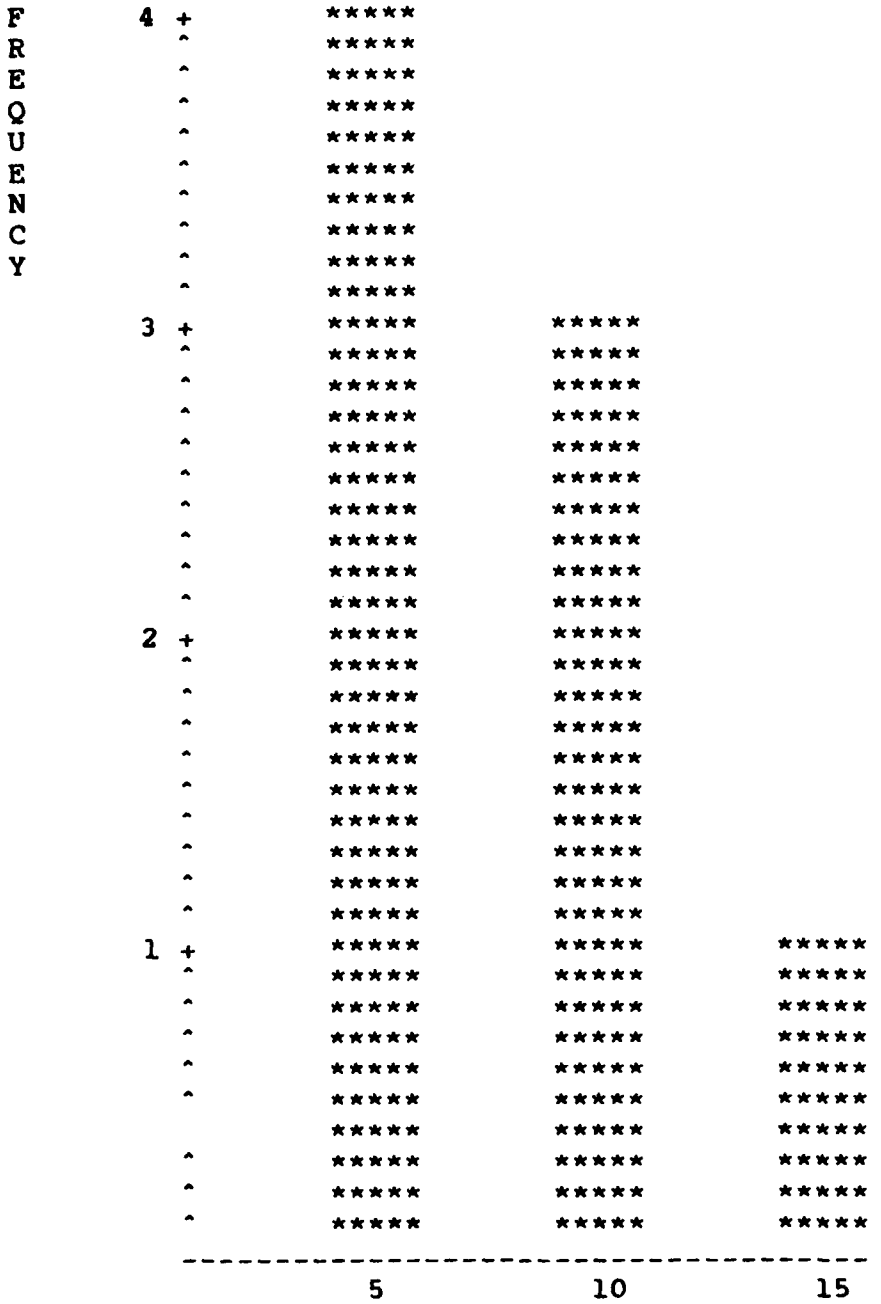

Figure 4. Frequency Bar Chart for FSG 38

Appendix B (continued):

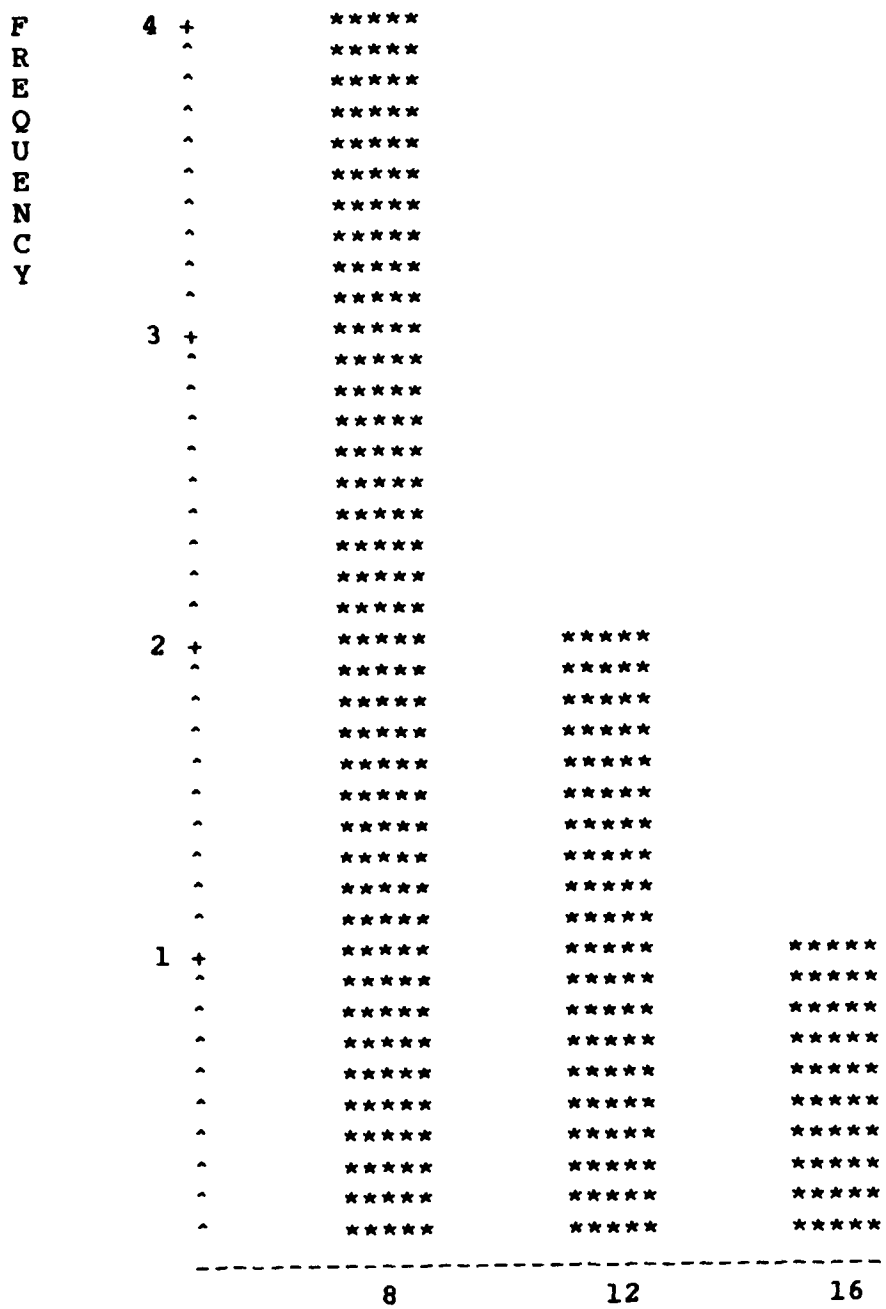

Figure 5. Frequency Bar Chart for FSG 41

Appendix B (continued):

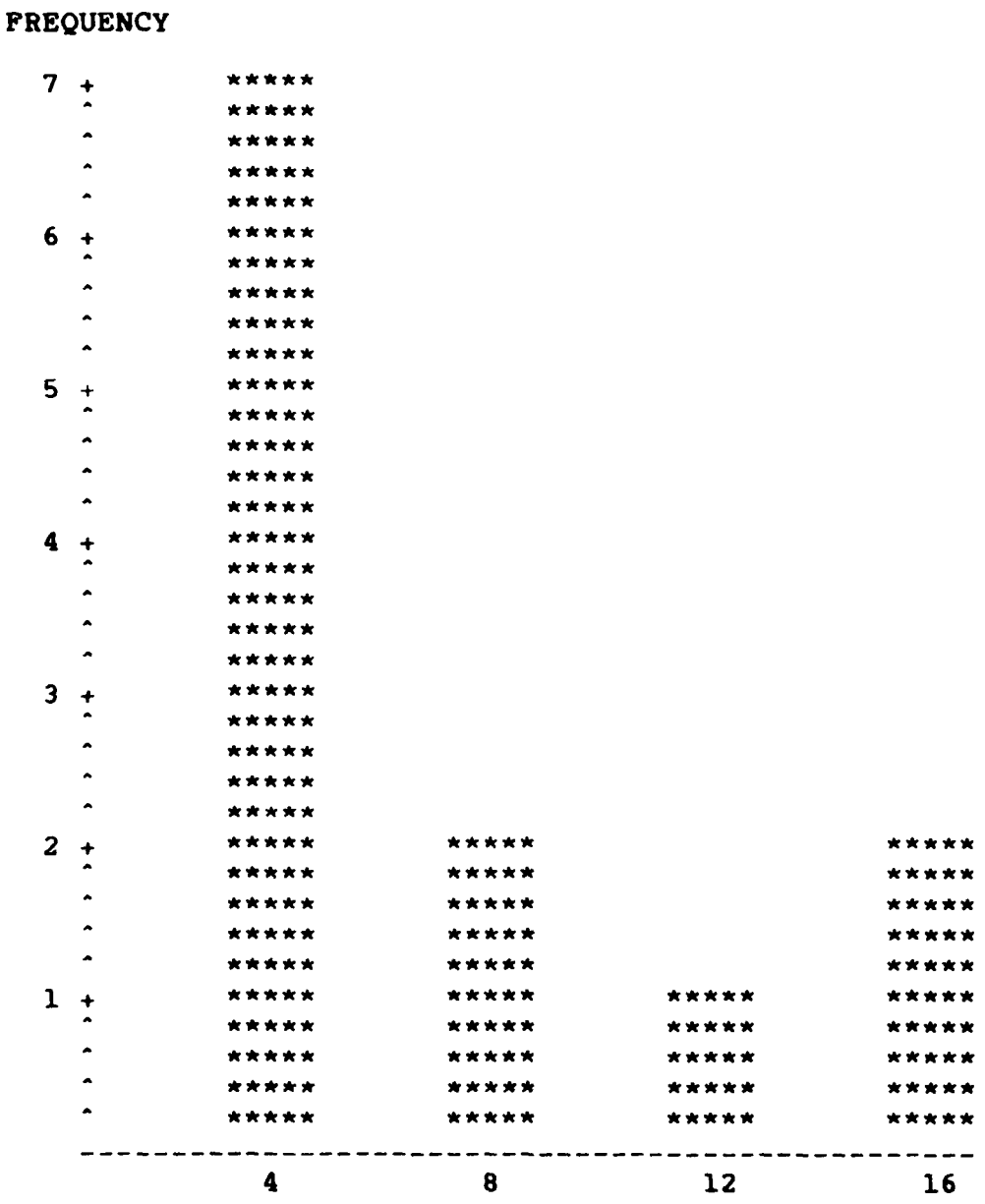

Figure 6. Frequency Bar Chart for FSG 49

Appendix B (continued):

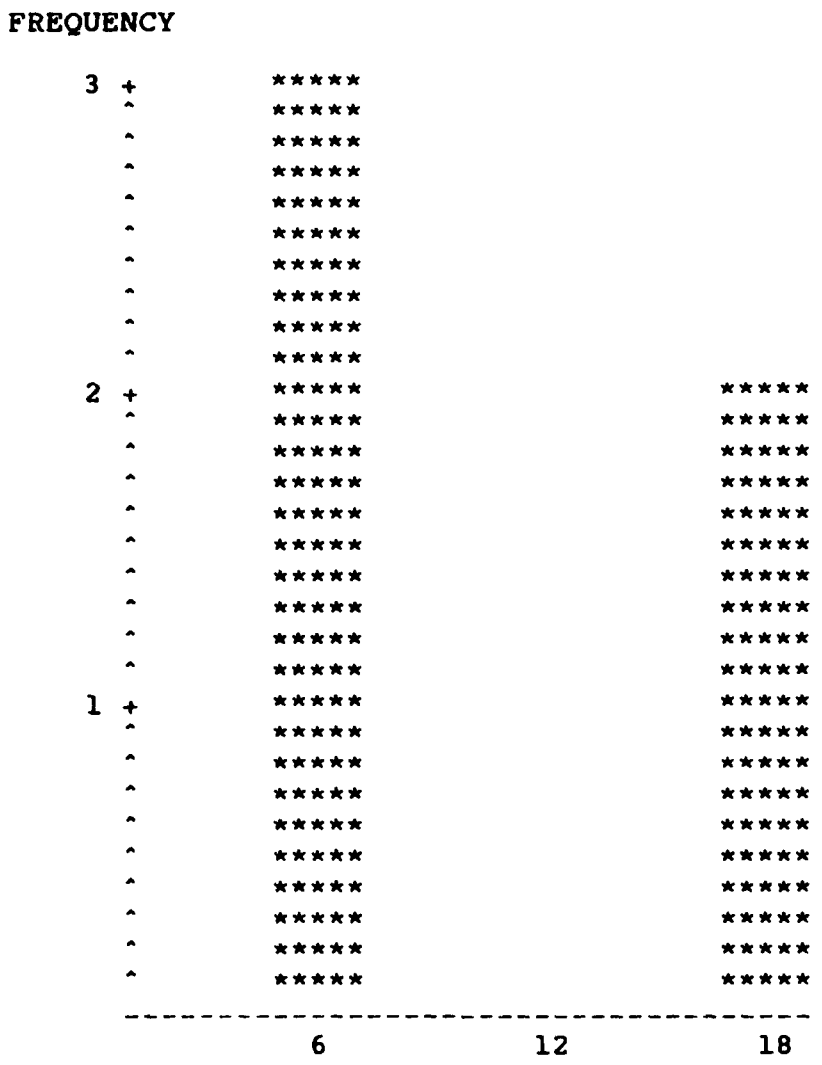

Figure 7. Frequency Bar Chart for FSG 58

Appendix B (continued):

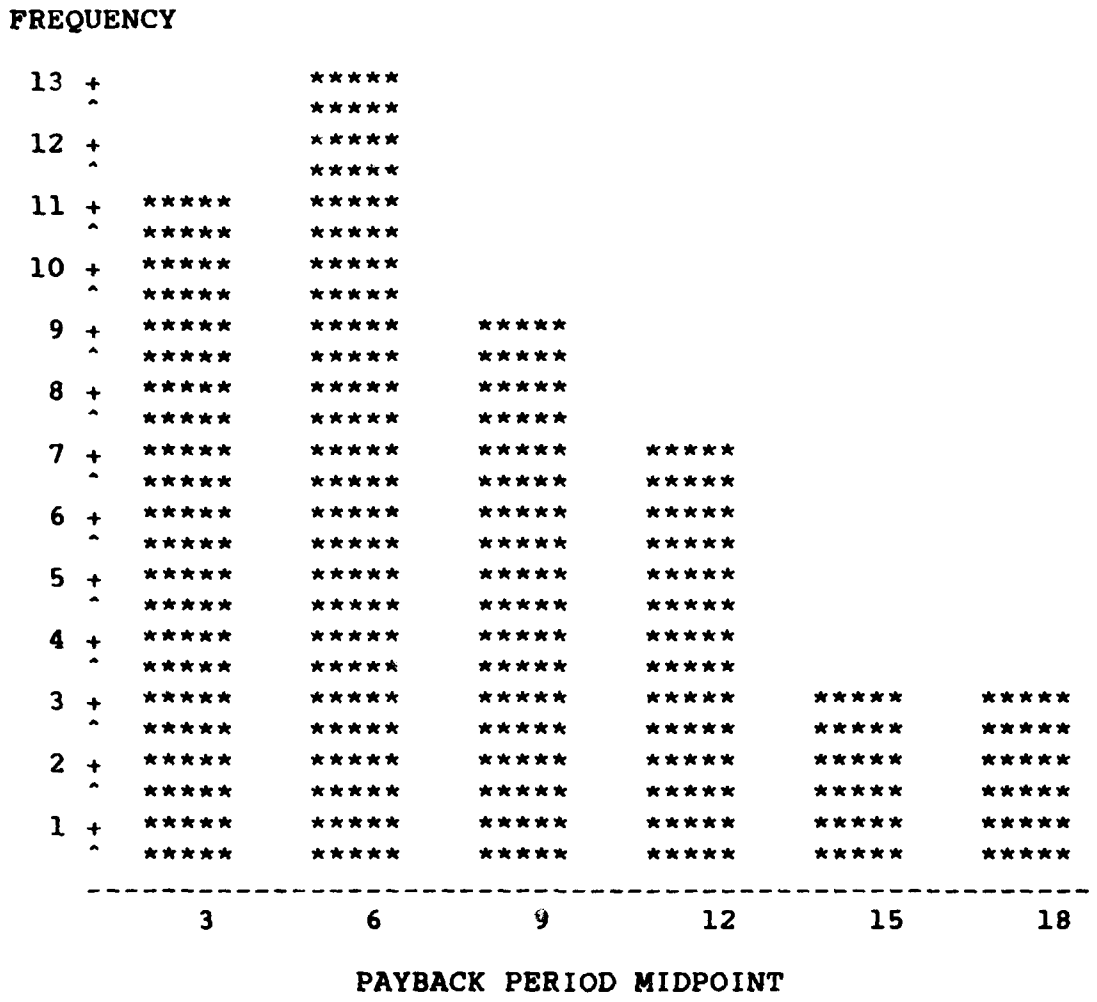

Figure 8. Frequency Bar Chart for FSG 65

Appendix B (continued):

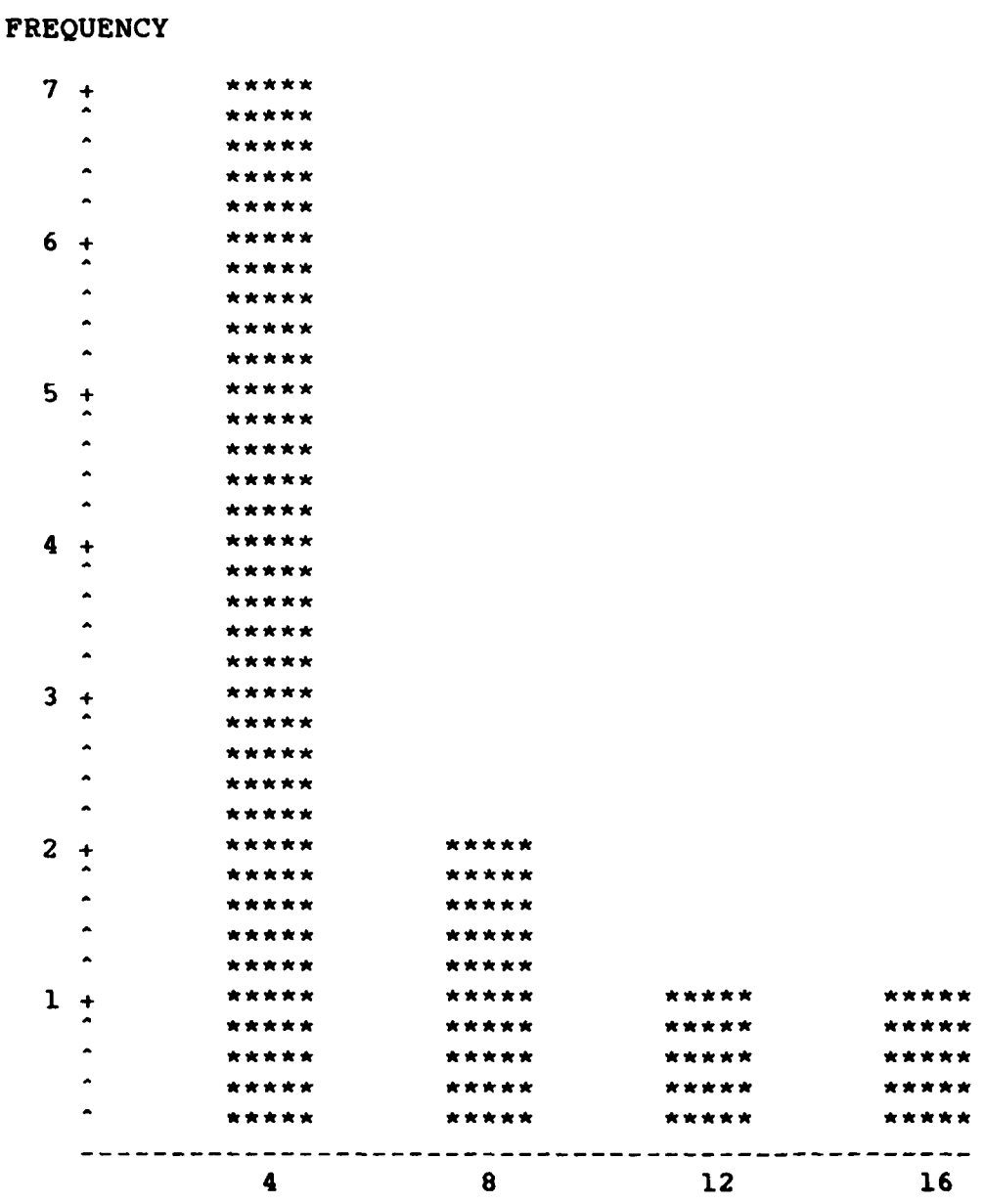

Figure 9. Frequency Bar Chart for FSG 66

Appendix B (continued):

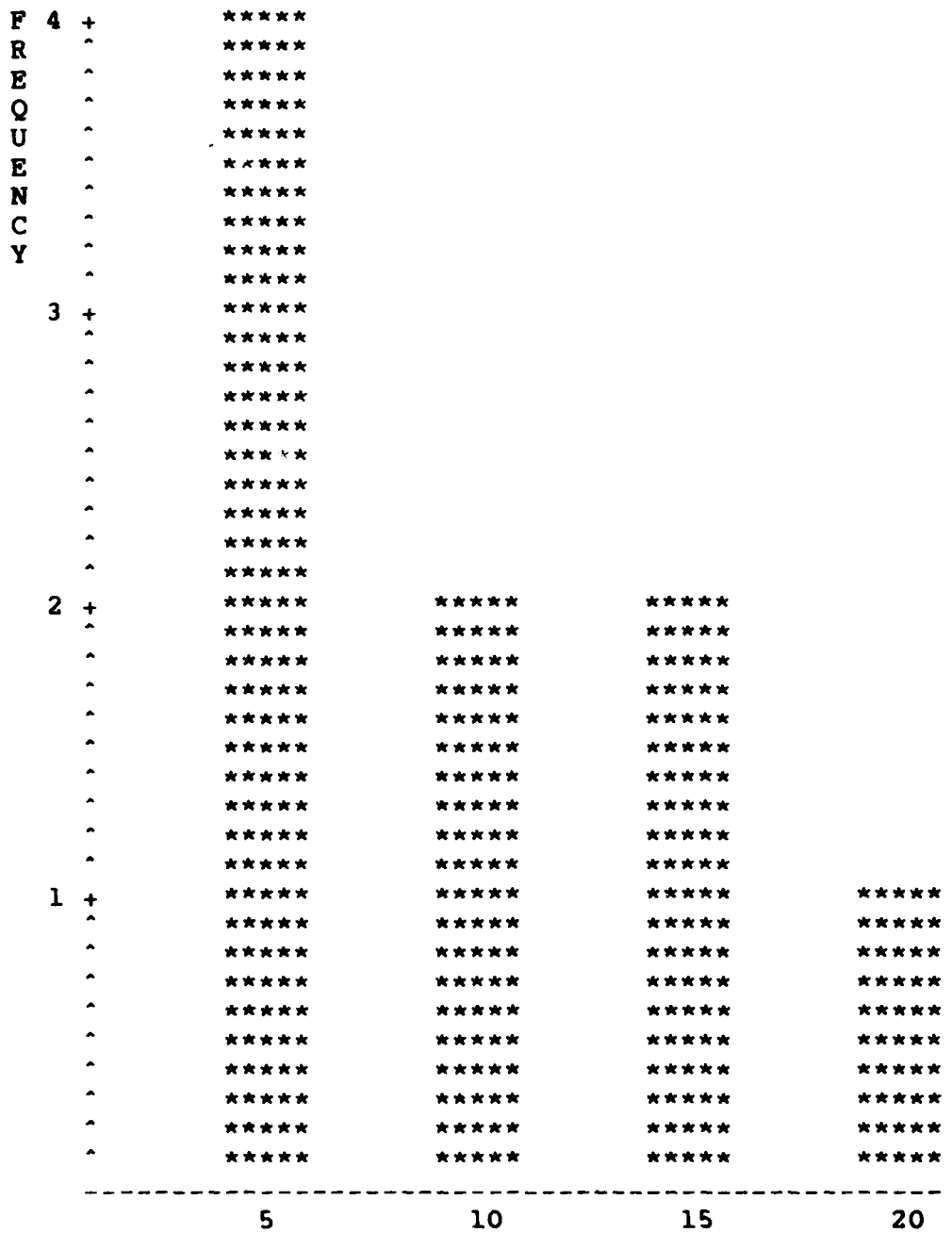

Figure 10. Frequency Bar Chart for FSG 67

Appendix B (continued):

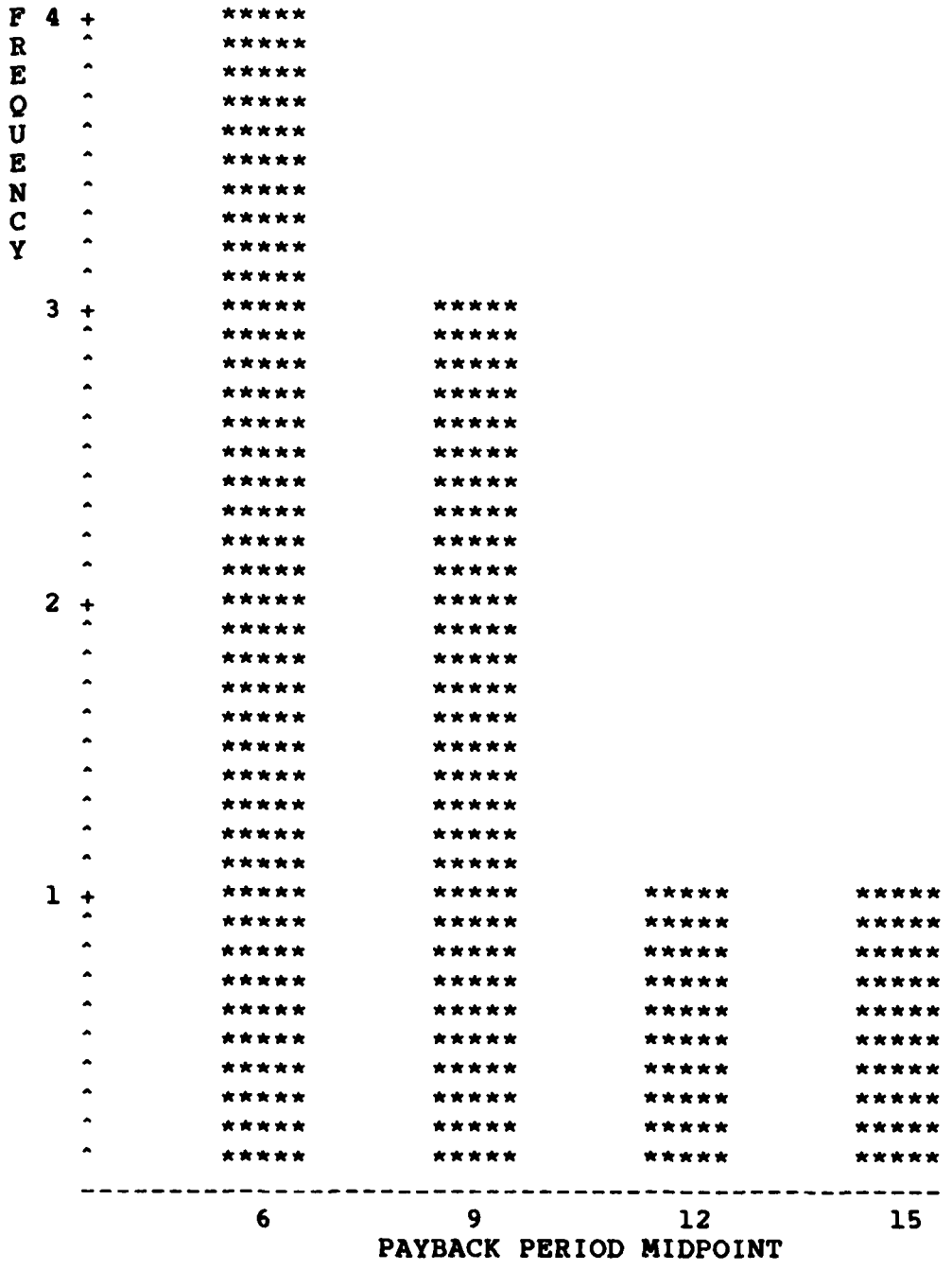

Figure 11. Frequency Bar Chart for FSG 70

Appendix B (continued):

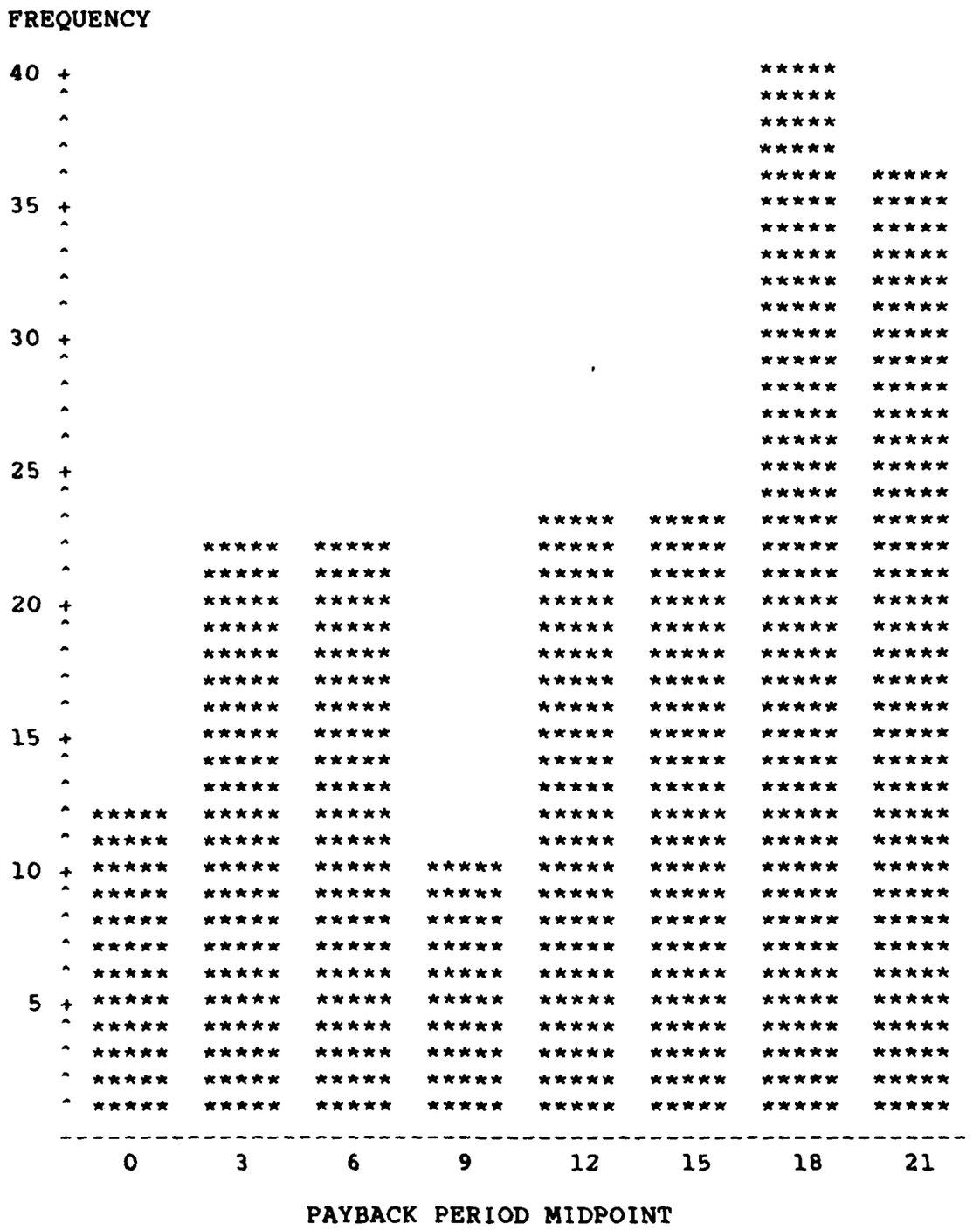

Figure 12. Frequency Bar Chart for FSG 74

Appendix C: Chi^2 Goodness of Fit Test

Degrees of Freedom = Number of Classes - 3
.1 Level of Significance

FSG 74:

CLASS	PROBABILITY	E_i	Y_i	$Y_i - E_i$	$(Y_i - E_i)^2/E_i$
1	.06	11	12	1	.09
2	.07	13	22	9	6.20
3	.12	23	22	- 1	.04
4	.16	30	10	-20	13.33
5	.18	34	23	-11	3.60
6	.16	30	40	10	3.33
7	.12	23	36	13	5.63
8	.13	24	23	- 1	.04
Totals	1.00	188	188	0	χ^2 = 32.26

NORMALITY IS REJECTED IF χ^2 calculated $\geq \chi^2_{\alpha,5}$

$\chi^2_{.1,5} = 9.236$

$32.26 \geq 9.236$ SO REJECT THAT DISTRIBUTION IS NORMAL

FSG 36:

CLASS	PROBABILITY	E_i	Y_i	$Y_i - E_i$	$(Y_i - E_i)^2/E_i$
1	.18	6	4	-2	.667
2	.15	5	6	1	.200
3	.20	6	5	-1	.200
4	.15	5	2	-3	1.800
5	.32	10	15	5	2.500
Totals	1.00	32	32	0	χ^2 = 5.367

NORMALITY IS REJECTED IF χ^2 calculated $\geq \chi^2_{\alpha,2}$

$\chi^2_{.1,2} = 4.605$

$5.367 \geq 4.605$ SO REJECT THAT DISTRIBUTION IS NORMAL

Appendix D: Ranking of Projects for Kruskal-Wallis Test

PROJNR: First digit blank = 1980
First digit one = 1981
First digit two = 1982
Last three digits = project number

PAYPER Payback period in months

RANKPAY Rank among all observations by payback period

OBS	PROJNR	FSG	PAYPER	RANKPAY
1	1122	38	0.2	1.5
2	2116	74	0.2	1.5
3	1092	74	0.3	3.5
4	1127	74	0.3	3.5
5	2220	58	0.4	6.0
6	1126	74	0.4	6.0
7	1141	74	0.4	6.0
8	1185	74	0.5	8.5
9	2115	74	0.5	8.5
10	1113	74	0.6	10.5
11	2114	74	0.6	10.5
12	105	66	0.7	13.0
13	1087	66	0.7	13.0
14	2112	74	0.7	13.0
15	1150	74	0.9	15.5
16	2113	74	0.9	15.5
17	2042	67	1.4	17.0
18	1082	65	1.6	19.5
19	2172	74	1.6	19.5
20	1037	74	1.6	19.5
21	2145	74	1.6	19.5
22	2083	65	1.7	22.0
23	1096	74	1.9	24.0
24	2154	74	1.9	24.0
25	2155	74	1.9	24.0
26	2158	74	2.0	26.0
27	2146	74	2.1	27.5
28	2153	74	2.1	27.5
29	1074	66	2.2	29.0
30	2090	65	2.3	30.0
31	2085	74	2.4	31.0
32	2001	65	2.5	32.5

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
33	1070	74	2.5	32.5
34	2147	74	2.6	34.0
35	1036	66	2.7	35.5
36	38	67	2.7	35.5
37	1003	74	2.8	37.5
38	2151	74	2.8	37.5
39	2148	74	2.9	39.0
40	1016	67	3.0	40.0
41	1083	49	3.1	41.0
42	122	49	3.2	42.5
43	1039	74	3.2	42.5
44	1014	49	3.3	44.0
45	2199	38	3.4	45.0
46	2067	65	3.6	48.0
47	2096	65	3.6	48.0
48	2135	74	3.6	48.0
49	2202	74	3.6	48.0
50	2098	74	3.6	48.0
51	1057	49	3.7	52.0
52	1111	49	3.7	52.0
53	2032	65	3.7	52.0
54	1044	74	3.8	54.0
55	1115	49	3.9	55.5
56	78	65	3.9	55.5
57	1048	38	4.0	58.0
58	2117	65	4.0	58.0
59	3	74	4.0	58.0
60	1136	74	4.1	60.0
61	2143	65	4.2	61.0
62	5	37	4.3	62.0
63	1084	65	4.4	63.0
64	2118	65	4.5	64.0
65	1065	74	4.6	65.0
66	72	36	4.7	68.5
67	2033	65	4.7	68.5
68	53	67	4.7	68.5
69	1094	70	4.7	68.5
70	1071	74	4.7	68.5
71	1073	74	4.7	68.5
72	2088	65	4.8	73.0
73	2076	66	4.8	73.0
74	1148	70	4.8	73.0

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
75	124	38	4.9	76.0
76	2013	65	4.9	76.0
77	14	74	4.9	76.0
78	115	66	5.0	79.5
79	30	66	5.0	79.5
80	1030	74	5.0	79.5
81	2022	74	5.0	79.5
82	2010	65	5.1	82.5
83	2200	74	5.1	82.5
84	1020	36	5.2	84.5
85	1040	74	5.2	84.5
86	1137	74	5.3	86.0
87	49	41	5.5	88.5
88	1005	74	5.5	88.5
89	2203	74	5.5	88.5
90	1028	74	5.5	88.5
91	97	37	5.7	92.0
92	1042	74	5.7	92.0
93	1043	74	5.7	92.0
94	6	36	5.8	96.0
95	108	65	5.8	96.0
96	2169	65	5.8	96.0
97	2079	65	5.8	96.0
98	51	74	5.8	96.0
99	2017	36	5.9	99.5
100	4	49	5.9	99.5
101	39	65	6.0	101.5
102	1019	66	6.0	101.5
103	109	65	6.3	104.0
104	52	70	6.3	104.0
105	2140	74	6.3	104.0
106	41	49	6.4	106.5
107	1024	74	6.4	106.5
108	7	49	6.5	109.0
109	1033	74	6.5	109.0
110	93	74	6.5	109.0
111	1015	58	6.7	111.0
112	83	66	6.8	112.5
113	1139	74	6.8	112.5
114	2078	41	6.9	115.0
115	42	70	6.9	115.0
116	1027	74	6.9	115.0

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
117	1050	65	7.0	117.0
118	64	65	7.1	118.0
119	1041	58	7.3	119.5
120	2165	74	7.3	119.5
121	54	65	7.4	121.0
122	1021	70	7.5	122.0
123	12	36	7.7	123.5
124	19	41	7.7	123.5
125	60	36	7.8	125.0
126	26	65	7.9	126.5
127	2007	70	7.9	126.5
128	2011	74	8.0	128.0
129	2020	36	8.2	129.0
130	1090	74	8.3	130.0
131	24	74	8.4	131.0
132	2080	67	8.5	133.0
133	2041	74	8.5	133.0
134	2212	74	8.5	133.0
135	2105	37	8.6	135.5
136	1151	41	8.6	135.5
137	94	65	9.0	137.5
138	1104	65	9.0	137.5
139	89	38	9.2	140.5
140	1106	65	9.2	140.5
141	2053	65	9.2	140.5
142	68	74	9.2	140.5
143	2051	36	9.3	143.5
144	95	65	9.3	143.5
145	2133	65	9.4	145.5
146	2119	74	9.4	145.5
147	2167	65	9.5	147.5
148	2048	74	9.5	147.5
149	61	65	9.6	149.0
150	2054	36	9.7	151.0
151	2038	74	9.7	151.0
152	2089	74	9.7	151.0
153	84	67	9.9	153.0
154	1029	70	10.0	154.0
155	1121	36	10.1	155.5
156	58	49	10.1	155.5
157	73	36	10.5	159.0
158	1069	74	10.5	159.0

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
159	11	74	10.5	159.0
160	1089	74	10.5	159.0
161	1098	74	10.5	159.0
162	120	65	10.6	163.0
163	2142	65	10.6	163.0
164	2120	74	10.6	163.0
165	2	37	10.7	165.5
166	1129	74	10.7	165.5
167	47	36	11.0	167.5
168	36	41	11.0	167.5
169	1058	65	11.1	169.5
170	1114	74	11.1	169.5
171	57	36	11.2	171.0
172	2127	65	11.3	174.0
173	63	74	11.3	174.0
174	8	74	11.3	174.0
175	1023	74	11.3	174.0
176	1038	74	11.3	174.0
177	1047	36	11.4	178.0
178	2171	74	11.4	178.0
179	2222	74	11.4	178.0
180	1060	38	11.5	180.5
181	2106	66	11.5	180.5
182	2003	65	11.6	182.0
183	2141	38	11.9	183.5
184	1081	74	11.9	183.5
185	2094	74	12.0	185.0
186	21	65	12.1	186.0
187	1086	65	12.4	187.5
188	102	74	12.4	187.5
189	125	36	12.5	190.0
190	1140	74	12.5	190.0
191	1077	74	12.5	190.0
192	2071	74	12.6	192.0
193	2138	70	12.7	193.5
194	2069	74	12.7	193.5
195	88	37	12.9	195.5
196	35	41	12.9	195.5
197	101	74	13.0	197.5
198	1099	74	13.0	197.5
199	1147	74	13.1	199.0
200	2015	74	13.5	200.0

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
201	1187	74	13.6	202.0
202	1068	74	13.6	202.0
203	1138	74	13.6	202.0
204	1002	36	13.9	205.0
205	1008	74	13.9	205.0
206	1034	74	13.9	205.0
207	2045	37	14.0	208.0
208	90	74	14.0	208.0
209	2075	74	14.0	208.0
210	1142	74	14.2	210.0
211	2217	65	14.3	211.5
212	2065	74	14.3	211.5
213	1075	74	14.4	213.0
214	2030	74	14.5	214.0
215	45	74	14.7	216.0
216	2055	74	14.7	216.0
217	1168	74	14.7	216.0
218	2002	36	14.8	220.0
219	1101	74	14.8	220.0
220	2036	74	14.8	220.0
221	113	74	14.8	220.0
222	1100	74	14.8	220.0
223	2020	74	14.9	223.0
224	1167	74	15.1	224.5
225	1061	74	15.1	224.5
226	1064	74	15.2	226.5
227	2012	74	15.2	226.5
228	20	49	15.3	230.0
229	1128	74	15.3	230.0
230	1001	74	15.3	230.0
231	1062	74	15.3	230.0
232	2043	74	15.3	230.0
233	2024	65	15.5	233.0
234	2057	74	15.6	234.0
235	2164	65	15.7	235.0
236	1097	74	15.8	236.0
237	1045	74	15.9	237.0
238	1018	49	16.0	238.5
239	76	74	16.0	238.5
240	92	67	16.1	241.0
241	87	74	16.1	241.0
242	2034	74	16.1	241.0

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
243	2072	58	16.2	245.0
244	2126	74	16.2	245.0
245	2082	74	16.2	245.0
246	2006	74	16.2	245.0
247	2073	74	16.2	245.0
248	2161	74	16.3	248.5
249	2159	74	16.3	248.5
250	1007	36	16.6	250.5
251	1170	74	16.6	250.5
252	1146	74	16.7	252.0
253	44	74	16.8	253.5
254	2059	74	16.8	253.5
255	1022	65	16.9	255.5
256	2139	74	16.9	255.5
257	2099	36	17.0	257.5
258	62	74	17.0	257.5
259	1004	36	17.1	260.5
260	18	74	17.1	260.5
261	1110	74	17.1	260.5
262	1152	74	17.1	260.5
263	1009	74	17.2	263.0
264	2125	74	17.3	264.0
265	2046	36	17.4	267.0
266	2192	36	17.4	267.0
267	2009	67	17.4	267.0
268	2091	74	17.4	267.0
269	37	74	17.4	267.0
270	1169	74	17.5	270.0
271	1	36	17.6	272.0
272	121	65	17.6	272.0
273	1117	74	17.6	272.0
274	2040	74	17.8	274.5
275	1066	74	17.8	274.5
276	1035	66	17.9	277.0
277	69	74	17.9	277.0
278	1080	74	17.9	277.0
279	1012	36	18.0	281.5
280	85	74	18.0	281.5
281	79	74	18.0	281.5
282	86	74	18.0	281.5
283	1046	74	18.0	281.5
284	2039	74	18.0	281.5

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
285	1017	36	18.1	286.5
286	56	41	18.1	286.5
287	1171	74	18.1	286.5
288	1144	74	18.1	286.5
289	27	74	18.3	289.5
290	67	74	18.3	289.5
291	50	58	18.4	292.0
292	1031	74	18.4	292.0
293	33	74	18.4	292.0
294	1105	70	18.5	295.0
295	2102	74	18.5	295.0
296	1055	74	18.5	295.0
297	1067	74	18.6	297.0
298	2123	74	18.8	298.0
299	2124	74	19.0	299.0
300	2121	74	19.1	300.0
301	2162	36	19.2	301.0
302	34	74	19.5	302.5
303	2107	74	19.5	302.5
304	98	67	19.6	304.0
305	1093	74	19.7	305.0
306	2109	36	19.8	307.5
307	1053	74	19.8	307.5
308	2092	74	19.8	307.5
309	2122	74	19.8	307.5
310	1116	74	19.9	310.5
311	2062	74	19.9	310.5
312	1056	74	20.1	312.5
313	1132	74	20.1	312.5
314	2060	36	20.2	314.5
315	2031	74	20.2	314.5
316	2130	74	20.3	316.0
317	1143	74	20.6	317.0
318	22	37	20.7	318.0
319	1134	74	20.8	319.0
320	2050	65	20.9	320.0
321	2104	36	21.1	321.0
322	2100	36	21.6	322.0
323	2108	36	21.7	323.5
324	2021	74	21.7	323.5
325	40	36	21.8	326.0
326	1054	38	21.8	326.0

Appendix D (continued):

OBS	PROJNR	FSG	PAYPER	RANKPAY
327	1145	74	21.8	326.0
328	2023	74	21.9	328.0
329	2025	74	22.5	329.0
330	81	74	23.0	330.5
331	2084	74	23.0	330.5
332	88	74	23.2	332.0
333	2028	74	23.3	333.0
334	1013	74	23.4	334.0

Appendix E: Details of Kruskal-Wallis Test Computation

$$K = \frac{12}{N(N+1)} \sum_{i=1}^{I} \frac{R_i^2}{n_i} - 3(N+1) \qquad (3)$$

where

R = sum of ranks in a group (FSG)

I = number of groups (FSGs)

N = total number of observations (projects)

n = number of observations (projects) in group (FSG)

FSG	R	n	$R^2 \div n$
36	6824.5	32	1,455,431.257
37	1176.5	7	197,736.036
38	1011.0	8	127,765.125
41	1112.0	7	176,649.143
49	1226.0	12	125,256.333
58	773.5	5	119,660.450
65	5723.0	46	712,015.848
66	994.0	11	89,821.454
67	1259.0	9	176,120.111
70	1251.5	9	174,028.028
74	34,594.0	188	6,365,664.021
			9,720,127.800

$$K = \frac{12}{334(334+1)} \sum_{i=1}^{11} \frac{R_i^2}{n_i} - 3(334+1)$$

$$= \frac{12}{111,890} (9,720,127.8) - 1005$$

$$= 1042.4661 - 1005$$

$$= 37.466$$

Appendix E (continued):

DIVIDE K BY ADJUSTMENT FACTOR DUE TO TIES IN RANKS

$$\text{ADJUSTMENT FACTOR} = 1 - \frac{\sum(\tau_i - 1)(\tau_i)(\tau_i + 1)}{(N^3 - N)} \qquad (4)$$

where

τ_i is the number of ties in the i^{th} group of ties and the sum is over all groups of ties

CALCULATION OF ADJUSTMENT FACTOR

τ	No. of τs Occurring in Ranked Payperiods
2	52
3	26
4	7
5	8
6	2

$$\text{ADJUSTMENT FACTOR} = 1 - \frac{52(1\cdot2\cdot3)+26(2\cdot3\cdot4)+7(3\cdot4\cdot5)+8(4\cdot5\cdot6)+2(5\cdot6\cdot7)}{334^3 - 334}$$

$$= 1 - \frac{2736}{37,259,370}$$

$$= .9999266$$

KRUSKAL-WALLIS ADJUSTED K STATISTIC = K ÷ ADJUSTMENT FACTOR

= 37.466 ÷ .9999266

= 37.46875

Reject $H_0: \mu_1 = \mu_2 = \ldots = \mu_{11}$ if $K \geq \chi^2_{\alpha, I-1}$

$\chi^2_{.05,10} = 18.307$

$37.47 \geq 18.307$ $\therefore$ Reject H_0

Appendix F: Wilcoxon Rank-Sum Test Example

FSG 36 and FSG 65
tested at the .05 level of significance

$H_0: \mu_1 - \mu_2 = 0$ Reject if $Z \geq 1.96$ or ≤ -1.96

m=32 FSG 36

n=46 FSG 65

W=sum of ranks of FSG 36 = 1696

$$Z = \frac{W - [m(m+n+1)]/2}{\sqrt{[mn(m+n+1)]/12 - \{(mn)/[12(m+n)(m+n-1)]\} \cdot \sum(\tau_i - 1)(\tau_i)(\tau_i + 1)}} * \qquad (5,6)$$

$$= \frac{W - [32(32+46+1)]/2}{\sqrt{(32)(46)(32+46+1)/12 - \{(32)(46)/[12(32+46)(32+46-1)]\} \cdot \{8[(1)(2)(3)] + 1[(3)(4)(5)]\}}}$$

$$= \frac{1696 - 1264}{\sqrt{9690.67 - (.020424)(108)}}$$

$$= \frac{432}{\sqrt{9688.4609}}$$

$$= \frac{432}{98.42998}$$

$$= 4.3889067$$

$4.39 \geq 1.96$ So reject the null hypothesis

* Denominator reflects tie in ranks

Appendix G: Summarization of Results of Wilcoxon Rank-Sum Test

At .05 level of significance, reject
$H_0: \mu_1 - \mu_2 = 0$ If $Z \geq 1.96$ or ≤ -1.96

FSGs	Z	* IF NULL HYPOTHESIS WAS REJECTED
36-66	-3.5494	*
36-49	-3.5976	*
36-65	4.3838	*
36-38	-2.029	*
36-70	-2.363	*
36-67	-1.985	*
36-58	-1.31	-
36-41	-1.57	-
36-37	-1.19	-
36-74	1.38	-
74-66	-2.833	*
74-49	-2.562	*
74-65	-3.795	*
74-38	-1.607	-
74-70	-1.466	-
74-67	-1.402	-
74-58	-.600	-
74-41	-.883	-
74-37	-.573	-
37-66	1.904	-
37-49	1.733	-
37-65	1.301	-
37-38	.984	-
37-70	.847	-
37-67	.741	-
37-58	-.162	-
37-41	.256	-

Appendix G (continued):

FSGs	Z	* IF NULL HYPOTHESIS WAS REJECTED
41-66	2.267	*
41-49	1.902	-
41-65	1.169	-
41-38	.752	-
41-70	.795	-
41-67	.529	-
41-58	-.162	-
58-66	1.135	-
58-49	1.213	-
58-65	.523	-
58-38	.366	-
58-70	.000	-
58-67	.000	-
67-66	.951	-
67-49	.391	-
67-65	.060	-
67-38	.048	-
67-70	-.221	-
70-66	1.787	-
70-49	1.600	-
70-65	.603	-
70-38	-.433	-
38-66	.661	-
38-49	.579	-
38-65	-.183	-
65-66	-1.628	-
65-49	-1.248	-
49-66	.585	-

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This thesis was an investigation of payback periods of equipment purchased through the Fast Payback Capital Investment Program (FASCAP). The average payback period for all FASCAP projects was about one year at the time this research was accomplished. The purpose of this thesis was to identify any equipment type that amortized significantly faster or slower than the one year average.

Projects approved in 1980, 1981, and 1982 that amortized within two years were included in the analysis. These projects were grouped into eleven equipment types based on Federal Supply Classification. Average payback periods for each group were statistically analyzed for significant differences. The data was not normally distributed so nonparametric methods were used. The Kruskal-Wallis test indicated that there were significant differences among the averages of the groups. The Wilcoxon rank-sum test was then performed to identify which pairs of average payback periods differed significantly.

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