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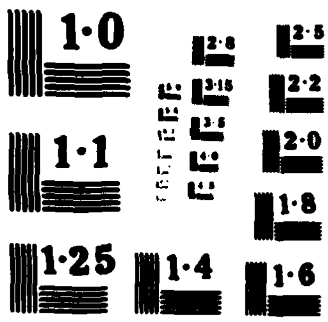
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THESIS

A STUDY OF PILOT SELECTION
FOR
THE KOREAN AIR FORCE

by

Park, Jang Kyong

September 1987

Thesis Advisor: Douglas E. Neil
Co-Advisor: Thomas M. Mitchell

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The Operation with Economic Efficiency (OEE) Program in the Republic of Korea Air Force (ROKAF) was designed to reduce the cost and improve the efficiency of all ROKAF operations. The ROKAF is now faced with the problem of developing a more efficient pilot candidate selection and training program which will improve pilot quality and reduce attrition rates and the number of aircraft accidents. The present research provides a starting point for the development of a more efficient pilot selection and training program. If successful this program should result in the selection of pilot candidates exhibiting a significantly higher probability of completing the pilot training program. This thesis also provides a summary of aviation selection test batteries presently in use by the U.S. Air Force and U.S. Navy and applies the principles of decision theory in determining whether a change in the ROKAF's present pilot selection system is feasible.

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A STUDY OF PILOT SELECTION FOR THE KOREAN AIR FORCE

by

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B.S., Korea Air Force Academy, Seoul, 1981

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The Operation with Economic Efficiency (OEE) Program in the Republic of Korea Air Force (ROKAF) was designed to reduce the cost and improve the efficiency of all ROKAF operations. The ROKAF is now faced with the problem of developing a more efficient pilot candidate selection and training program which will improve pilot quality and reduce attrition rates and the number of aircraft accidents. The present research provides a starting point for the development of a more efficient pilot selection and training program. If successful this program should result in the selection of pilot candidates exhibiting a significantly higher probability of completing the pilot training program. This thesis also provides a summary of aviation selection test batteries presently in use by the U.S. Air Force and U.S. Navy and applies the principles of decision theory in determining whether a change in the ROKAF's present pilot selection system is feasible.

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I. INTRODUCTION

A. BACKGROUND

Throughout the history of aviation there has been constant concern with selecting those individuals with both mental and physical qualities desirable for optimum performance in flight environments. The intensity and quantity of research performed over the years in the particular area of pilot selection highlights the fact that the key to combat air superiority is the selection of high quality pilot candidates. During World War II and the Korean conflict it became further apparent that the ability to gain total tactical and strategic advantage over the enemy depended on whether or not air superiority was achieved. Fortunately the U.S. was able to achieve this superiority in the air during the last three major conflicts. Unfortunately there is a growing consensus among military analysts that the U.S. may be lulling itself into a sense of complacency. The following quotation from a publication by B. K. Holloway underscores the basis for this growing complacency: [Ref. 1]

- "Twenty-six million living Americans are veterans of military service, and most of them have served in wartime. How many of these 26 million ever had to face an enemy who held air superiority ? ... In all, probably no more than one out of 150, for after February 1943 the U.S. and allies had undisputed air superiority in the Mediterranean and Western Europe; after August of 1943 we had it in the Pacific... In Korea we won air superiority twice - from the North Korean Air Force in the first two months of that war, and again from the Chinese Air Force after November 1950. In South Vietnam, our air superiority has come by default. In North Vietnam it has yet to be seriously challenged."

Today we have reached an age of strategic parity where Eastern block technological developments in air combat systems are advancing at a rate comparable with those as the West. The key in future conflicts thus becomes improved combat effectiveness and thus, ultimately, the development of improved aircrew selection and training programs.

The essence of these programs might be summarized simply as:

1) Using an effective selection method, find the best candidate pilot,
2) Provide him/her with the best and most cost effective training,
3) Significantly improve retention rates to maximize the training investment.

The first step, selecting the best pilot candidate, is not an easy one. The key questions become, "What mental and physical characteristics do we look for ?" and "What are our selection criteria ?" The answers to these two basic questions have been the object of much of the pilot candidate selection research, which will be addressed in the following section.

The ROKAF is currently experiencing an excessive and unacceptable attrition rate in its pilot training programs. This problem is further compounded by the fact that the total number of candidates admitted to the flight training program has steadily increased since the early 1980's, while training resources remained limited. As a result the candidates who remain in the program are afforded fewer hours of instruction in the air and thus do not receive the desired quality or quantity of training.

In the early 1960's both the U.S. Navy and Air Force flight training programs suffered similar attrition problems. Figure 1.1 provides a summary of the attrition categories for the respective services at that time and Appendix A provides a detailed description of attrition categories. The comparison of attrition rates between USN and USAF presented in Figure 1.1 as a result of various factors. USN had 60.5% attrition rate and 21.5% of that was due to flight failure. Similarly USAF had 49.0% due to flight failure out of 33.8% attrition. However, with the significant improvement in existing selection methods and the incorporation of new methods of psychological screening both services were able to decrease their respective attrition rates by almost 30% by 1977 [Ref. 2].

The present research attempts to summarize some of these improved selection methods utilized by both the U.S. Navy and Air Force and presents recommendations based on this summary for improving the pilot selection program of the ROKAF.

B. OBJECTIVE

The Korean Air Force (ROKAF) needs a more effective way to select and predict performance of pilot candidates for success in primary flight training and operational flight training to maintain its air superiority. The purpose of this thesis, therefore, is to suggest a pilot selection system which selects potential successes in flight training and improves pilot quality. This research also provides a) an overview of pilot selection research, b) testing methods, and c) a related decision theory and cost effectiveness model.

USN	USAF
60.5 %	33.8 %

Motivational Attrition

NOM 18.4% (Not Officer Material)	DOR[1] 42.1% (Drop on Request or Voluntary Withdrawal)	SIE 22.4% (Self Initiated Elimination)	MOA 11.4% (Manifestation of Apprehension)

Flight

FF 21.5% (Flight Failure)	FD 49.0% (Flying Deficiency)

Medical

NPQ 14.9% (Not Physically Qualified)	M 12.3% (Medical)

Academic

2.0%	2.9%

Other

1.1%	2.0%

[1] includes 3.6% Air Sickness.

Figure 1.1 Representative Navy and Air Force Pilot Attrition Categories (From Ref.2).

II. U.S. PILOT SELECTION RESEARCH

A. WORLD WARS

It was first noted during WW I that a significant number of aircraft accidents were due not primarily to aircraft failures but to human error. Thus, based on this data France, Italy and England all initiated programs to aid in the prediction of pilot success during primary flight training. U.S. efforts began as early as 1919. [Ref. 3] Early selection tests in U.S. were based primarily on Paper-and-Pencil Perceptual/Cognitive tests with psychomotor devices and were able to predict flight performance of pilot candidates with resonable validity.

The development of selection tests continued between the First and Second World Wars. Much of this effort was aimed at the development of psychomotor test devices which simulated stick and rudder movements of the aircraft. Perceptual/Cognitive Paper-and-Pencil tests likewise continued to be developed but both these and the psychomotor tests lacked significant predictive validity. A contributor to this fact was the deficiency in external criteria of in-flight performance. During WW II the demand to train large numbers of pilots in a short amount of time along with increased training cost created the necessity for minimizing attrition due to poor proficiency. The Navy thus incorporated in its selection test battery numerous items previously evaluated in the civilian pilot training program. In the "Pensacola 1000 aviator study", evaluation was made of the validity of more than 60 psychological, physiological and psychomotor test items from the Navy selection test battery utilizing over 900 Navy flight candidates. Results indicated that *psychological and psychomotor* measures exhibited greater validity for the prediction of success in flight training than did physiological measures and verified the validity and effectiveness of these psychological instruments and psychomotor tests in the prediction of flight success. [Ref. 3]

The US Army and Air Force also developed their pilot selection testing battery during WW II and several useful methods such as the Complex Coordination test and Divided Attention test are still used in the present selection test battery. The Complex Coordination test, similar to USN one, used by the requires the candidate to make simple controlled movements of a stick and rudder in response to patterns of visual stimuli. During WW II it was the most useful and most highly weighted test. Other testing methods developed included the Finger Dexterity, Rudder Control Test and Two Hand Pursuit Test. Typical apparatus test validity coefficients for pilots, navigators and bombardiers are presented in Table 1 [Ref. 4]. Note that the test most highly related to pilots is the Complex Coordination Test. The Discrimination Reaction Time is significantly related to navigators and bombardiers.

TABLE 1

VALIDITY OF APPARATUS TESTS

(year, sample size)

	Pilots	Navigators	Bombardiers
Complex Coordination	(1943, 3151) $r = .33$, $r_c = .40$	(1942, 1022) $r = .17$, $r_c = .24$	(1943, 1829) $r = .10$, $r_c = .13$
Rotary Pursuit with Divided Attention	(1943, 3146) $r = .14$, $r_c = .22$		
Finger Dexterity	(1943, 4779) $r = .07$, $r_c = .10$	(1943, 1021) $r = .10$, $r_c = .13$	(1943, 1828) $r = .13$, $r_c = .15$
Discrimination Reaction Time	(1943, 4779) $r = .25$, $r_c = .28$	(1942, 1022) $r = .27$, $r_c = .35$	(1942, 1829) $r = .22$, $r_c = .25$
Rudder Control Test	(1943, 3146) $r = .22$, $r_c = .30$		
Two Hand Pursuit	(1943, 1385) $r = .27$, (average)		
Two Hand Coordination	(1943, 4779) $r = .31$, $r_c = .35$	(1942, 1022) $r = .26$, $r_c = .29$	(1943, 1828) $r = .09$, $r_c = .12$

r = validity coefficient based on dichotomous pass/fail training criterion.

r_c = validity coefficient corrected for restriction in range.

(From Reference 4)

B. POST WAR RESEARCH

Psychomotor Tests were used in USAF selection battery until 1951 but were deleted due to administrative, quality control and reliability problems. A subsequent study of the revision of the psychomotor tests indicated that the use of simple motor skill tests offered little if any predictive value for flight school success. It was concluded that this was due to: [Ref. 5]

1) The unreliability of both predictor and criterion scores,
2) The use of inappropriate motor tests for the particular criteria being evaluated, and
3) The task of flying an airplane is too complex for simple motor skill tests to be of substantial benefit.

This indicated that other more complex abilities were necessary for successful pilot performance and that the goal of future research should be to:

1) Define the abilities,
2) Quantify the basic behaviors making up the abilities,
3) Devise accurate test measures.

These problems were considered continuously through the 1970s. As a result, currently the USAF has been achieving great success in predicting flight performance in its UPT program. This success will be addressed in more detail in Chapter III.

The other type test which has been the most widely and easily used as a selection test has been the Perceptual/Cognitive Paper-and-Pencil tests. The U.S. military service paper-and-pencil test battery consisted of: [Ref. 3]

1) A general intelligence component composed of verbal and quantitative items,
2) Mechanical comprehension,
3) A spatial component, and
4) A background or biographical inventory composed of miscellaneous subset of items usually of an historical nature known to relate to aviator success.

The analysis of EEG (Electroencephalogram) recordings has also received much attention as a possible predictor of aircraft accidents. It has been found that individuals with abnormal EEG's are involved in accidents at three times the rate of those individuals with normal EEG's[1] [Ref. 3]. As a result of these and similar findings the Navy now screens all new student aviators for abnormal EEG's prior to commencement of flight training.

[1]These findings have resulted in the Danish Air Force's use of EEG recordings in the selection of pilot candidates.

C. CURRENT RESEARCH

The establishment of reliable criterion measures is a prime factor in any selection process. This continues to be an extremely difficult and dynamic task. For example, the Navy has recently found that selection variables or criterion used to predict undergraduate training success and early aviation training performance measures may not be related or may even be inversely related to performance in the advanced operational environment [Ref. 3].

One facility which has been invaluable in providing insight into the establishment of viable performance criterion for possible use in selection tests is the Navy Air Combat Maneuvering Range (ACMR). This facility allows multiple fighter aircraft to engage in a tactical environment, allowing the simulated employment of air to air weapons as a means of providing training in tactical skills, weapon utilization and weapon envelope recognition. Several problems arise from utilizing ACMR generated criterion, however. First, the high psychological stress levels associated with actual combat may be absent, secondly, individual performance is dependent on adversary performance. Thus an independent performance assessment is difficult if not impossible. Plans are ongoing to better utilize this facility in understanding aviator skills which appear to enhance ACMR performance.

Finally, Perceptual Psychomotor Testing and Division of Attention Tests are being improved by both the U.S. and Israeli Air Force respectively. Psychomotor testing has already made a unique contribution to the USAF UPT selection program. Israeli Air Force has likewise experienced success in predicting training success in high performance jet aircraft using the Division of Attention Test[2] [Ref. 6].

We have now discussed what testing methods have been developed and exist today, and have established how important they are in developing the pilot selection program. We now suggest useful pilot selection methods for the ROKAF which hopefully will result in considerable resource savings and significant improvements in pilot quality.

---

[2]Approximately for 2,000 subjects, the data was significantly related to success in jet training.

III. AVIATOR SELECTION METHODS FOR ROKAF

Although the human resources and materials for the flight training program in the ROKAF have increased only slightly, the number of pilot candidates is increasing every year as the number of Korean Air Force Academy (KAFA) cadets increases. Since the only admission requirement to the KAFA for flight training is a medical clearance, and most pass the medical examination, the ROKAF pilot training command cannot handle the number of cadets and candidates from other sources (AFROTC and Navy). This increased number of pilot candidates has created the necessity for minimizing the number of candidates lost due to poor or unsatisfactory proficiency in the UPT program; maximizing the probability that potential failures will be screened out prior to flight training.

The present pilot selection procedures of the ROKAF do not adequately take into account candidates' mental abilities. The electrocadiogram, however, is being used for fighter pilots, and an abnormal electrocadiogram will prohibit continuation of flight training. All of the KAFA cadets who pass the medical examination enter the flight training program and have a chance to fly. Flight training starts early before graduation from the KAFA and ends about a year after graduation. This system, with flight training begining early before graduation was adapted during the 1980's. However the current system does not appear to represent a significant improvement in previous program. Cadets who fail as a cadet find it difficult to continue the program and those who fail as an officer after graduation and commissioning find it difficult to adapt to different specialties. Candidates are divided into several subgroups in order to meet the limited training squadron resources. Graduates of the subgroups enter the next phase of training with attrites returning to the KAFA. Attritions continue through the flight training - from the primary training program up to the advanced program over several years. The only way that candidates could be differentiated is on some amount of actual flying at the training squadron and the failures would be totally subjective based on instructors' feeling, knowledge and their experiences, except for voluntary withdrawal or drop on request (DOR).

The following demonstrates a useful way to help in solving the existing short comings of the current ROKAF pilot training program and suggests pilot candidate selection methods which might be used as a starting point in alleviating these problems.

A. METHODS

This section suggests selection methods for the ROKAF which are currently being used in the U.S. The purpose of the tests are to select candidates who have a high probability of completing the flight training program. Multitask performance is being used in USN and it has enjoyed considerable success in predicting flight training [Ref. 7]. The USAF uses a psychomotor screening system for selecting candidates as well as identifying whether the candidate is suited for fighter pilot training [Ref. 8]. The USAF also suggests that an integrated model including psychomotor testing and other available information - AFOQT scores, technical degree, prior flying experience, age of subjects, etc. - is better than using only the psychomotor test. All three methods use a psychomotor test since the psychomotor scores have been found to relate significantly to flight training pass/fail criteria. As the USN adapted the EEG recordings as a direct result of the Danish Air Force as we discussed in Chapter II, the ROKAF may choose one of these three methods or a combination and apply it to ROKAF cadet selection with some possible modifications. The following text describes the three methods which could be used and modified for the ROKAF and shows how the predicted results may be related to the actual outcomes.

1. Multitask Performance

The USN had great success in predicting student success in primary flight training utilizing multitask performance tests in 1986 [Ref. 7]. A Psychomotor Test (PMT) and a Dichotic Listening Task (DLT) were administered under single-task and multitask conditions separately and in combination. Testing procedures were as follows: [Ref. 7]

1) Psychomotor Test (PMT)

- **The PMT requires subjects to simultaneously center two visually presented cursors on fixed targets displayed on a CRT screen. The test performance measurements were the accumulated X, Y, and Z axis error distances between the target and the cursor point. A diagram of the experimental apparatus of Psychomotor Task (PMT) is depicted in Figure 3.1 .**

2) Dichotic Listening Task (DLT)

- **The DLT first requires subjects to attend to auditory information presented to one ear, while ignoring similar information presented to the opposite ear, and then after considering an auditory cue, to switch attention rapidly to the previously attended ear, or maintain attention to the previously attended channel. The modified Dichotic Listening task (DLT) [Ref. 9] consisted of letter-digit string sets of 24 listening trials for**

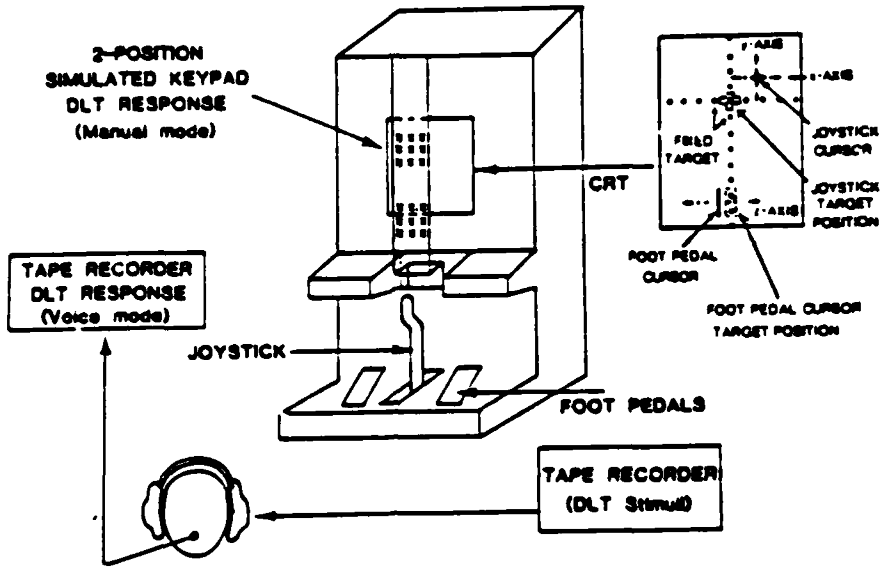


Figure 3.1 Experimental Apparatus (adapted from Ref.7).

each of 3 counter-balanced response modalities. Written, keypad and verbal response conditions were employed. The subjects were instructed to direct attention to one ear while ignoring the other, and correctly report the nine digits per trial. An example DLT trial is depicted in Figure 3.2 . The single-task performance measure for the DLT was simply the number of correct responses per 24 trials.

3) Multitask Performance

- For the multitask condition, subjects performed two sessions of the DLT and PMT simultaneously. Performance measures for the PMT and DLT in the multitask conditions were identical to those of the single-task conditions except that multitask DLT performance was based on 12 rather than 24 trials.

The tests were performed in order such as:

1) Psychomotor Test (PMT),
2) Dichotic Listening Task (DLT) and

	PART I	
Left Ear	R 8 N S M Y 2 G B 7 F L 6 R L 5	
"Right" (Vocal Channel "attend" Command)		
Right Ear	Y L 3 S R 4 F Z 9 X F 0 F N 1 L	
	PART II	
Left Ear	B F 4 3 7 9	
"Left" (Vocal Channel "attend" Command)		
Right Ear	G L 1 5 6 2	

Figure 3.2 DLT Trial Examples (adapted from Ref.7).

3) Multitask, that is, PMT and DLT simultaneously.

To validate the test criteria, subjects' flight performance were tracked until completing pilot training. Table 2 shows the mean and pass/fail correlation of each test measure. Correlations between each testing measure are presented in Table 3 . As you can see in Table 2 , testing measures 1, 5, 9, and 11 are significantly related to the flight training pass/fail criteria. Table 3 presents a correlation matrix of test measures.

2. **Psychomotor Test**

The USAF has utilized psychomotor testing in relation to pilot selection. The USAF primary objective has been an attempt to develop reliable and valid test devices and validation of test scores. In 1969, the Air Force Human Resource Laboratory (AFHRL) attempted to determine the reliability of two computer-based psychomotor tests (i.e., Two-Hand Coordination and Complex Coordination) [Ref. 8]. Both tests were employed to measure the subject's ability to coordinate movements. Subjects were from Air Force Academy (AFA), Air Force Reserve Officer Training Corps (AFROTC), and Officer Training School (OTS). The largest group of the sample was AFROTC and additional subjects from Williams AFB were used for validation of testing results.

TABLE 2

DESCRIPTIVE STATISTICS FOR SINGLE AND MULTITASK MEASURES AND SELECTION TESTS

Test Measure	Mean	(percent correct) Pass/Fail (r)
1. PMT Session 1, X,Y,Z error combined	19116.36	-.283
2. PMT Session 2, X,Y,Z error combined	11541.20	-.028
3. PMT Session 3, X,Y,Z error combined	9896.90	-.241
4. PMT Session 4, X,Y,Z error combined	9550.82	-.120
5. DLT written response, No. correct	211.48 (97.9%)	.360
6. DLT keypad response, No. correct	210.60 (97.5%)	.162
7. DLT vocal response, No. correct	207.52 (96.1%)	.244
8. PMT X,Y,Z error (with keypad DLT)	21816.92	.036
9. DLT keypad response (with PMT)	102.34 (94.8%)	.413
10. PMT X,Y,Z error (with vocal DLT)	14038.10	-.002
11. DLT vocal response (with PMT)	101.44 (93.9%)	.395
12. AQT standard score	5.66	.172
13. FAR standard score	6.80	.361

** Measure 1-7 : single-task

** Measure 8-11 : multitask

** Measure 12,13 : selection test

(From Reference 7)

Testing procedures were as follows: [Ref. 8]

1) Two-Hand Coordination

- The first of the tests presented a triangular-shaped target and a cross-shaped pipper on the CRT (Figure 3.3). The computer moved the target in an elliptical path and with varying speeds - faster near the 4 o'clock and slower near the 11 o'clock position. The, subjects were instructed to use both joysticks simultaneously (one is for up-down and the other is for left-right) in a coordinated manner to move the pipper, keeping it as close as possible to the target on the CRT. The computer measured absolute distance from the pipper to the target. The horizontal error (X_1) and

TABLE 3

CORRELATION MATRIX FOR SINGLE AND MULTITASK MEASURES AND SELECTION TESTS

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	.401											
3	.727	.544										
4	.520	.667	.838									
5	-.626	-.131	-.694	-.443								
6	-.616	-.490	-.523	-.453	.540							
7	-.494	-.182	-.407	-.325	.708	.544						
8	.393	.500	.501	.597	-.385	-.503	-.612					
9	-.708	-.244	-.782	-.508	.869	.588	.563	-.348				
10	.526	.298	.532	.443	-.531	-.468	-.669	.873	-.445			
11	-.737	-.243	-.732	-.457	.913	.540	.644	-.363	.887	-.529		
12	-.157	-.067	.060	-.021	.058	.104	.147	.048	.116	.037	.058	
13	-.368	-.239	-.223	-.287	.050	.144	.223	.254	.144	.230	.099	.511

** See Table 2 for description of numbered variables.

(From Reference 7)

vertical error (Y_1) measurement were accumulated during 5-min test period.

2) Complex Coordination

- The second test presented a set of cross-hairs centered on the CRT, a dot-shaped pipper, and a thin vertical bar at the bottom of the CRT (Figure 3.4). The subject controlled the pipper, both horizontally and vertically, using the floor-mounted joystick. The control responses were the reverse of what is traditionally required on aircraft to reduce the advantage of a subject with prior flying experience. The subjects were instructed to use the joystick to center the pipper horizontally and vertically on the intersection of the cross-hairs and simultaneously press the appropriate rudder-style pedal to center the "rudder bar" over the lower part of the vertical cross-hair. The computer measured in inches and accumulated during 5-min test period the the absolute distance from the pipper to the

PSYCHOMOTOR TEST I

LEFT — RIGHT HAND COORDINATION
(10 minutes)

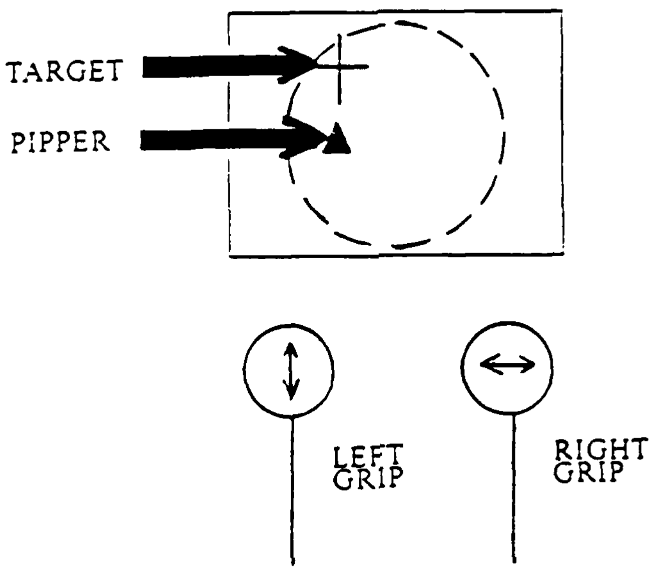


Figure 3.3 Two-Hand Coordination Test Depiction (adapted from Ref.7).

intersection of the cross-hairs and from the rudder bar to the vertical cross-hair. The three scores obtained from this test were the cumulative horizontal error (X_2), vertical error (Y_2), and horizontal error for rudder bar (Z_2).

Table 4 presents five error scores (X_1, Y_1, X_2, Y_2, Z_2) for each subject. These data show that the Two-Hand Coordination test was more difficult than the Complex Coordination. There might also be some common information about the subjects since all five test scores measured psychomotor ability. Table 5 shows intercorrelations across the tests. Two psychomotor tests were measuring different abilities with very little in common between the tests as indicated in Table 5 . To validate the psychomotor testing scores, the mean scores of UPT graduates and eliminees were compared following completion of flight training. Table 6 presents the

PSYCHOMOTOR TEST II

STICK & RUDDER SKILLS
(10 minutes)

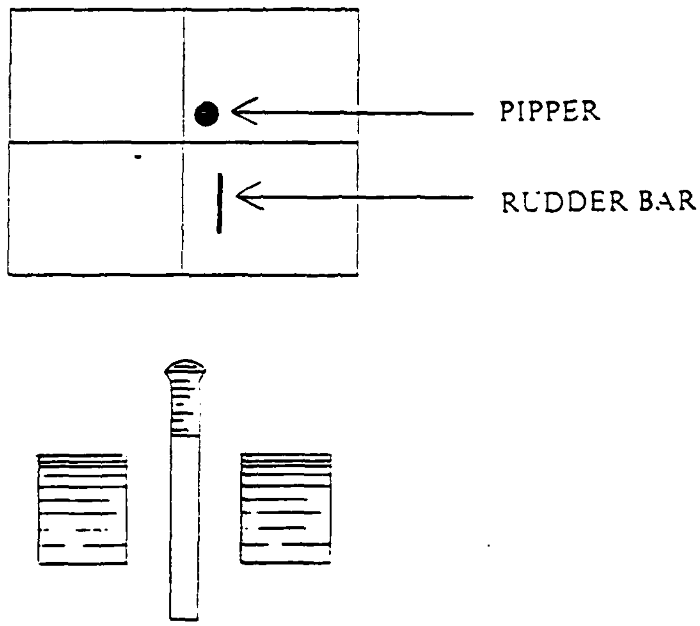


Figure 3.4 Complex Coordination Test Depiction (adapted from Ref.7).

mean of the psychomotor scores among three categories: UPT graduates, all UPT eliminees, and UPT flying deficiency eliminees. All five scores had significant differences between graduates and either category of eliminees. Note that for all three of the Complex scores (X_2, Y_2, and Z_2) were significantly worse than the graduates' means. These results were used to identify subjects more likely to be fighter pilots. Figure 3.5 presents this result of all five means for both fighter-recommended (FR) and non-FR students. The FR students had significantly better scores than the non-FR students. The psychomotor screening equation was finally developed and the most useful screening score based on psychomotor ability can be computed from the following equation [Ref. 8]:

TABLE 4
DESCRIPTIVE STATISTICS

(inch)

Test Score	Mean	SD	Range
Two-Hand Coordination			
X1 (Horizon)	14,709	5,400	428 - 65,268
Y1 (Vertical)	16,748	5,538	5,687 - 57,292
Complex Coordination			
X2 (Horizon)	4,514	6,520	326 - 71,040
Y2 (Vertical)	3,860	6,445	486 - 76,320
Z2 (Rudder)	5,580	6,018	167 - 71,040

(From Reference 8)

TABLE 5
CORRELATION MATRIX

	X_1	Y_1	X_2	Y_2
X1 (Horizon)				
Y1 (Vertical)	.87			
X2 (Horizon)	.20	.25		
Y2 (Vertical)	.19	.23	.86	
Z2 (Rudder)	.20	.24	.77	.71

(From Reference 8)

$$Y_i = a + (b_1 \times X1_i) + (b_2 \times Y2_i)$$

where Y_i = psychomotor screening score of *i*th subject
a = constant (0.95648)

TABLE 6

MEAN PSYCHOMOTOR SCORES BY UPT OUTCOME

	X_1	Y_1	X_2	Y_2	Z_2
Graduate Means (N = 1,348)	14,315	16,341	3,559	2,058	4,725
All Elim. Means (N = 377)	15,829	17,621	4,936	4,173	6,678
Flying Deficiency (FD) Elim. Means (N = 199)	16,302	18,007	5,593	4,702	7,580

(From Reference 8)

b_1 = weight of psychomotor X1 score (-.0000075748)

b_2 = weight of psychomotor Y2 score (-.000020375)

$X1_i$ = psychomotor X_1 score of *i*th subject

$Y2_i$ = psychomotor Y_2 score of *i*th subject

This equation provides a screening score based on psychomotor ability. These scores could be used in a selection system by rank ordering; and the best candidates could be selected to fill the required training quotas.

3. **Integrated Selection System**

Although psychomotor testing scores are significantly related to pass/fail criteria in UPT, the ideal pilot selection method would consider all available informations on the subjects.

Current operational USAF pilot selection criteria consider information from the five composite scores of the AFOQT, age at the start of UPT, possession of a college technical degree, and possession of a private pilot's license or completion of a USAF light aircraft flying program [Ref. 8]. Table 7 lists the correlations of all available measures with the UPT pass/fail criterion for all reasons (FY79 to FY83).

The integrated model was developed based on the USAF psychomotor testing. Because pilot candidates are chosen differently, depending on their source of commission, three different Integrated Pilot Candidate Selection Models (IPCSMs) were developed.

The three IPCSMs equations were developed and will produce a score corresponding to the probability of UPT success using the following equations :

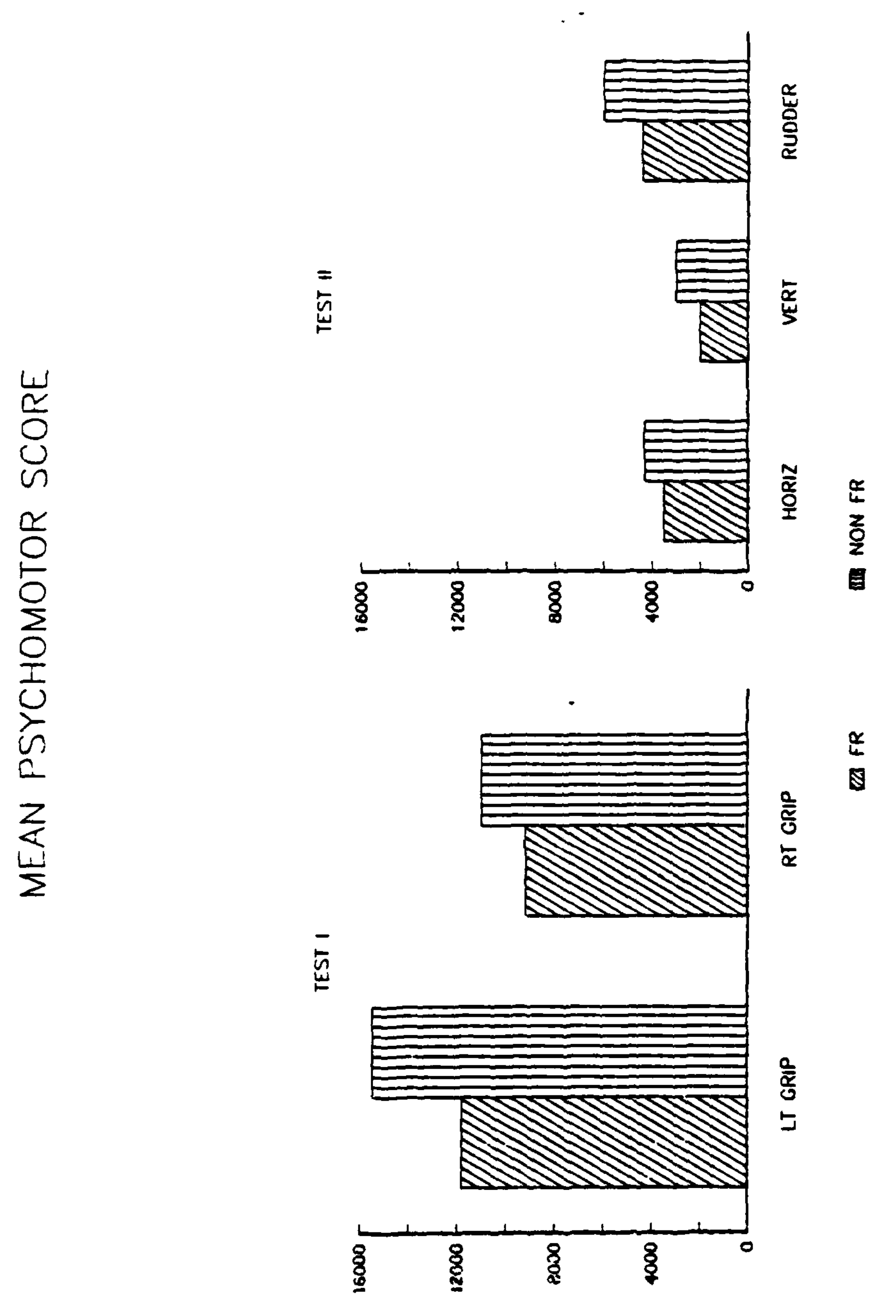


Figure 3.5 Mean Psychomotor Scores by FR/non-FR.

TABLE 7

CORRELATIONS OF IPCSM PREDICTIONS WITH UPT OUTCOME

Predictors	Correlation with UPT Pass/Fail	Sample Sizes
FSP Pass/Fail	.137	1,534
FSP Final Grade	.271	1,534
FSP Sum of Grades	.303	1,534
AFOQT Pilot Score	.158	4,460
AFOQT Navigator Tech Score	.148	4,460
AFOQT Academic Score	.080	4,577
AFOQT Verbal Score	.007	4,576
AFOQT Quantitative Score	.138	4,577
Psychomotor X1 Score	-.118	1,918
Psychomotor Y1 Score	-.099	1,919
Psychomotor X2 Score	-.153	1,906
Psychomotor Y2 Score	-.181	1,910
Psychomotor Z2 Score	-.146	1,916
Age	-.120	8,438
Gender	.033	8,438
Race	.110	8,292
Possession of Tech Degree	.111	8,183

(From Reference 8)

1) IPCSM I (OTS Model)

$$
\begin{aligned}
Y_i = a \; &+ (b_1 \times X1_i) + (b_2 \times Y2_i) + (b_3 \times age_i) \\
&+ (b_4 \times AFOQTP_i) + (b_5 \times AFOQTN_i) \\
&+ (b_6 \times FSP1_i) + (b_7 \times FSP2_i)
\end{aligned}
$$

where Y_i = IPCSM I score for *i*th subject

a = constant (0.10192)

b_1 = weight for psychomotor X1 score (-.000015211)

b_2	=	weight for psychomotor Y2 score (-.000010618)
b_3	=	weight for age of subject (-.0012)
b_4	=	weight for AFOQTP/AFOQT pilot score (0.00112)
b_5	=	weight for AFOQTN/AFOQT navigator score (0.00029067)
b_6	=	weight for FSP1/FSP final grade (0.08249)
b_7	=	weight for FSP2/FSP sum of grades (0.01923)
$X1_i$	=	psychomotor X1 score of *i*th subject
$Y2_i$	=	psychomotor Y2 score of *i*th subject
age_i	=	age at start of UPT of *i*th subject
$AFOQTP_i$	=	AFOQT pilot composite score of *i*th subject
$AFOQTN_i$	=	AFOQT navigator composite score of *i*th subject
$FSP1_i$	=	FSP final grade of *i*th subject
$FSP2_i$	=	FSP sum of grade of *i*th subject

2) IPCSM II (AFROTC Model)

$$Y_i = a + (b_1 \times X1_i) + (b_2 \times Y2_i) + (b_3 \times age_i) + (b_4 \times AFOQTP_i) + (b_5 \times AFOQTN_i)$$

where	Y_i	=	IPCSM II score for *i*th subject
	a	=	constant (1.72485)
	b_1	=	weight for psychomotor X1 score (-.0000030409)
	b_2	=	weight for psychomotor Y2 score (-.000022526)
	b_3	=	weight for age of subject (-.04517)
	b_4	=	weight for AFOQTP/AFOQT pilot score (0.00124)
	b_5	=	weight for AFOQTN/AFOQT navigator score (0.00225)

3) IPCSM III (AFA Model)

$$Y_i = a + (b_1 \times X1_i) + (b_2 \times Y2_i) + (b_3 \times age_i) + (b_4 \times tech_i)$$

where	Y_i	=	IPCSM III score of *i*th subject
	a	=	constant (1.43056)
	b_1	=	weight for psychomotor X1 score (-.0000050818)
	b_2	=	weight for psychomotor Y2 score (-.0000072309)
	b_3	=	weight for age of subject (-.02111)
	b_4	=	weight for possession of technical degree (.08756)
	$tech_i$	=	1 if *i*th subject has a technical degree, 0 otherwise

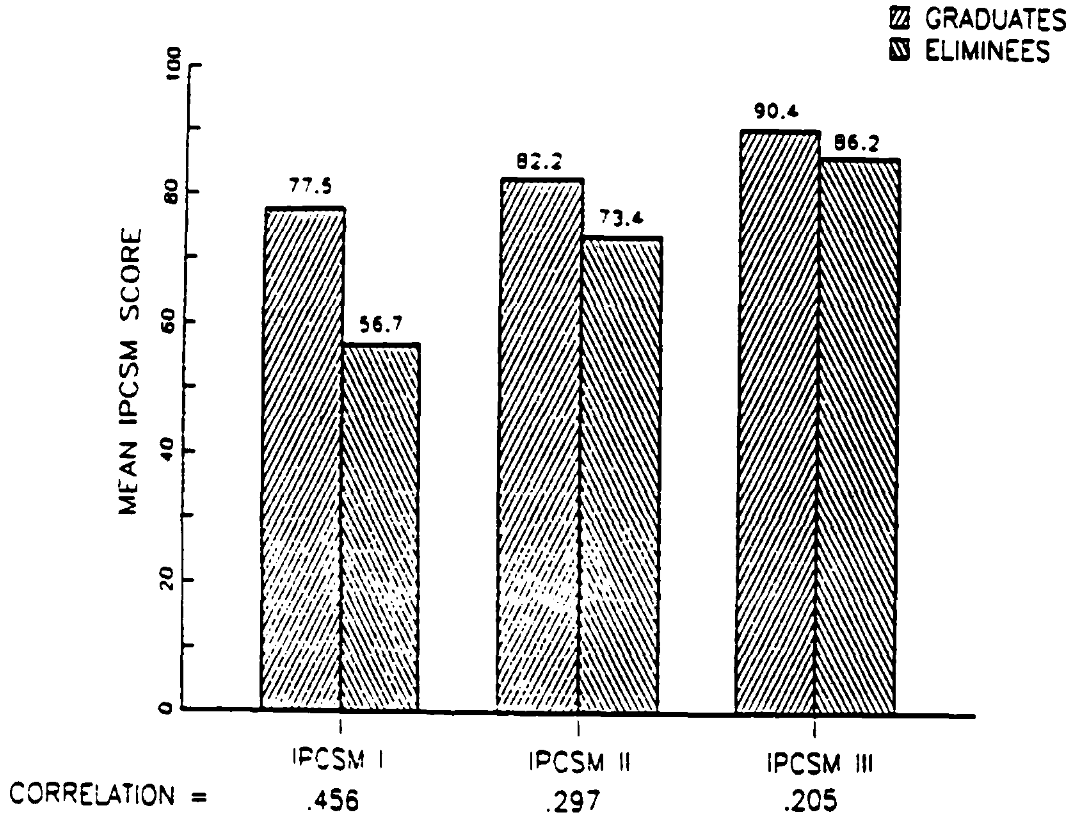


Figure 3.6 Mean IPCSM Scores by UPT outcome.

The mean of the IPCSM scores are graphically presented in Figure 3.6 . The differences between the means were significant and generated the better prediction than using the psychomotor test only. One way to select candidates is to accept only those candidates who obtain a screening score above a predetermined cutoff. The cutoff score would be determined by the quota required and attrition rate. The higher the cutoff score is set, the greater the impact on attrition in pilot training program. The FY83 UPT sample was used to cross-validate the three IPCSMs and resulted in the IPCSM scores were significantly correlated with UPT outcome. Since the "Whole Person Concept" is imbedded in this multi-dimensional IPCSM approach to pilot selection, the integrated selection method has better predictors than the psychomotor test only does.

As we can see through the Chapter, all three pilot selection methods include a psychomotor testing which means psychomotor testing scores are significantly different between the successes and the failures. It should have the same result if psychomotor tests were applied to ROKAF. The only thing different between U.S. and ROKAF would be the cutoff score as a different required quota. The ROKAF decision maker, however, must know the advantages of using an experimental testing method in terms of their utilities or cost effectiveness. Chapter IV provides one way to make a decision and evaluate the outcomes.

IV. EVALUATION OF TESTING METHOD

This chapter discusses how to make appropriate decisions which maximize an overall Measure of Effectiveness (MOE) or Utility which might be used in a pilot selection program. The final goal of personnel selection programs has traditionally been to achieve maximum accuracy of measurement and efficiency of prediction. Decision theory recognizes that the outcomes of predictions are of primary importance to individuals and organizations. As discussed in Chapter III, for example, Korean AFA cadets are commissioned as officers after four years of attendance. Some fail either in undergraduate or operational flight training. This results in high attrition cost, dissatisfaction, lowered morale, and a number of officers totally unneeded in the service. Since the measurement and prediction are simply technical components of a system designed to make decisions, we have to define the MOE before making any decisions. There are, however, a number of possible MOEs in most decision problems. For example, there would be three possible MOEs in a pilot selection problem:

1) Costs - selection, attrition and training,
2) Pilot quality, and
3) Probability that the quota will be satisfied.

Thus decision outcomes should be evaluated in terms of their consequences for individuals and organizations. That is, in terms of their overall MOE or Utility. This provides us with a consistent way in which to combine different figures of merit or subjective and judgemental factors, and probabilistic aspects of outcomes into an overall MOE.

To construct and evaluate a decision model, we have to find parameters which function in pilot selection outcomes. The major factors are [Ref. 10]:

a) the base rate (the proportion of persons currently accepted who are satisfactory)
b) the selection ratio (the proportion of applicants accepted) and
c) the validity coefficient (the predictor criterion correlation).

Taylor and Russell [Ref. 10] published a series of tables which illustrated that the value of a test was a function of the three considerations listed above.

A. BASE RATE (BR)

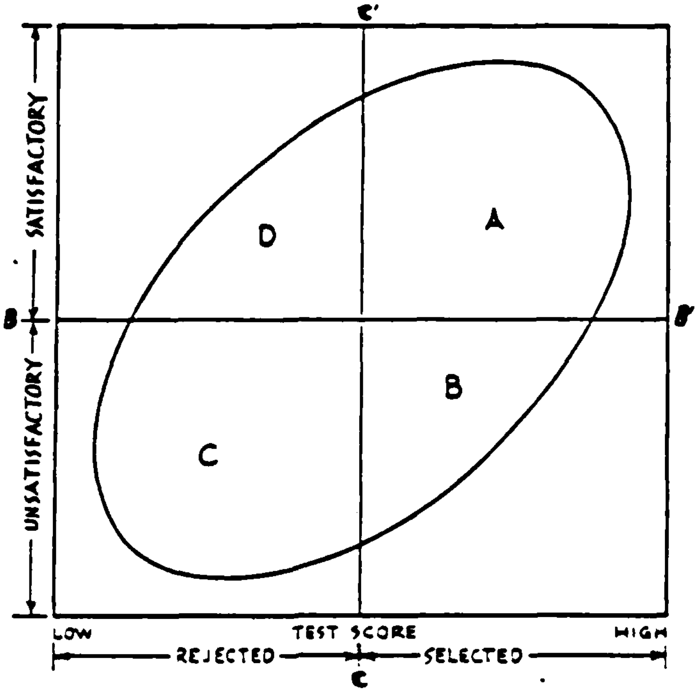


Figure 4.1 Four possible outcomes of personnel selection (adapted from Ref.11).

The possible outcomes of personnel selection programs are illustrated in Figure 4.1 . This figure depicts a bivariate plot for a selection test with a validity of .50. The horizontal axis, BB′, represents a particular base rate of satisfactory criterion performance, in this case, 50 %. The vertical axis, CC′, denotes the cutting score for a 50 % selection ratio. Thus, Quadrant A contains a number of satisfactory subjects above the cutting score (valid positives, VP), Quadrant B contains unsatisfactory subjects above the cutting score (false positives, FP), Quadrant C contains unsatisfactory subjects below the cutting score (valid negatives, VN), and Quadrant D contains satisfactory subjects below the cutting score (false negatives, FN). [Ref. 11] Once the cutoff score is set, a definite number of predictions of success and failure are made. As Figure 4.1 shows, the total number of predictive positives, N_{pp}, may be calculated from :

$$N_{pp} = VP + FP$$

Similarly, the total number of predictive negatives, N_{pn}, is given by:

$$N_{pn} = FN + VN$$

The total number of actual positives, N_{ap}, is given by:

$$N_{ap} = FN + VP$$

And the total number of actual negatives, N_{an}, is calculated by:

$$N_{an} = VN + FP$$

The probability of a valid positives, P(VP), is thus:

$$P(VP) = VP/(N_{ap} + N_{an}) = VP/TN$$

where TN is the total number of candidates. Figure 4.2 presents the probabilities and their relationships.

When outcomes are expressed as probabilities they are referred to as "hit rates". The probabilities or proportions of actual positives that exist in the total sample of candidates is called the "Base Rate" (BR).[3] The probability may be calculated directly $BR = N_{ap}/TN$ or from the probabilities of two outcomes $BR = P(FN) + P(VP)$ as in Figure 4.2 . The BR has reference to the base rate of the positive class and so the probability or base rate of negative in the total sample is given : $1 - BR$.

Selection measures are most useful when BRs are about .50 [Ref. 10]. As the BR departs radically in either direction from .50, the benefit of an additional predictor becomes questionable.

[3]The proportion of candidates who would be *successful* in flight training without use of the test.

Actual Diagnosis	Test Diagnosis: Positive	Test Diagnosis: Negative	Total
Positive	$P(VP) = VP/TN$ valid positive rate (Proportion of positives called positive)	$P(FN) = FN/TN$ false negative rate (Proportion of positives called negative)	$BR = N_{ap}/TN$ Base Rate (Probability of actual positives)
Negative	$P(FP) = FP/TN$ false positive rate (Proportion of negatives called positive)	$P(VN) = VN/TN$ valid negative rate (Proportion of negatives called negative)	$1 - BR = N_{an}/TN$ (Probability of actual negatives)
Total	$SR = N_{pp}/(N_{pp} + N_{pn})$ Selection Ratio (Probability of predicted positives)	$1 - SR = N_{pn}/(N_{pp} + N_{pn})$ (Probability of predicted negatives)	

Figure 4.2 Outcomes Expressed as Probabilities.

B. SELECTION RATIO (SR)

The probability or proportion of predicted positives among the total sample of candidates is called the "Selection Ratio" (SR).[4] This probability may be calculated directly as follows:

$$SR = N_{pp}/(N_{pp} + N_{pn})$$

[4]The proportion of candidates selected with the use of test.

or from the probabilities of two outcomes such that .

$$SR = P(VP) + P(FP)$$

Whenever a quota exists on the total number of candidates that may be accepted, the selection rate becomes more important. As the SR approaches 1.0, for example, which means all candidates must be selected, it will be dominated by other alternatives and as the SR approaches zero, it dominates all other alternatives which means a decision maker can afford to be selective. Cronbach and Glesser [Ref. 12] have shown that when the frequency distributions of the two groups (accept/reject) are plotted separately along the same base line, the optimum cutting score for distinguishing between the two groups will occur at that point where the two distributions intersect. However, in most practical selection situations, the decision maker is not free to vary selection ratios.

C. VALIDITY COEFFICIENT

Evaluating the benefit obtained from tests is of considerable practical interest and has been a problem in industrial psychology. The relation of benefit to validity has long been regarded as an important question. Most attempts to evaluate benefits have focused on the validity coefficient. As at least five formulas for interpreting the validity coefficient have been given, we face the problem of choosing between them or of modifying them. [Ref. 12]

The validity coefficient is usually defined as the correlation of test score with outcome or criterion score. We shall use r_{xy} in our discussion because the decision maker is interested in predicting the ***evaluated outcome***, that is, the outcome expressed in utility units. The rule having the longest history translates the validity coefficient r_{xy} into the "index of forecasting efficiency" [Ref. 12],

$$E = \sqrt{1 - (1 - r^2_{xy})} = | r_{xy} |$$

Although the validity coefficient r_{xy} is a useful index, there are many ways in which it falls short of accurately predicting success. From a practical point of view, the number of correct decisions made by a psychological test or assessment is more important than the degree of association which exists between predicted and obtained scores [Ref. 12]. When two variables are expressed in dichotomous form (success-failure, select-reject) as in Figure 4.1 , the correlation between them is given by the point-biserial "r_p coefficient". A simplified computational formula for the r_p coefficient is: [Ref. 13]

$$r_p = \frac{P(VP) - BR \times SR}{[\, BR(1 - BR)SR(1 - SR)\,]^{1/2}}$$

The value of r_p is computed knowing only three values:

1) The probability of a valid positive, P(VP),
2) The base rate, BR, and
3) The selection ratio, SR.

The computational formula for the r_p coefficient can be solved for the probability of valid positives:

$$P(VP) = BR \times SR + r_p\sqrt{BR(1 - BR)SR(1 - SR)}$$

This expression is especially useful in evaluating the outcomes of test prediction. Given the validity of a test r_p, the base rate, BR, and the proportion of candidates to be selected, SR, it is possible to completely specify the outcomes of predictions.

Taylor and Russell [Ref. 14] denounced the practice of evaluating the effectiveness of predictor variables solely on the basis of their validity coefficients. They prepared tables for determining the effectiveness of a selection test by estimating the proportion of selectees that are considered satisfactory when the test validity, base rate, and selection ratio are known or assumed.

D. DECISION STRATEGIES

There are mainly two different decision strategies which are single-stage (nonsequential) and multi-stage (sequential) [Ref. 12]. The major difference between these two strategies is when the terminal decision is made. The general decision process is illustrated schematically in Figure 4.3 .

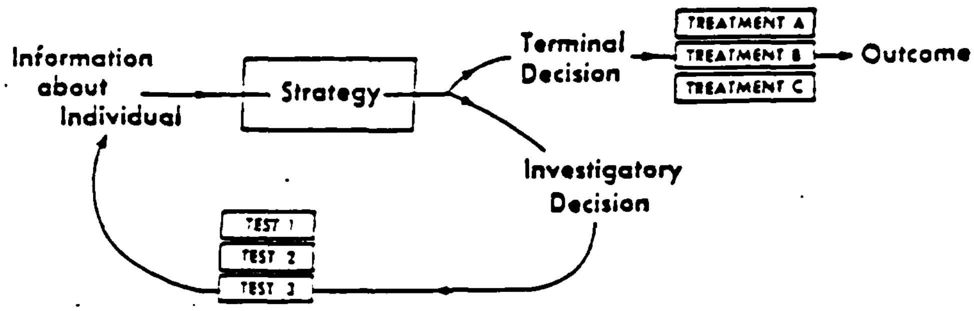


Figure 4.3 Schematic View of a Decision Process (adapted from Ref.12).

1. **Single-Stage Strategy**

A test or test battery is employed to all candidates. Based on a predetermined cutting score, the terminal decision is made. Individuals are either selected or rejected and no further decisions are made. This strategy corresponds to selecting candidates randomly or by a medical examination only in pilot selection.

2. **Multi-Stage Strategy**

Terminal decisions are made only from the view point of a decision maker in multi-stage strategy. The cutting score on a test battery may be used to make investigatory decisions. This decision calls for additional information, dictating what test or procedure will be used to gather that information. This then leads to a further decision. The investigatory decisions may continue through a number of stages of subsequent testing until terminal decisions are made regarding all applicants. This type of decision process is used to select pilot candidates using one or more experimental testing method until a decision maker is satisfying.

E. THE EXPECTED UTILITIES (EU)

As discussed at the beginning of this Chapter, utility provides a consistent way to compare each different selection method. The comparison would be accomplished by expected utility, i.e., maximizes the expected utility across the possible outcomes. If the four possible outcomes such that valid positive, false positive, valid negative and false negative have utility U_{vp}, U_{fp}, U_{vn} and U_{fn} respectively, then the expected utility can be described generally:

$$EU = U_{vp} \times P(VP) + U_{fp} \times P(FP) + U_{vn} \times P(VN) + U_{fn} \times P(FN) - U_T$$

where U_T is the utility of testing method employed. Under different decision strategies, the expected utility should be considered separately so that we can figure out which decision strategy is better with which testing method such that expected utility for all possible outcomes can be maximized.

A number of different decision strategies can result from combining different testing procedures. In the ROKAF selection problem, consideration in given to two simple decision strategies, i.e., single-stage decision with random or medical examination, or double-stage decision with medical and one experimental test. This is based on the assumption that ROKAF has only two alternatives.

1. Single-Stage Decision with Random Selection

If the Korean Air Force uses a random selection process, providing that the SR, BR, number of applicants N, then the expected utility is going to be:

$$EU = U_{vp} \times P(VP) + U_{fp} \times P(FP) + U_{vn} \times P(VN) + U_{fn} \times P(FN)$$

where $P(VP) = BR \times SR$ since $r_p = 0$

$P(FP) = SR - P(VP)$

$P(FN) = BR - P(VP)$

$P(VN) = (1 - BR) - P(FP) = (1 - SR) - P(FN)$ and

$U_T = 0$ since no testing employed.

Whenever the ROKAF has data available this calculation gives the ROKAF a consistent way to compare alternatives with their utilities. For the present effort, it is possible to simulate ROKAF data and evaluate the results. Suppose ROKAF data is as follows:

- SR = .6, BR = .5, N = 500,
- utility of valid positive, in dollar, U_{vp} = $80,000,
- utility of false positive, U_{fp} = - $80,000,
- utility of valid negative, U_{vn} = $50,000,
- utility of false negative, U_{fn} = 0,

Now we can compute the expected utility of a random selection process when the ROKAF uses random selection of KAFA cadets;

$$P(VP) = BR \times SR = .5 \times .6 = .3$$
$$P(FP) = SR - P(VP) = .6 - .3 = .3$$
$$P(FN) = BR - P(VP) = .5 - .3 = .2$$
$$P(VN) = (1 - SR) - P(FN) = (1 - .6) - .2 = .2$$

then

$$EU = 80{,}000 \times .3 - 80{,}000 \times .3 + 50{,}000 \times .2 + 0 \times .2$$
$$= \$10{,}000 \text{ per candidate}$$

2. Single-Stage Decision with Medical Examination

When a medical examination is employed the probability of valid positive becomes:

$$P(VP) = PS \times SR$$

where PS is proportion of satisfactory candidates among those selected by a test. Taylor and Russell developed a table for this PS value and Appendix C provides these values as different BR and SR which is similar to Taylor and Russell tables but more appropriate for point-biserial correlation, r_p, by Abrahams, Alf and Wolfe [Ref. 10]. If r_p is .25, then the PS = .582 with SR = .6, BR = .5 at Table given in Appendix C.

Assuming the utility of medical examination is $50 then the expected utility becomes:

$$P(VP) = PS \times SR = .582 \times .6 = .3492$$
$$P(FP) = SR - P(VP) = .6 - .3492 = .2508$$
$$P(FN) = BR - P(VP) = .5 - .3492 = .1746$$

$$P(VN) = (1 - SR) - P(FN) = (1 - .6) - .1746 = .2254$$

thus,

$$EU = 80{,}000 \times .3492 - 80{,}000 \times .2508 + 50{,}000 \times .2254 - 50$$
$$= \$19{,}092 \text{ per candidate}$$

which is more than the previous random selection with the amount of $9,092 utility using only a medical examination. This result indicates that selection via the medical examination is more effective than random selection. In other words, the medical examination increases a certain amount of utility of possible personnel selection outcomes.

3. **Double-Stage Decision with Medical and an Experimental Test**

Since the terminal decision is made via medical and experimental test decisions, it is reasonable to select enough candidates at the first decision so as to meet the required quota at the second decision. In the second decision, the terminal decision is made concerning the provisionally accepted applicants on the basis of the first test. If we assume that SR = .7 in this case and $r_p = .8$ from the table with the same BR then the value of PS equals .709. With the utility of the experimental test equal to $80, the calculation of the expected utility is, therefore, as follows:

$$P(VP) = PS \times SR = .709 \times .7 = .4963$$
$$P(FP) = SR - P(VP) = .7 - .4963 = .2037$$
$$P(FN) = BR - P(VP) = .5 - .4963 = .0037$$
$$P(VN) = (1 - SR) - P(FN) = (1 - .7) - .0037 = .2963$$

then

$$EU = 80{,}000 \times .4963 - 80{,}000 \times .2037 + 50{,}000 \times .2963 - 50 - 80$$
$$= \$38{,}093 \text{ per candidate}$$

which is more than three times the random selection utility and more than $19,000 utility per candidate via medical test only. This result shows that if the ROKAF changes the present pilot selection method and uses an experimental test method with medical examination, the increased expected utility of that change is about $19,000 per candidate even if using small scale simulated data.

In other words, the potential advantages in changing the present ROKAF pilot selection system are obviously considerable.

F. CAPER MODEL EVALUATION

To this point decision strategies have been discussed in terms of their utilities and advantages. Managers of personnel systems, however, justifiablely demand an estimate of the payoff, in dollars, which can be expected to result from the implementation of a proposed selection program. It might appear that, for a given test validity and base rate, a personnel manager always should lower the selection ratio (i.e, become more selective) this strategy may or may not be cost effective since lowering selection ratio causes expanding recruit and selection efforts to meet the required quota.

The purpose of this section is again to evaluate whether the changes are still feasible in terms of cost-effectiveness by using the Cost of Attaining Personnel Requirements (CAPER) model. Sands [Ref. 11] defined the CAPER model as follows:

- "The CAPER model is designed to evaluate the cost consequences of alternative recruiting-selection strategies. Specifically, the CAPER model determines an optimal recruiting-selection strategy for minimizing the estimated total cost of recruiting, selecting, inducting, and training a sufficient number of persons to meet a specified quota of satisfactory personnel. In addition, the CAPER model considers the cost of an erroneous acceptance (selecting a person for a training program who subsequently fails to graduate) and the cost of erroneous rejection (rejecting a person who would have succeeded if given the opportunity)."

Suppose that the ROKAF General Staff provides specific information for pilot selection policy such that the quota, the base rate and cost data for selection, recruiting, induction, training, erroneous acceptance and rejections, etc. Example of input data for the ROKAF is provided in Table 8 [Ref. 13] and shows that 500 of 1,000 persons graduated, indicating a .500 base rate. Suppose the data was given as follows:

- the cost of recruiting an individual is $4,000,
- the cost of the present selection procedure (medical examination) is $150 including the physicians' salaries and laboratory fees,
- the cost of administering and scoring the experimental test is $100,
- the induction cost per individual is estimated as $150,
- the cost for training is $3,500,
- the cost of erroneous acceptance is set at $1,000, and
- the cost of erroneous rejection is estimated as $800.

TABLE 8
EXAMPLE CAPER MODEL INPUT DATA FOR ROKAF

Cuting	Graduates			Failures		
	Qualified for Acceptance			Qualified for Acceptance		
Score	Frequency	Number	Proportion	Frequency	Number	Proportion
0	0	500	1.000	0	500	1.000
1	0	500	1.000	7	500	1.000
2	0	500	1.000	10	493	.986
3	0	500	1.000	17	483	.966
4	2	500	1.000	29	466	.932
5	6	498	.996	45	437	.874
6	11	492	.984	58	392	.784
7	21	481	.962	68	334	.668
8	36	460	.920	72	266	.532
9	52	424	.848	66	194	.388
10	66	372	.744	52	128	.256
11	72	306	.612	36	76	.152
12	68	234	.468	21	40	.080
13	58	166	.332	11	19	.038
14	45	108	.216	6	8	.016
15	29	63	.126	2	2	.004
16	17	34	.068	0	0	.000
17	10	17	.034	0	0	.000
18	7	7	.014	0	0	.000

Given the simulated data, the ROKAF can plug into the CAPER model the equations and compute costs the present ROKAF selection process and the new selection process. The set of equations is used once for each possible cutting score on the new selection process. A cutting score of eight on the test will be used for illustration.

Equation (1) gives the formula for estimating the number of applicants who must be recruited in order to meet the quota :

$$NR = Q / [(BR)(PG_i)] \qquad BR > 0, PG_i > 0 \tag{1}$$

where NR is the number recruited,

Q is the quota of satisfactory personnel,

BR is the base rate, and

PG_i is the proportion of graduates who would qualify for acceptance at the *i*th cutting score on the test.

Substituting the data of the present ROKAF selection procedure into Equation (1) gives:

$$NR_p = 50 / [(0.50)(1.00)] = 100$$

Similarly, for the experimental selection procedure ($i = 8$):

$$NR_e = 50 / [(0.50)(0.92)] = 109$$

Equation (2) gives the formula for estimating the number of erroneous acceptances :

$$NEA = NR(1 - BR)PF_i \tag{2}$$

where NEA is the number of erroneous acceptances,

PF_i is the proportion of failures who would qualify for acceptance at the *i*th cutting score on the test, and the remaining symbols are defined above.

Substituting the data of the present ROKAF selection procedure into Equation (2) gives:

$$NEA_p = (100)(1 - 0.50)(1.00) = 50$$

Similarly, for the experimental selection procedure ($i = 8$):

$$NEA_e = (109)(1 - 0.50)(0.532) = 29$$

Equation (3) gives the formula for estimating the number of erroneous rejections:

$$NER = (NR)(BR)(1 - PG_i) \quad (3)$$

where NER is the number of erroneous rejections, and the remaining symbols are defined above.

Substituting the data of the present ROKAF selection procedure into Equation (3) gives:

$$NER_p = (100)(0.50)(1 - 1.00) = 0$$

Similarly, for the experimental selection procedure ($i = 8$):

$$NER_e = (109)(0.50)(1 - 0.92) = 4$$

Equation (4) gives the formula for estimating the number of persons who will accepted :

$$NA = Q + NEA \quad (4)$$

where NA is the number accepted and the others are the same as above.

Substituting the data of the present ROKAF selection procedure into Equation (4) gives:

$$NA_p = 50 + 50 = 100$$

Similarly, for the experimental selection procedure ($i = 8$):

$$NA_e = 50 + 29 = 79$$

The total cost of the present selection procedure and the experimental selection procedure should be calculated by separate equation.

Equation (5a) gives the formula for estimating the total cost of employing the present selection procedure to meet the quota of satisfactory personnel :

$$\begin{aligned} TC_p = {} & [(NR)(CR)] + [(NR)(CP)] + [(NA)(CI)] \\ & + [(NA)(CT)] + [(NEA)(CEA) + (NER)(CER)] \end{aligned} \qquad (5a)$$

where TC_p is the total cost of using the present selection procedure to meet the quota.

CR is the cost of recruiting a person,

CP is the cost of administering the present procedure,

CI is the cost of inducting a person,

CT is the cost of training a person,

CEA is the cost of an erroneous acceptance,

CER is the cost of an erroneous rejection, and the others are the same as above.

Substituting the data of the present ROKAF selection procedure into Equation (5a) gives:

$$\begin{aligned} TC_p & = [(100)(\$4000)] + [(100)(\$1500)] + [(100)(\$100)] \\ & \quad + [(100)(\$35000)] + [(50)(\$8000) + (0)(\$1500)] \\ & = \$3,619,120 \end{aligned}$$

Equation (5b) gives the formula for estimating the total cost of employing the experimental selection procedure to meet the quota :

$$\begin{aligned} TC_e = {} & [(NR)(CR)] + [(NR)(CP)] + [(NR)(CE)] + [(NA)(CI)] \\ & + [(NA)(CT)] + [(NEA)(CEA) + (NER)(CER)] \end{aligned} \qquad (5b)$$

where TC_e is the total cost of using the experimental selection procedure to meet the quota, CE is the cost of administering the experimental procedure, and the others are the same as above.

Using Equation (5b) for the experimental selection procedure ($i = 8$) gives:

$$TC_e = [(109)(\$4000)] + [(109)(\$1500)] + [(109)(\$80)] + [(79)(\$100)] + [(79)(\$35000)] + [(29)(\$8000) + (4)(\$1500)] = \$751,920$$

A useful program for various data values is provided in Appendix B and creates a sample CAPER model output data for ROKAF in Table 9 for the different values. This output contains five types of information :

1) number recruited,
2) number of erroneous acceptance,
3) number of erroneous rejections,
4) number accepted,
5) total cost.

These five estimates may suffice for many personnel program managers. And also contains cost for each of the following:

1) recruiting
2) selection
3) induction
4) training, and
5) erroneous decisions.

Table 9 shows that as the cutting score increases the subsequent results are as follows :

1) a greater number of persons must be recruited,
2) a smaller number of persons is accepted,
3) the number of erroneous acceptances decreases, and
4) there is an increase in erroneous rejections.

These four consequences have cost complications. As recruiting and selection costs increase, induction and training costs are decreased. The cost of erroneous acceptances and erroneous rejections, decreases at first, hits the cutting score that minimizes the sum of both costs ($i = 11$) and then increases as the cutting score is raised farther and the total cost changes similarly. Figure 4.4 graphically shows this changes of total cost as increasing the cutoff scores.

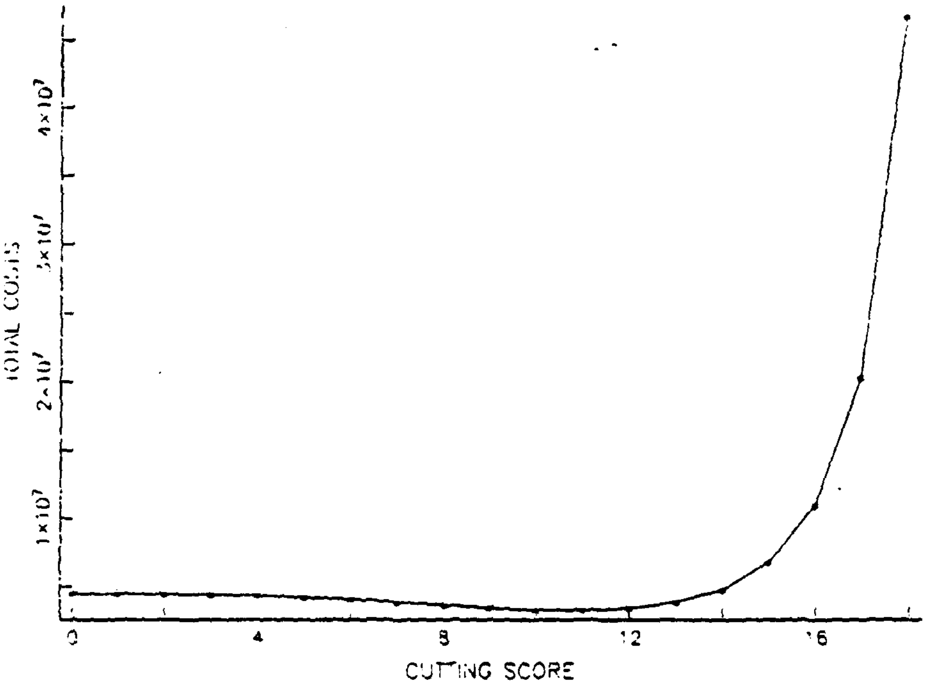
If the ROKAF wants to achieve 50 graduates at a minimum total cost, comparing the estimated total cost of the present selection procedure (\$4,460,000) in

TABLE 9
EXAMPLE OF CAPER MODEL OUTPUT DATA OF ROKAF

CUT SCORE	NO REC	NO ACC.	NO ERR. ACC.	NO ERR. REJ.	COST RECRUIT	SELECT	INDUCT	TRAINING	ERR.DEC.	TOTAL
NA	100	100	50	0	400000.	150000.	10000.	3500000.	400000.	4460000.
0	100	100	50	0	400000.	158000.	10000.	3500000.	400000.	4468000.
1	100	100	50	0	400000.	158000.	10000.	3500000.	400000.	4468000.
2	100	99	49	0	400000.	158000.	9900.	3465000.	392000.	4424900.
3	100	98	48	0	400000.	158000.	9800.	3430000.	384000.	4381800.
4	100	97	47	0	400000.	158000.	9700.	3395000.	376000.	4338700.
5	100	94	44	0	400000.	158000.	9400.	3290000.	352000.	4209400.
6	102	90	40	1	408000.	161160.	9000.	3150000.	321500.	4049660.
7	104	85	35	2	416000.	164320.	8500.	2975000.	283000.	3846820.
8	109	79	29	4	436000.	172220.	7900.	2765000.	238000.	3619120.
9	118	73	23	9	472000.	186440.	7300.	2555000.	197500.	3418240.
10	134	67	17	17	536000.	211720.	6700.	2345000.	161500.	3260920.
11	163	62	12	32	652000.	257540.	6200.	2170000.	144000.	3229740.
12	214	59	9	57	856000.	338120.	5900.	2065000.	157500.	3422520.
13	301	56	6	101	1204000	475580.	5600.	1960000.	199500.	3844680.
14	463	54	4	181	1852000.	731540.	5400.	1890000.	303500.	4782440.
15	794	52	2	347	3176000.	1254520.	5200.	1820000.	536500.	6792220.
16	1471	50	0	685	5884000.	2324180.	5000.	1750000.	1027500.	10990680.
17	2941	50	0	1421	11764000.	4646780.	5000.	1750000.	2131500.	20297280.
18	7143	50	0	3521	28572000.	11285940.	5000.	1750000.	5281500.	46894416.

Table 9 suggest that using the experimental testing procedure with a cutting score of 8 ($3,619,120) would be cost effective which is the same result as the utility evaluation.

Table 9 shows that the minimum total cost of attaining the quota, 50 graduates, is $3,229,740 using a cutting score 11 on the test and the optimal recruiting-selection strategy is to recruit 163 persons. The best estimate is that 62 of these persons will qualify for acceptance and 12 of the selectees can be expected to fail the training course, leaving the 50 graduates required to meet the required quota. In comparison with the present selection procedure, the use of the experimental selection procedure will save an estimated $1,230,260 or $24,605.20 per graduate.



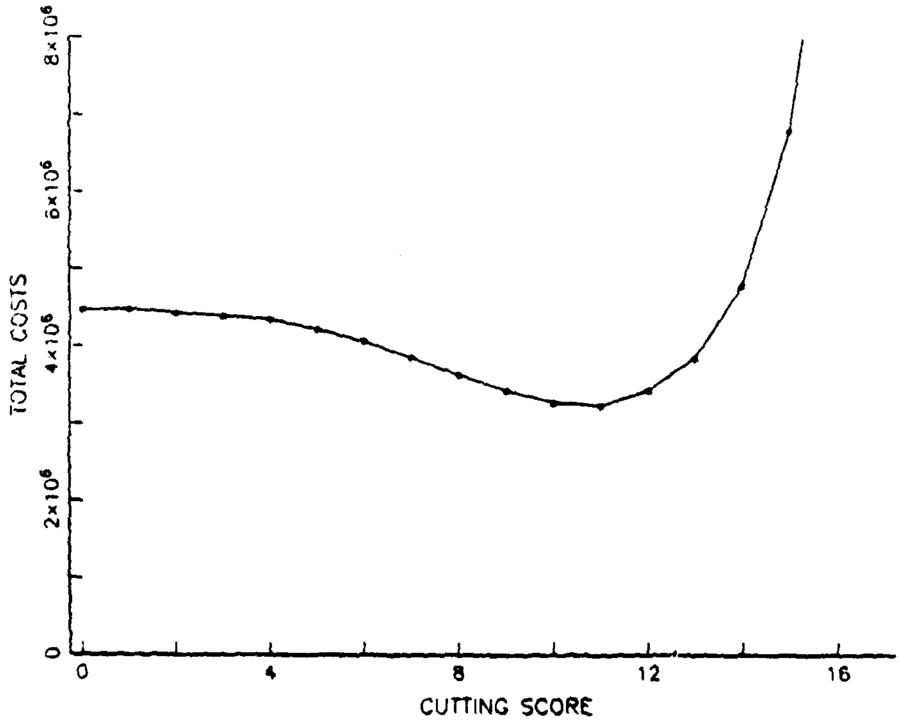


Figure 4.4 Graphical view of CAPER model output.

V. DISCUSSION

The increasing number of pilot candidates entering the ROKAF has resulted in increasing costs due to high attrition rates and decreasing quality of pilots who do complete the program. Further, training funds and personnel resources remain limited. Solving these problems will not be an easy task. It appears that there is not a single simple solution. However, it is imperative that some restructuring of the selection process be initiated as soon as possible as the potential negative impact these problems will have continues to increase. It is hoped that the current "Operations with Economic Efficiency (OEE) Program", which is attempting to maximize the cost effectiveness of all ROKAF operations will be able to adequately address the pilot selection problems. This thesis represents an attempt to suggest an effective method for improving the selection process.

As was discussed in Chapter I, other nations - France, Italy and England - initiated the selection testing efforts as early as World War I and the USN (USAF) reduced the attrition rate from 60% to 30% (25%) using psychological testing in the early 1970s. The Pensacola 1000 aviator study found that psychological and psychomotor measures had more validity for the prediction of success in flight training than did physiological measures. The psychomotor testing scores are significantly related to flight training pass/fail criteria. The ROKAF pilot selection system, however, only depends on actual flight performance.

As we evaluated its potential benefits to the ROKAF in Chapter IV, the expected utilities and CAPER model, could have a significant impact on pilot selection, pilot training and aircraft accidents. In terms of the analytic CAPER model, where output data are fixed by the values of the input data, the utility of the CAPER output can be no better than the accuracy of the input data. If the cost estimates are inaccurate, cost forecasts and the optimal recruiting-selection strategy will be distorted. This may not be a serious problem since the approximations are usually adequate for the kinds of decisions that estimates are used to make, and there is no need for utility estimate down to the last dollar.

It has been shown that a greater number of pilot candidates attrite during actual flight training than during the pre-training medical screening process. These candidates, though often having the option to continue their military careers in other aviation related fields, frequently feel that they are inferior officers because of the failure during flight training. These feelings of low self esteem, morale and motivation often result in poor performance and the involuntary termination of the officer's career. It is suggested that if a viable psychological test battery was administered in addition to medical screening and a candidate failed that test then (1) there would be a significant savings in actual flight training time for that candidate and (2) his being identified as "not aeronautically adaptable" might not have the psychological impact as having failed because of poor performance during actual training flights.

A. RECOMMENDATIONS

This study which is one of the OEE programs planned to reduce the cost and improve the efficiency of all ROKAF operations was essentially designed to emphasize the importance and necessity of mental testing methods on pilot selection for successfully screening out potential failures and suggests useful pilot screening methods to ROKAF. Also provided are evaluation techniques for decision makers which are the decision strategies and CAPER model.

It is clear from the overall study results that the use of psychological tests or test batteries of other nations can improve the prediction outcomes of the ROKAF pilot candidate selection method. Many other national Air Forces have used psychomotor screening to select their pilot candidates and continue efforts to develop this methodology. Some of the psychomotor scores are significantly different between candidates who graduate from UPT and those who are eliminated. The ideal selection system, however, would measure and consider all relevant characteristics of a candidate. The UPT selection system currently used by the ROKAF does not consider all relevant information about candidates and many candidates fail training because of deficiencies in flying aptitude. The intense situation of ROKAF, moreover, requires selecting high quality student pilots and the candidates with the lowest probability of success would be screened out before training. The higher the cutoff point is set, the better the pilot quality, cost effectiveness not with standing. The "false rejection", however, is a problem with all screening systems, including flight screening, and must be evaluated in terms of the percentage screened and the quality of the graduating students.

As suggested in Chapter IV, a change using experimental testing on ROKAF pilot selection method is feasible. It suggests a savings of $24,605.20 per graduate in our example. Multitask performance is useful for the primary flight training performance prediction. The experiment takes only 20 minutes and is easy to administer. The psychomotor screening system used by the USAF, which includes Two-Hand Coordination and Complex Coordination, has been shown to be useful in screening not only candidates for UPT but also for identifying those who demonstrate a potential for successfully completing advanced fighter training. Any of three Integrated Pilot Candidate Selection Models could be used to select UPT candidates in the same manner as the psychomotor screening system. The whole person concept is imbedded in the multidimensional IPCSM approach to pilot selection.

The implementation of psychomotor screening and multitask performance will improve the quality of student candidates and reduce attritions in ROKAF UPT. Based on overall considerations, however, an integrated selection system including psychomotor screening is recommended for ROKAF.

One of the preferable pre-selection systems that suggests for ROKAF pilot selection system of AFA cadets in this study would be:

1) The General Staff defines the number of pilots needed, and a circular is issued identifying the number of candidates required.
2) The selection process includes:
   a) Preliminary Examination - Medical
   b) EEG recordings (Electroencephalogram)
   c) Integrated Psychological Test
   d) Individual interview.
3) Cadets must wait until after their graduation from the KAFA and commission as officers before starting flight training.

Other useful methods which might also be incorporated in a pre-selection screening process would be:

- Perceptual/Cognitive Paper-and-Pencil Tests,
- Neurological Test,
- Residual Attention Test.

The Residual Attention Test could be especially valuable in predicting how well an individual will handle emergency situations. This could potentially have an impact on the aircraft accident rate in accidents due to human error, incorrect procedures or just poor handling of the aircraft during emergencies. It is obvious that with the many types of individual psychological and psychomotor tests available that further research must now address which individual tests and combinations of tests and batteries of must now address which individual tests and combinations of tests and batteries of tests should be incorporated into the ROKAF selection program. It is strongly recommended that a ROKAF pilot selection program research and development (R & D) team be organized to address this and other selection issues. The team could also benefit greatly from a close liaison with U.S. Navy and Air Force R & D centers currently engaged in aircrew selection methodology.

It is hoped that this study will be useful in stimulating the ROKAF in developing improved selection methods and in predicting success in training as a means of increasing aircrew training program cost effectiveness.

List of Abbreviation

ACTB	Aircrew Classification Test Battery
AFA	Air Force Academy
AFB	Air Force Base
AFHRL	Air Force Human Resources Laboratory (AFSC)
AFOQT	Air Force Officer Qualifying Test
AFROTC	Air Force Reserve Officer Training Corps
AOC	Aviator Officer Candidate
AQT	Aviation Qualification Test
ASTB	Aviator Selection Test Battery
FAR	Flight Aptitude Rating
FR	Fighter Recommended
FSP	Flight Screening Program (OTS)
IPCSM	Integrated Pilot Candidate Selection Model
KAFA	Korea Air Force Academy
OEE	Operations with Economic Efficiency
OTS	Officer Training School
ROKAF	Republic of Korea Air Force
R&D	Research and Development
UPT	Undergraduate Pilot Training
USAF	United States Air Force
USN	United States Navy

APPENDIX A
ATTRITION CATEGORIES

A student pilot can be dropped from a training program for several reasons. It is agreed that there is no one simple causative factor nor a quick and easy solution. Some of the primary reasons for student attrition are :

1. Voluntary Withdrawal or Drop On Request (DOR)

Over 50 research reports and findings associate the main reason of DOR with anxiety, tension or fear. Most of the specific reasons for the DOR are expressed an anxiety or tension with regard to flying, fear of flying, or lack of confidence in handling aircraft. Also mentioned are a dislike or distaste of flying and a shift to a civilian career interest. Some of the researches indicate a connection of fear of aircraft accidents or crashing with failure in training.

2. Not Phisically Qualified

Most research suggests that "a person with anxiety may see the flight surgeon when he has a symptom which he knows might result in his being dropped from the program; whereas, a nonanxious, highly motivated person might never go to the flight surgeon."

3. Flight Failure (FF)

Figure 1.1 mentions the types of attrition by stage of training. The data provide dramatic evidence of the relationship of DOR and FF in primary training and the transition phase.

The research literature generally supports the view that anxiety is both a cause and a symptom of inadequate or inferior performance in training. It can be broken down into two subcategories:

1) A student group prone to anxiety or with anxiety predisposition.

2) A student group going through a transient anxiety producing situation.

4. Not Officer Material

Is a statistic more oriented to the time during which attrition occurs rather than a specific type of attrition.

5. Academic Failure

Unsatisfactory performance in academic work.

6. ***Transfer to Another Training Program***

This is a small percentage of the total attrition and means a request to change one's specialty.

7. ***Practical Work Failure***

Unsatisfactory performance in a ground simulator or training device.

APPENDIX B
CAPER MODEL PROGRAM

```
************************************************************************
*                                                                      *
*                             CAPER MODEL                              *
*                                                                      *
*   This program provides a CAPER MODEL OUTPUT as various input data.  *
* The program reads data from data file, CAPER DATA, and creates a     *
* formated output, CAPEROU LISTING on your disk automatically using    *
* exec file.  The data used are from the Table 8 and there is no       *
* no meaning of ROKAF data but only for showing how the program works. *
*                                                                      *
* The key variables used are :                                         *
*                                                                      *
*              NR  : number recruited                                  *
*              NA  : number accepted                                   *
*              NEA : number of erroneous acceptances                   *
*              NER : number of erroneous rejections                    *
*              NQ  : the quota of satisfactory personnel               *
*              BR  : base rate                                         *
*              PG  : proportion of graduates who would qualify for     *
*                    acceptance at the ith cutting score on test       *
*              PF  : proportion of failures who would qualify for      *
*                    acceptance at the ith cutting score on test       *
*              CR  : cost of recruiting a person                       *
*              CP  : cost of administering the present procedure       *
*              CE  : cost of administering the experimental procedure  *
*              CI  : cost of inducting a person                        *
*              CT  : cost of training a person                         *
*              CEA : cost of an erroneous acceptance                   *
*              CER : cost of an erroneous rejection                    *
*              TCP : total cost of using the present selection         *
*                    procedure to meet the quota                       *
*              TCE : total cost of using the experimental selection    *
*                    procedure to meet the quota                       *
*                                                                      *
*     This program could be used effectively for other CAPER MODEL     *
* changing only the data and also useful for interactive program with  *
* some developments.                                                   *
*                                                                      *
************************************************************************
       PARAMETER (N=20)
       REAL PG(N),PF(N)
       DATA NQ/50/,BR/.5/,CR/4000./,CP/1500./,CI/100./,CE/80./,CT/35000./
      *     CEA/8000/,CER/1500/
*** READ DATA FROM DATA FILE ***
       DO 10 I=1,N
          READ (1,5) PG(I),PF(I)
10     CONTINUE
*** OUTPUT FORMAT ***
       WRITE(3,15)
       WRITE(3,65)
65     FORMAT(1X,'| CUT | NO  | NO  | NO  | NO  |',72X,'|')
       WRITE(3,75)
75     FORMAT(1X,'|SCORE| REC. | ACC. | ERR. | ERR. |',34X,'COST',34X,'|'
      *)
       WRITE(3,*) '|     |     |     |     |     |'
       WRITE(3,25)
       WRITE(3,*) '|     |     |     | ACC. | REJ. |    RECRUIT |    SEL
      *ECT  |    INDUCT   |  TRAINING |  ERR.DEC. |    TOTAL    |'
```

```
      WRITE(3,15)
      WRITE(3,*)
*** CALCULATE TOTAL COST ***
      DO 20 J=1,N
         NR = NINT(NO/(BR * PG(J)))
         NEA = NINT(NR * (1 - BR) * PF(J))
         NER = NINT(NR * BR * (1 - PG(J)))
         NA = NO + NEA
         TR = NR * CR
         SP = NR * CP
         SE = NR * CP + NR * CE
         TI = NA * CI
         TT = NA * CT
         TE = NEA * CEA + NER * CER
         TCS = TR + TI + TT + TE
         TCP = TCS + SP
         TCE = TCS + SE
         IF (J.EQ.1) THEN
            WRITE(3,35) NR,NA,NEA,NER,TR,SP,TI,TT,TE,TCP
            WRITE(3,55)
         ELSE
            WRITE(3,45) (J-2),NR,NA,NEA,NER,TR,SE,TI,TT,TE,TCE
         END IF
20    CONTINUE
      WRITE(3,15)
5     FORMAT (F5.3,5X,F5.3)
15    FORMAT (1X,'+',106('-'),'+')
25    FORMAT ('+',T37,72('='),'|')
35    FORMAT(1X,'| NA  | ',4(I4,' | '),6(F10.0,' |'))
45    FORMAT(1X,'| ',I2,'  | ',4(I4,' | '),6(F10.0,' |'))
55    FORMAT(1X,'|',T8,'| ',4(4X,' | '),6(10X,' |'))
      STOP
      END
```

```
*** DATA FILE ***
  PG        PF
1.000     1.000
1.000     1.000
1.000     1.000
1.000      .986
1.000      .966
1.000      .932
 .996      .874
 .984      .784
 .962      .668
 .920      .532
 .848      .388
 .744      .256
 .612      .152
 .468      .080
 .332      .038
 .216      .016
 .126      .004
 .068      .000
 .034      .000
 .014      .000
```

APPENDIX C
TAYLOR AND RUSSELL TABLES

N. M. Abrahams, E. F. Alf, and J. H. Wolfe

TABLE 1

Proportion Who Will Be Satisfactory Among Those Selected, for Given values of the Proportion of Present Employees Considered Satisfactory, the Selection Ratio, and Point-Biserial r

r_{pb}	Selection ratio										
	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	.950
Proportion of employees considered satisfactory = .05											
.00	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050
.05	.076	.072	.066	.063	.061	.059	.057	.055	.054	.052	.051
.10	.112	.099	.086	.078	.072	.067	.063	.060	.056	.053	.052
.15	.157	.131	.106	.092	.082	.075	.068	.063	.058	.054	.052
.20	.213	.169	.128	.107	.092	.082	.073	.066	.060	.055	.052
.25	.278	.210	.151	.121	.101	.087	.076	.068	.061	.055	.052
.30	.352	.255	.173	.133	.109	.092	.079	.070	.062	.055	.053
.35	.433	.302	.194	.144	.115	.095	.081	.070	.062	.056	.053
.40	.519	.348	.212	.153	.119	.097	.082	.071	.062	.056	.053
.45	.607	.393	.227	.159	.122	.099	.083	.071	.062	.056	.053
.50	.694	.431	.238	.163	.124	.100	.083	.071	.062	.056	.053
.55	.776	.462	.245	.165	.124	.100	.083	.071	.062	.056	.053
.60	.849	.484	.248	.166	.125	.100	.083	.071	.062	.056	.053
.65	.909	.495	.250	.167	.125	.100	.083	.071	.062	.056	.053
.70	.954	.499	.250	.167	.125	.100	.083	.071	.062	.056	.053
.75	.982	.500	.250	.167	.125	.100	.083	.071	.062	.056	.053
.80	.996	.500	.250	.167	.125	.100	.083	.071	.062	.056	.053
.85	.996	.500	.250	.167	.125	.100	.083	.071	.062	.056	.053
.90	.996	.500	.250	.167	.125	.100	.083	.071	.062	.056	.053
.95	1.000	.500	.250	.167	.125	.100	.083	.071	.062	.056	.053
1.00	1.000	.500	.250	.167	.125	.100	.083	.071	.062	.056	.053
Proportion of employees considered satisfactory = .10											
.00	.100	.100	.100	.100	.100	.100	.100	.100	.100	.100	.100
.05	.134	.129	.122	.118	.115	.112	.110	.107	.105	.103	.102
.10	.176	.162	.147	.137	.130	.124	.118	.114	.109	.105	.103
.15	.226	.200	.173	.157	.145	.135	.127	.120	.113	.107	.104
.20	.284	.243	.202	.177	.160	.146	.135	.125	.116	.108	.104
.25	.349	.290	.232	.198	.175	.157	.142	.130	.119	.109	.104
.30	.422	.343	.264	.219	.189	.166	.148	.133	.121	.110	.105
.35	.502	.399	.297	.240	.202	.175	.153	.136	.122	.110	.105
.40	.588	.460	.330	.260	.214	.182	.158	.139	.123	.111	.105
.45	.676	.525	.364	.278	.225	.188	.161	.140	.124	.111	.105
.50	.765	.592	.397	.295	.234	.193	.164	.142	.125	.111	.105
.55	.847	.661	.427	.309	.240	.196	.165	.142	.125	.111	.105
.60	.917	.731	.454	.320	.245	.198	.166	.143	.125	.111	.105
.65	.966	.800	.476	.327	.248	.199	.166	.143	.125	.111	.105
.70	.991	.864	.490	.331	.249	.200	.167	.143	.125	.111	.105
.75	.999	.920	.497	.333	.250	.200	.167	.143	.125	.111	.105
.80	1.000	.964	.500	.333	.250	.200	.167	.143	.125	.111	.105
.85	1.000	.990	.500	.333	.250	.200	.167	.143	.125	.111	.105
.90	1.000	.999	.500	.333	.250	.200	.167	.143	.125	.111	.105
.95	1.000	.999	.500	.333	.250	.200	.167	.143	.125	.111	.105
1.00	1.000	1.000	.500	.333	.250	.200	.167	.143	.125	.111	.105

TABLE 1—(*Continued*)

r_{pb}	Selection ratio										
	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	.950
	Proportion of employees considered satisfactory = .20										
.00	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200
.05	.244	.237	.229	.224	.220	.216	.213	.210	.207	.204	.202
.10	.293	.277	.260	.248	.239	.232	.225	.219	.213	.207	.204
.15	.347	.320	.292	.274	.260	.248	.238	.228	.219	.210	.205
.20	.405	.368	.326	.300	.280	.264	.249	.236	.224	.213	.207
.25	.468	.418	.363	.328	.301	.280	.261	.244	.229	.215	.208
.30	.535	.472	.401	.356	.322	.295	.272	.252	.234	.217	.208
.35	.605	.529	.441	.385	.344	.311	.283	.259	.238	.218	.209
.40	.676	.589	.484	.416	.366	.326	.293	.265	.241	.220	.210
.45	.747	.652	.529	.448	.387	.340	.302	.270	.244	.220	.210
.50	.815	.717	.577	.480	.409	.354	.310	.275	.246	.221	.210
.55	.876	.782	.627	.514	.430	.367	.318	.279	.248	.222	.210
.60	.927	.846	.680	.547	.450	.378	.324	.282	.249	.222	.210
.65	.964	.904	.736	.581	.468	.387	.328	.284	.249	.222	.210
.70	.986	.952	.794	.612	.482	.394	.331	.285	.250	.222	.210
.75	.996	.983	.852	.639	.492	.398	.333	.286	.250	.222	.210
.80	1.000	.997	.909	.657	.498	.400	.333	.286	.250	.222	.210
.85	1.000	1.000	.958	.665	.500	.400	.333	.286	.250	.222	.210
.90	1.000	1.000	.990	.667	.500	.400	.333	.286	.250	.222	.210
.95	1.000	1.000	.990	.667	.500	.400	.333	.286	.250	.222	.210
1.00	1.000	1.000	1.000	.667	.500	.400	.333	.286	.250	.222	.211
	Proportion of employees considered satisfactory = .30										
.00	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300
.05	.349	.341	.333	.327	.322	.318	.315	.311	.308	.304	.302
.10	.401	.385	.367	.354	.345	.337	.329	.322	.316	.308	.305
.15	.456	.430	.402	.383	.368	.355	.344	.333	.323	.312	.307
.20	.513	.478	.438	.412	.391	.374	.358	.344	.330	.316	.308
.25	.572	.528	.476	.442	.415	.393	.372	.354	.336	.319	.310
.30	.632	.579	.516	.473	.440	.412	.387	.364	.343	.322	.311
.35	.692	.632	.557	.506	.465	.431	.401	.374	.349	.324	.312
.40	.751	.686	.600	.540	.492	.451	.415	.383	.354	.327	.314
.45	.808	.740	.646	.576	.519	.471	.429	.392	.359	.329	.314
.50	.860	.794	.693	.614	.547	.491	.443	.401	.363	.330	.315
.55	.905	.846	.742	.653	.577	.512	.456	.408	.367	.331	.315
.60	.942	.894	.794	.696	.608	.532	.468	.415	.370	.332	.316
.65	.970	.936	.846	.741	.639	.552	.479	.420	.372	.333	.316
.70	.987	.967	.897	.789	.671	.570	.488	.424	.374	.333	.316
.75	.996	.988	.944	.839	.702	.584	.495	.427	.375	.333	.316
.80	.999	.997	.979	.891	.728	.594	.498	.428	.375	.333	.316
.85	1.000	1.000	.997	.941	.745	.599	.500	.428	.375	.333	.316
.90	1.000	1.000	1.000	.982	.750	.600	.500	.429	.375	.333	.316
.95	1.000	1.000	1.000	.982	.750	.600	.500	.429	.375	.333	.316
1.00	1.000	1.000	1.000	1.000	.750	.600	.500	.429	.375	.333	.316
	Proportion of employees considered satisfactory = .40										
.00	.400	.400	.400	.400	.400	.400	.400	.400	.400	.400	.400
.05	.451	.444	.435	.429	.424	.420	.416	.412	.408	.405	.403
.10	.504	.488	.470	.458	.448	.439	.432	.424	.417	.409	.405
.15	.557	.534	.506	.487	.472	.459	.447	.436	.425	.414	.408
.20	.611	.580	.542	.517	.497	.479	.463	.448	.433	.418	.410

TABLE 1—(*Continued*)

r_{pb}	Selection ratio										
	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	.950
	Proportion of employees considered satisfactory = .40										
.25	.665	.626	.580	.548	.522	.500	.479	.460	.441	.422	.412
.30	.717	.673	.618	.580	.548	.521	.496	.472	.449	.426	.414
.35	.768	.720	.658	.613	.575	.542	.512	.484	.456	.429	.415
.40	.816	.766	.698	.647	.603	.564	.529	.496	.464	.433	.417
.45	.860	.811	.740	.682	.632	.588	.546	.508	.471	.436	.418
.50	.900	.854	.782	.720	[illegible]	.612	.564	.519	.477	.438	.419
.55	.933	.894	.824	.758	.696	.637	.582	.530	.483	.440	.420
.60	.959	.929	.866	.799	.730	.663	.600	.541	.489	.442	.420
.65	.978	.958	.906	.842	.768	.691	.617	.551	.493	.443	.421
.70	.990	.979	.943	.885	.807	.719	.634	.560	.496	.444	.421
.75	.997	.992	.972	.928	.850	.748	.649	.566	.498	.444	[illegible]
.80	.999	.998	.991	.966	.894	.774	.660	.570	.500	.444	[illegible]
.85	1.000	1.000	.998	.992	.939	.792	.665	.571	.500	.444	.421
.90	1.000	1.000	1.000	1.000	.979	.800	.667	.571	.500	.444	.421
.95	1.000	1.000	1.000	1.000	.979	.800	.667	.571	.500	.444	.421
1.00	1.000	1.000	1.000	1.000	1.000	.800	.667	.571	.500	.444	.421
	Proportion of employees considered satisfactory = .50										
.00	.500	.500	.500	.500	.500	.500	.500	.500	.500	.300	.500
.05	.552	.544	.535	.529	.524	.520	.516	.512	.509	.505	.503
.10	.602	.588	.570	.558	.548	.540	.532	.525	.518	.510	.505
.15	.653	.631	.605	.587	.573	.560	.549	.538	.526	.515	[illegible]
.20	.702	.674	.640	.617	.598	.581	.565	.550	.535	.519	[illegible]
.25	.748	.716	.676	.647	.623	.602	.582	.563	.544	.524	[illegible]
.30	.793	.757	.712	.678	.649	.623	.599	.576	.553	.529	.515
.35	.834	.797	.747	.709	.676	.646	.617	.590	.562	.533	.518
.40	.872	.835	.783	.741	.703	.669	.636	.603	.571	.537	.520
.45	.905	.871	.818	.773	.732	.693	.655	.617	.580	.541	.521
.50	.933	.903	.853	.807	.762	.718	.675	.631	.588	.545	523
.55	.956	.932	.886	.840	.793	.745	.696	.646	.597	.548	.524
.60	.974	.956	.918	.875	.826	.773	.718	.660	.604	.551	.525
.65	.986	.975	.946	.908	.861	.804	.740	.675	.612	.553	.526
.70	.994	.988	.969	.940	.896	.836	.764	.689	.617	.554	.526
.75	.998	.995	.986	.968	.932	.872	.788	.700	.622	.555	.526
.80	1.000	.999	.996	.988	.966	.909	.810	.709	.624	.555	[illegible]
.85	1.000	1.000	.999	.998	.990	.947	.827	.713	.625	.556	[illegible]
.90	1.000	1.000	1.000	1.000	.999	.980	.833	.714	.625	.556	[illegible]
.95	1.000	1.000	1.000	1.000	1.000	.999	.833	.714	.625	.556	526
1.00	1.000	1.000	1.000	1.000	1.000	1.000	.833	.714	.625	.556	.526
	Proportion of employees considered satisfactory = .60										
.00	.600	.600	.600	.600	.600	.600	.600	.600	.600	.600	.600
.05	.650	.642	.634	.628	.624	.620	.616	.612	.609	.605	.603
.10	.697	.684	.667	.656	.647	.639	.632	.625	.618	.610	.606
.15	.742	.723	.700	.684	.671	.659	.648	.637	.626	.615	.608
.20	.784	.761	.733	.712	.695	.679	.664	.650	.636	.620	.611
.25	.874	.798	.764	.740	.719	.700	.681	.663	.645	.625	.614
.30	.859	.832	.796	.768	.743	.721	.699	.677	.655	.630	.617
.35	.891	.864	.826	.796	.768	.742	.717	.691	.664	.636	.619
.40	.918	.893	.855	.823	.793	.764	.735	.706	.675	.641	.622
.45	.942	.920	.883	.851	.819	.788	.755	.721	.685	.646	.624

TABLE 1—(*Continued*)

r_{pb}	Selection ratio										
	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	.950
	Proportion of employees considered satisfactory = .60										
.50	.961	.942	.910	.878	.846	.812	.776	.737	.695	.650	.626
.55	.976	.961	.934	.905	.872	.837	.797	.754	.706	.655	.628
.60	.986	.976	.955	.930	.900	.863	.820	.771	.716	.659	.629
.65	.993	.987	.972	.953	.926	.891	.845	.789	.727	.662	.630
.70	.997	.994	.986	.972	.951	.919	.872	.808	.736	.664	.631
.75	.999	.998	.994	.987	.973	.948	.900	.826	.743	.666	.631
.80	1.000	1.000	.998	.996	.990	.974	.930	.843	.748	.666	.632
.85	1.000	1.000	1.000	.999	.998	.992	.960	.854	.750	.667	.632
.90	1.000	1.000	1.000	1.000	1.000	1.000	.986	.857	.750	.667	.632
.95	1.000	1.000	1.000	1.000	1.000	1.000	.999	.857	.750	.667	.632
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.857	.750	.667	.632
	Proportion of employees considered satisfactory = .70										
.00	.700	.700	.700	.700	.700	.700	.700	.700	.700	.700	.700
.05	.746	.739	.732	.726	.722	.718	.715	.712	.708	.705	.703
.10	.787	.776	.762	.752	.744	.737	.730	.723	.717	.709	.705
.15	.826	.810	.791	.777	.766	.755	.745	.736	.725	.714	.708
.20	.860	.842	.819	.802	.787	.774	.761	.748	.735	.720	.711
.25	.890	.871	.846	.826	.809	.793	.777	.761	.744	.725	.714
.30	.916	.897	.871	.849	.830	.812	.793	.774	.754	.731	.718
.35	.938	.920	.894	.872	.852	.831	.810	.788	.764	.737	.721
.40	.956	.941	.916	.894	.873	.851	.828	.803	.775	.743	.724
.45	.970	.958	.936	.915	.894	.871	.846	.818	.786	.749	.727
.50	.981	.972	.953	.935	.914	.891	.865	.834	.798	.755	.730
.55	.989	.982	.968	.952	.934	.912	.885	.851	.811	.761	.732
.60	.994	.990	.980	.968	.952	.932	.905	.870	.823	.766	.734
.65	.997	.995	.989	.981	.969	.952	.926	.889	.836	.771	.735
.70	.999	.998	.995	.990	.982	.970	.948	.909	.849	.774	.736
.75	1.000	1.000	1.000	.996	.992	.984	.968	.931	.861	.776	.737
.80	1.000	1.000	1.000	.999	.998	.994	.986	.953	.870	.778	.737
.85	1.000	1.000	1.000	1.000	1.000	.999	.997	.975	.874	.778	.737
.90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.992	.875	.778	.737
.95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.992	.875	.778	.737
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.875	.778	.737
	Proportion of employees considered satisfactory = .80										
.00	.800	.800	.800	.800	.800	.800	.800	.800	.800	.800	.800
.05	.839	.833	.827	.823	.819	.816	.813	.810	.807	.804	.802
.10	.872	.864	.852	.844	.838	.832	.826	.821	.815	.809	.805
.15	.901	.890	.876	.865	.856	.848	.840	.832	.823	.813	.808
.20	.926	.914	.898	.885	.874	.864	.853	.843	.832	.819	.811
.25	.946	.934	.917	.904	.891	.880	.867	.855	.841	.824	.814
.30	.962	.951	.935	.921	.908	.895	.882	.867	.850	.830	.818
.35	.974	.965	.950	.937	.924	.911	.896	.879	.860	.836	.821
.40	.983	.976	.964	.952	.939	.926	.910	.892	.871	.843	.825
.45	.990	.984	.975	.964	.953	.940	.925	.906	.882	.850	.829
.50	.994	.991	.984	.975	.966	.954	.939	.920	.894	.857	.832
.55	.997	.995	.990	.984	.977	.967	.953	.934	.907	.865	.836
.60	.999	.998	.995	.991	.985	.978	.966	.949	.920	.872	.838
.65	1.000	1.000	1.000	1.000	.992	.987	.978	.963	.934	.878	.840
.70	1.000	1.000	1.000	1.000	1.000	.994	.988	.977	.948	.884	.841

TABLE 1—(*Continued*)

r_{pb}	Selection ratio .050	.100	.200	.300	.400	.500	.600	.700	.800	.900	.950
	Proportion of employees considered satisfactory = .80										
.75	1.000	1.000	1.000	1.000	1.000	1.000	.995	.988	.963	.887	.842
.80	1.000	1.000	1.000	1.000	1.000	1.000	.999	.996	.977	.888	.842
.85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999	.990	.889	.842
.90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998	.889	.842
.95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998	.889	.842
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.889	.842
	Proportion of employees considered satisfactory = .90										
.00	.900	.900	.900	.900	.900	.900	.900	.900	.900	.900	.900
.05	.928	.924	.920	.917	.914	.912	.910	.908	.906	.903	.902
.10	.949	.944	.937	.932	.928	.924	.920	.916	.912	.907	.904
.15	.966	.960	.952	.946	.940	.935	.930	.924	.918	.911	.907
.20	.978	.972	.965	.958	.952	.946	.940	.933	.925	.916	.910
.25	.986	.982	.975	.969	.963	.957	.950	.942	.933	.921	.913
.30	.992	.989	.983	.978	.972	.966	.959	.951	.941	.927	.917
.35	.996	.993	.989	.985	.980	.975	.968	.960	.949	.933	.921
.40	.998	.996	.994	.990	.987	.982	.976	.968	.958	.940	.926
.45	.999	.998	.996	.994	.992	.988	.983	.976	.966	.947	.930
.50	1.000	1.000	1.000	1.000	.995	.993	.989	.984	.974	.955	.935
.55	1.000	1.000	1.000	1.000	1.000	1.000	.994	.990	.982	.962	.939
.60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.994	.989	.970	.943
.65	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.994	.978	.946
.70	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998	.985	.947
.75	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999	.991	.947
.80	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.996	.947
.85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999	.947
.90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.947
.95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.947
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.947
	Proportion of employees considered satisfactory = .95										
.00	.950	.950	.950	.950	.950	.950	.950	.950	.950	.950	.950
.05	.969	.967	.964	.962	.960	.959	.957	.956	.954	.952	.951
.10	.982	.979	.975	.972	.970	.967	.964	.962	.959	.955	.953
.15	.990	.987	.984	.981	.978	.975	.972	.968	.964	.959	.956
.20	.995	.993	.990	.987	.984	.982	.978	.974	.970	.963	.959
.25	.998	.996	.994	.992	.990	.987	.984	.980	.975	.968	.962
.30	.999	.998	.997	.996	.994	.992	.989	.986	.981	.973	.966
.35	1.000	1.000	1.000	.998	.996	.995	.993	.990	.986	.978	.970
.40	1.000	1.000	1.000	1.000	1.000	.997	.996	.994	.991	.983	.975
.45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.997	.994	.988	.979
.50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.997	.992	.984
.55	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.996	.988
.60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998	.992
.65	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999	.995
.70	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998
.75	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999
.80	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

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