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EXTENDING THE TIME TO PROFICIENCY MODEL FOR SIMULTANEOUS APPLICATION TO MULTIPLE JOBS

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The Time to Proficiency (TTP) Model (Carpenter, Monaco, O'Mara, & Teachout, 1989) lined job performance and enlistment standards. The model considered aptitude, productivity, cost, and attrition data on first-term Avionics Communications Specialists (328X0). It combined the data to identify an aptitude standard which minimized cost per productive unit for the specialty. A problem with the Carpenter et al. (1989) model is that it only allowed analysis of a single Air Force specialty (AFS), independent of others. This results in minimum standards for an AFS that are too high when Air Force-wide manning requirements and the finite applicant pool are considered. This paper proposes an extension of the model to accommodate several AFSs simultaneously and interdependently. The extended model allocates a given recruit pool to AFSs such that cost per productive unit is minimized across the specialties. The extended model allows determination of the effects on standards, of changes in the recruit pool or AFS manning requirements. The paper demonstrates the extended model using six AFSs with job performance measures collected under the Job Performance Measurement project.

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SUMMARY

The Time to Proficiency (TTP) Model (Carpenter, Monaco, O'Mara, & Teachout, 1989) was developed as a means for linking job performance and enlistment standards. The Model took into account aptitude, productivity, cost, and attrition data on first term airmen in the Avionics Communications Specialist career field (328X0). It combined the data into meaningful relationships which allowed for identification of a minimal aptitude standard for the specialty that would minimize cost per productive unit. A problem with the Model specified by Carpenter et al. (1989) is that it allowed only for the analysis of a single Air Force Specialty (AFS), independent of others. This results in minimum standards for an AFS that are too high when Air Force-wide mannning requirements and the finite applicant pool are considered. To solve this problem, this paper proposes a method for extending the TTP Model to accomodate several AFSs simultaneously and interdependently. The extended TTP Model determines minimal aptitude standards by allocating a given recruit pool to AFSs such that cost per productive unit is minimized across the specialties. The extended Model allows the analyst to determine the effects on standards, of changing the recruit pool or the manning requirements of AFSs. Last, this paper provides a demonstration of the extended TTP using six AFSs with job performance measures that were col'-cted under the Job Performance Measurement System (JPMS) project.

PREFACE

This research and development effort was conducted as task order number 18 under Contract F41689-88-D-0251 (SBA 68822004) by Metrica, Inc. for the Force Acquisition Branch, Manpower and Personnel Division, Air Force Human Resources Laboratory. Purpose of the effort was to further develop a Time to Proficiency Model proposed earlier in a paper by Carpenter, Monaco, O'Mara, & Teachout (Time to proficiency: a preliminary investigation of the effects of aptitude and experience on productive capacity, AFHRL-TP-88-17).

This paper was written and prepared by the first two authors from analyses and material provided by the remaining authors. The Model, as modified for this paper, demonstrates strong promise as a means for both establishing Air Force selection and job classification standards and allocating incoming personnel among competing job vacancies. If properly established in the problem specifications, most policy dictated constraints can be accomodated by the Model. It should also be a valuable tool for policy makers in exploring impact of various possible policy (constraint) changes on personnel allocation among Air Force jobs.

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I. INTRODUCTION

The Armed Services Vocational Aptitude Battery (ASVAB) contains 10 subtests and is given to all service applicants. It measures multiple aptitudes. The Air Force uses composite scores from the ASVAB to select applicants for enlistment, and to classify these recruits into Air Force Specialties (AFSs). The ASVAB is the Air Force's primary selection and classifi-cation test battery. Table 1 provides a list of ASVAB subtests, and Table 2 lists composites used by the Air Force, as well as their definitions.

Table 1. ASVAB Subtests

Subtest name	Number of items	Test time (minutes)	Test type
General Science (GS)	25	11	Power
Arithmetic Reasoning (AR)	30	36	Power
Word Knowledge (WK)	35	11	Power
Paragraph Comprehension (PC)	15	13	Power
Numerical Operations (NO)	50	3	Speed
Coding Speed (CS)	84	7	Speed
Auto Shop Information (AS)	25	11	Power
Mathematics Knowledge (MK)	25	24	Power
Mechanical Comprehension (MC)	25	19	Power
Electronics Information (EI)	20	9	Power

Table 2. ASVAB Composites Used by the Air Force

Composite name	Definition
Armed Forces Qualification Test (AFQT)	2(WK + PC) + AR + MK
Mechanical (M)	MC + GS + 2AS
Administrative (A)	NO + CS + WK + PC
General (G)	WK + PC + AR
Electronic (E)	AR + MK + EI + GS

Note. Composites are sums of subtest standard scores. The subtests preceded by "2" are double weighted to form the composite.

Air Force composites include the Armed Forces Qualification Test (AFQT), and the Mechanical (M), Administrative (A), General (G) and Electronic (E) aptitude indexes (AIs). For Air Force selection, cut scores on both the AFQT and G are applied. In addition, a cut score on the sum of M, A, G, and E is applied. The Air Force uses scores on the M, A, G, and E AIs for classification. Also, special tests are used for classification into some AFSs.

A link between ASVAB performance and job performance would be of considerable value to the Air Force. Such a relationship would both validate the ASVAB for selection and classification and allow the Air Force to set empirically derived ASVAB cut score standards. In setting aptitude standards based on job performance, there are four important considerations. First, an accurate and precise measure of job performance is needed to determine how well airmen actually perform on the job. Second, a model which establishes relationships between job performance measures and variables such as aptitude, experience, and costs incurred is needed. Third, determination of a minimum acceptable level of measured job proficiency is needed. The ASVAB score level associated with this minimum proficiency level is not necessarily the minimum aptitude standard. The desired goal may dictate standards above this score. Finally, the Air Force must decide what force structure goal is to be met. The Air Force must choose to maximiztle force productivity, minimize the cost of fielding a force, or satisfy a goal between these extremes.

The Time to Proficiency (TTP) model (Carpenter, Monaco, O'Mara & Teachout, 1989) allows the analyst to account for these important considerations while linking job performance and enlistment standards. To satisfy the first consideration, Carpenter et al. (1989) developed a method to collect productivity data through supervisor estimates. Second, the TTP model establishes relationships between aptitude, productivity, cost, and attrition of first term airmen. Third, the model aids in identifying a minimum acceptable level of productivity. If the minimum acceptable level of productivity is known, the model can take this into account when setting standards. Finally, the TTP model provides ASVAB composite cut score standards that satisfy the goal of minimizing cost per productive unit.

The TTP model as originally defined, only allowed analysis of a single AFS, independent of others. This is unrealistic since there are actually many AFSs with various manning requirements, and a finite number of recruits to allocate. Consideration of a single AFS can lead to unrealistically high ASVAB score standards for the AFS. Inappropriately high standards for even a small number of AFSs may deplete the recruit pool of high aptitude individuals, leaving none for the remaining AFSs. With further extension and refinement, the TTP model can help establish aptitude cut scores for several AFSs simultaneously. It can also show the impact of changing the cut score for one AFS on the manning requirements for the others.

This paper reports further development of the TTP model to yield selection and classification standards that minimize cost per productive unit across multiple AFSs, and demonstrates the refined model.

II. BACKGROUND

The TTP model is comprised of three modules: (a) productive capacity, (b) attrition, and (c) cost. The modules are integrated to yield the ASVAB cut scores.

Carpenter et al. (1989) did preliminary research with the TTP model on AFS 328X0, Avionics Communications Specialist. Productivity data were collected on first-term airmen in the specialty. Attrition and cost functions were also estimated. The modules were integrated to yield recommended selection standards for the single AFS. Carpenter et al. (1989) describe the TTP model modules and their integration as follows.

Productive Capacity Module

The productive capacity module was defined as:

$$P = 1/ (1 + \exp (- b_0 - b_1x_1 - b_2x_2)) \qquad (1)$$

where P = productive capacity,
x_1 = experience (months in AFS),
x_2 = selector AI, and
b_0, b_1, b_2 = parameters to be estimated.

To estimate b_0, b_1, and b_2, the productive capacity equation was reformulated through algebraic manipulation and a log transformation to yield the following function:

$$\ln (P / (1 - P)) = b_0 + b_1X_1 + b_2X_2. \quad (2)$$

The parameters b_0, b_1, and b_2 were estimated using multiple linear regression with $\ln (P / (1 - P))$ as the dependent variable. Experience and selector AI score were explanatory variables.

Productive capacity, P, was defined as t^*/t. The time it takes an individual to complete a unit of work is designated as t. The fastest possible time to complete the unit of work at an acceptable quality level is estimated as t^*. The t^*/t formulation ensures a P value between 0 and 1, and can be considered a proportion of maximum productivity. For example, if an individual performs a task in 4 minutes ($t = 4$), and the estimated fastest performance time is 3 minutes ($t^* = 3$), the individual's P is .75. This implies that he/she is performing at 75% of maximum achievable productivity.

Carpenter et al. (1989) collected both objective and subjective productivity data. Emphasis was on validating a methodology using supervisory estimates as a surrogate for costly objective measures. The objective data were collected using Walk-Through Performance Test (WTPT) methodology (Hedge, 1984). Subjective data were collected in the form of supervisor estimates. To collect the subjective data, supervisors were given benchmark performance times estimated by Subject Matter Experts (SMEs), for tasks performed by workers in the specialty. Tasks were combined into groups based on coperformance, homogeneity of task learning difficulty, and other factors. Supervisors chose a benchmark worker who they thought would perform closest to the benchmark pace for each task group. To derive performance time (t) values for each worker, supervisors estimated how long that worker would take to accomplish work the benchmark person could perform in 1 hour. Values for t^* were obtained by subtracting 1 minute from the minimum performance time observed during the WTPT.

The productive capacity module was used to develop production isoquants (curves depicting combinations of experience and aptitude that yield fixed levels of P). Isoquants estimate expected productive capacity of individuals with a given aptitude level at given points in their careers. Using the isoquants, airmen could be selected by AI score to ensure that they meet a specified level of productivity by a given career point.

Attrition Module

The attrition module was defined as:

$$r(x,t) = b_0 + b_1 \ln [(t + s(x)) / (48 - t)] + b_4x \quad (3)$$

where $s(x) = \exp (b_2 + b_3x)$,
$r(x,t)$ = probability of an airman with AI score x remaining in service after t months ($t = 1$ to 48),
x = AI score,
t = months in service, and
b_0, b_1, b_2, b_3, b_4 = parameters to be estimated.

This equation represents attrition as the probability of an individual with AI score x, remaining in service after t months. Typically, the equation shows lower aptitude airmen attriting at higher rates.

Cost Module

Ideally, costs should be modeled as a function of both time in service and aptitude level. Cost by aptitude data are important because recruiting costs probably differ with aptitude level. Recruiting higher aptitude individuals probably costs more due to their higher opportunity costs. Training costs are also likely to differ by aptitude level since lower aptitude recruits may require more remedial training. However, cost by aptitude level data were not available (Carpenter et al., 1989). As a result, military pay increases due to promotions and longevity raises accounted for the only differences in cost within an AFS. Training costs accounted for differences across AFSs. The cost module was held constant across aptitude levels.

Model Integration and Solution

In the integration of the modules, Carpenter et al. (1989) considered two intermediate functions: expected productive capacity and expected cost. Expected productive capacity for a first-term airman was described as:

$$P(x) = \sum_{t=0}^{48} r(x,t)\ p(x,t) \tag{4}$$

where
- $P(x)$ = expected first-term productive capacity of an individual with an AI score of x,
- x = AI score,
- t = time in service (months),
- $r(x,t)$ = probability that an individual with an AI score of x is still in the service after t months, and
- $p(x,t)$ = productive capacity of an individual with an AI score of x and t months experience.

Expected first-term cost was described as:

$$C(x) = \sum_{t=0}^{48} r(x,t)\ c(x,t) \tag{5}$$

where
- $C(x)$ = expected first-term cost of an individual at AI score x,
- x = AI score,
- t = time in service (months), and
- $r(x,t)$ = probability that an individual with an AI score of x is still in the service after t months.

The expected first-term cost function suggests that as the probability of remaining in the service decreases, expected cost over the first term also decreases. This is true since an individual who has attrited from the service is no longer a cost to the service. However, another individual must be recruited, trained, and paid to fill the vacant slot. Thus, it is more appropriate to associate higher costs with higher attrition.

The ratio $C(x)/P(x)$ represents the expected cost per productive unit over the first enlistment term. Minimizing this ratio with respect to AI score level (x) yields the AI score that minimizes cost per productive unit. Because it is impractical to select only recruits at the optimum AI score, it was necessary to model productive capacity and cost as a function of minimum allowable AI score:

$$E[P(m)] = \sum f_m(x)\ P(x) \tag{6}$$

$$E[C(m)] = \sum f_m(x)\ C(x) \tag{7}$$

where m = minimum allowable AI score,

$E[P(m)]$ = expected average first-term productive capacity for the population of potential recruits,

$E[C(m)]$ = expected average first-term cost for the subpopulation,

$f_m(x)$ = conditional probability density function of AI scores for the population of potential recruits with AI scores of at least m,

$P(x)$ = expected first-term productive capacity of an individual with an AI score of x, and

$C(x)$ = expected first-term cost of an individual with an AI score of x, and

$x > m$

By minimizing the ratio $E[C(m)]/E[P(m)]$ with respect to m, the optimum minimum AI score was found. Since the Carpenter et al. (1989) cost module was constant across aptitude levels, the optimum solution was the aptitude score level associated with the highest level of P. Intuitively, this was the highest aptitude level. The selector AI for AFS 328X0 was the E composite, which was stratified into deciles. The recommended minimum standard according to the model, was an E score of 90.

III. EXTENSION OF THE TTP MODEL FOR SIMULTANEOUS APPLICATION TO MULTIPLE SPECIALTIES

A major limitation of the TTP model (Carpenter et al., 1989) was its inability to accommodate several AFSs simultaneously. The model only allowed analysis of a single AFS, independent of others. Analyzing single AFSs without considering others is unrealistic. The aptitude standards of a specialty are very much dependent upon the standards and manning requirements of other AFSs. To illustrate, consider the Carpenter et al. (1989) solution for AFS 328X0. The optimal minimum standard was found to be an aptitude score of 90. It is likely that if each of approximately 250 AFSs were analyzed independently, unrealistically high aptitude standards would have been determined for each. There simply would not be enough high aptitude recruits to meet manning requirements. This suggests a need to extend the model to accommodate several AFSs simultaneously.

Extended to analyze several specialties concurrently, the model becomes useful both for setting aptitude standards, and for allocating personnel to AFSs. For the TTP model to determine cut scores across AFSs, it must determine the minimum cost allocation of a given recruit pool to the various AFSs.

To illustrate, assume that a single aptitude measure is sufficient to predict applicant effectiveness and thus, cost per productive unit in all AFSs. The aptitude score level is denoted by x and the expected cost per productive unit for AFS k at aptitude level x is denoted by $CP_k(x)$.

For analysis purposes the applicant pool can be stratified into aptitude level groups. Group a_{90} includes all cases with scores 90 and above, a_{80} includes all cases with scores from 80 to 89, etc. Available cases in each aptitude level are denoted by a_x. The projected recruit manning requirement for each AFS is denoted by r_k.

The applicants are allocated to jobs such that the Air Force's cost per productive unit is minimal. The solution is obtained by minimizing:

$$\sum_k \sum_x \{[CP_k(x)] \cdot [n_{x,k}]\} \qquad (8)$$

subject to: $\sum_k n_{x,k} \leq a_x$ for all x (9)

$\sum_x n_{x,k} = r_k$ for all k (10)

$n_{x,k} \geq 0$ for all x and k (11)

where x = aptitude level/category,
k = the AFS,
$n_{x,k}$ = number of recruits assigned to AFS from aptitude level x,
r_k = manning requirement for AFS k,
$CP_k(x)$ = cost per productive unit for AFS k for aptitude level x, and
a_x = number of recruits for aptitude level x.

The objective function (8) is the total cost per productive unit of all people assigned to all AFSs from all aptitude levels. The allocation problem is solved by finding the minimum value for this function. The first constraint (9) says that the number of recruits assigned from an aptitude level can not exceed the number available. The second constraint (10) prohibits assigning personnel to an AFS beyond its manning requirement. However, if there is a manpower shortage, fewer individuals than required can be assigned to an AFS. The third constraint (11) simply specifies that a negative number of personnel cannot be assigned to an AFS from an aptitude level.

TTP Model Example Assuming a Single Aptitude Measure

Consider a hypothetical problem involving assignment of applicants to one or the other of two AFSs on the basis of a single aptitude score. Assume that 600 applicants were available for assignment to two specialities with the first requiring 300 and the second requiring 250. Assume productivity, aptitude, cost, and attrition data were collected and analyzed to obtain cost per productive unit. Expected cost per productive unit by AFS and aptitude level is given in Table 3. To solve the problem, one must minimize:

$$3264\, n_{90,1} + 2900\, n_{90,2} + 3523\, n_{80,1} + 4200\, n_{80,2} + 3829\, n_{70,1} + 5000\, n_{70,2}$$

subject to:

$$n_{90,1} + n_{90,2} \leq 100$$
$$n_{80,1} + n_{80,2} \leq 200$$
$$n_{70,1} + n_{70,2} \leq 300$$
$$n_{90,1} + n_{80,1} + n_{70,1} = 300$$
$$n_{90,2} + n_{80,2} + n_{70,2} = 250$$
$$n_{x,k} \geq 0 \text{ for } x = 90, 80, 70 \text{ and } k = 1, 2$$

Table 3. Cost, Availability, and Requirements Data for the Single Aptitude Score Example

Aptitude Level	AFS 1	AFS 2	Available N (a_x)
90	$3264.00	$2900.00	100
80	$3523.00	$4200.00	200
70	$3829.00	$5000.00	300
Required N (r_k)	300	250	

The minimum cost solution to this example problem is:

$$n_{90,1} = 0 \qquad n_{90,2} = 100$$
$$n_{80,1} = 50 \qquad n_{80,2} = 150$$
$$n_{70,1} = 250 \qquad n_{70,2} = 0$$

Fifty applicants in the 70 aptitude level are not assigned to either AFS. This is because there was a surplus of 50 applicants over the number of recruits needed. Thus, the "optimized" minimum aptitude cut-off score was set at 70 for the first specialty and at 80 for the second.

TTP Model Examples Assuming Multiple Aptitude Scores

Because a single aptitude score may not be appropriate across AFSs, the TTP model was extended to accomodate multiple aptitude scores. This extension causes no conceptional difficulties, but it's solution requires increased computation.

Expected cost per productive unit depends on the aptitude measure employed in the model. For instance, productivity in some AFSs is linked to Mechanical aptitude. For other AFSs, it is more closely linked to Electronics aptitude. Still other AFSs need two or more aptitude scores to capture their productive unit cost appropriately. Thus a minimum cost allocation model must incorporate multiple aptitude scores. This is accomplished in the following way.

Aptitude scores are stratified into decile groups such that levels of x are defined by particular score combinations. For example, one level of x may be characterized by individuals with a Mechanical score of 90, Administrative 80, General 70, and Electronics 60.

Expected cost per productive unit within each AFS is a function of x, EP(x). The decision rule which allocates individuals to the AFSs is a function of this multiple aptitude stratification, $n_k(x)$. The general model seeks to minimize:

$$\sum_k \sum_x \{[EP_k(x)] \cdot [n_k(x)]\} \tag{12}$$

subject to:

$$\sum_k n_k(x) \leq a(x) \text{ for all partitions } x \tag{13}$$

$$\sum_x n_k(x) = r_k \text{ for all } k \tag{14}$$

$$n_k(x) > 0 \text{ for all } k \text{ and } x \tag{15}$$

where $a(x)$ = number of applicants in aptitude level x, and
r_k = recruit requirement for AFS k.

Two Aptitude Score Example

An earlier example assigned recruits to two AFSs based on a single aptitude measure. In that example, the recruits were partitioned into score levels 70, 80, and 90. Assume that this score is Electronics. Further assume the Mechanical score also is available for these applicants. The Mechanical score is partitioned into only two levels, 60 and 80. Thus the applicants are partitioned into six cells. Assume productivity, aptitude, cost, and attrition data were analyzed to obtain expected cost per productive unit. These data are shown in Table 4. Note that productive unit costs are given for each of the six cells. The allocation problem must minimize:

$$3300\, n_{90,80,1} + 2900\, n_{90,80,2} + 3400\, n_{90,60,1} + 3100\, n_{90,60,2} + 3500\, n_{80,80,1} + 4200\, n_{80,80,2} +$$
$$3700\, n_{80,60,1} + 4500\, n_{80,60,2} + 3900\, n_{70,80,1} + 5000\, n_{70,80,2} + 4100\, n_{70,60,1} + 5200\, n_{70,60,2}$$

subject to:

$$n_{90,80,1} + n_{90,80,2} \le 40$$
$$n_{90,60,1} + n_{90,60,2} \le 60$$
$$n_{80,80,1} + n_{80,80,2} \le 80$$
$$n_{80,60,1} + n_{80,60,2} \le 120$$
$$n_{70,80,1} + n_{70,80,2} \le 150$$
$$n_{70,60,1} + n_{70,60,2} \le 150$$
$$n_{90,80,1} + n_{90,60,1} + n_{80,80,1} + n_{80,60,1} + n_{70,80,1} + n_{70,60,1} = 300$$
$$n_{90,80,2} + n_{90,60,2} + n_{80,80,2} + n_{80,60,2} + n_{70,80,2} + n_{70,60,2} = 200$$
$$n_{i,j,k} \ge 0, \text{ for all } i,j,k$$

A linear program, similar to that for the single aptitude score will also solve this problem. The minimum cost solution is:

$n_{90,80,1} = 0$ $\quad n_{90,80,2} = 40$
$n_{90,60,1} = 0$ $\quad n_{90,60,2} = 60$
$n_{80,80,1} = 0$ $\quad n_{80,80,2} = 80$
$n_{80,60,1} = 100$ $\quad n_{80,60,2} = 100$
$n_{70,80,1} = 150$ $\quad n_{70,80,2} = 0$
$n_{70,60,1} = 50$ $\quad n_{70,60,2} = 0$

Table 4. Cost, Availability and Requirements Data for the Two Aptitude Score Example

Aptitude Level		AFS		Available N
E	M	1	2	(a_x)
90	80	\$3300.00	\$2900.00	40
90	60	\$3400.00	\$3100.00	60
80	80	\$3500.00	\$4200.00	80
80	60	\$3700.00	\$4500.00	120
70	80	\$3900.00	\$5000.00	150
70	60	\$4100.00	\$5200.00	150
Requirements(r_k)		300	200	

There were 100 recruits from the $a_{70,60}$ aptitude level that were not allocated.

IV. DEMONSTRATION OF THE EXTENDED TTP MODEL USING EXISTING JOB PERFORMANCE DATA

In this section the linear programming approach is applied to manpower allocations among six AFSs with job performance measures from the Job Performance Measurement System (JPMS) project (Hedge & Teachout, 1986). The career fields are:

AFSC	Title	Relevant AI(s)
122X0	Aircrew Life Support	G
272X0	Air Traffic Control	G
328X0	Avionic Communications	E
423X5	Aerospace Ground Equipment	M,E
426X2	Jet Engine Mechanic	M
492X1	Information Systems Operator	A

Productive Capacity Module

No direct productive capacity measures were collected for JPMS subjects in these specialties. Consequently, P was estimated from other JPMS job performance indicators. Specifically, Walk-Through Performance Test (WTPT) total scores were used in estimating P for this demonstration (Hedge & Teachout, 1986). Several JPMS measures were considered as potential estimators of P. The total WTPT score was identified as the best choice. For a detailed explanation of the analyses and results which led to the selection of total WTPT, see Stone (1989). Productive capacity was calculated as t/t*, where t was the individual's total WTPT score, and t* was the highest obtained total score.

A general expression for productive capacity is:

$$P = f(x,t,z) \tag{16}$$

where P = productive capacity,
x = aptitude,
t = experience, and
z = other factors affecting productive capacity.

If this relationship is linear, the expression becomes:

$$P = b_0 + b_1x + b_2t + b_3z \tag{17}$$

where b_0 = intercept, and
b_1, b_2, b_3 = regression coefficients of x, t, and z respectively.

The coefficient b_1 is the quantitative change in productive capacity for each unit change in aptitude. Similarly, b_2 is the change in productive capacity for each unit change in experience.

Productive capacity was estimated as a linear function for this demonstration. The linear function yielded higher R^2s than did the logistic function described by Carpenter et al. (1989). Productive capacity was regressed on these three predictors:

1. APT - the Air Force's selector aptitude index for the particular AFS,

2. LTAFMS - the natural logarithm of Total Active Federal Military Service (TAFMS) (TAFMS is computed in months; the logarithm was used because it provides a better fit to productive capacity),

3. DPSK5 - a binary variable representing skill (Coded 1 if the individual's skill level is 5 or higher, 0 otherwise; skill level ranges from 1 to 9 and reflects the amount of training, experience, and expertise of an airman).

Table 5 presents the regressions of P on APT, LTAFMS, and DPSK5. For a more detailed explanation of this analysis, see Stone (1989). DPSK5 was included as a predictor because it accounted for some additional variance in P. However, emphasis will focus on aptitude and experience as predictors.

The APT regression coefficients were statistically different from zero (at the .05 level) in five of the seven analyses; for LTAFMS they were statistically significant in four of the seven analyses. The statistically significant APT regression coefficients range from .00136 in AFS 272X0 to .00384 in AFS 328X0. The statistically significant coefficients for LTAFMS range from .04695 in AFS 492X1 to .07991 in AFS 122X0. Thus, with experience held constant, an increase in APT of 10 points would increase productive capacity by .0136 to .0384. A 12 month increase in TAFMS, with aptitude held constant, would increase productive capacity by .1167 to .1986. Consider AFS 426X2. A 10 point aptitude increase results in a .0168 increase in productive capacity, while a 12 month increase in experience results in a .1815 increase in productive capacity. The associated R^2s range from .0972 (R = .31) for AFS 272X0 to .2254 (R = .47) for AFS 492X1.

Table 5. Regressions of Productive Capacity Using Relevant Aptitude Scores (AIs)

AFS(AI)	N	(b_0)	APT (b_1)	LTAFMS (b_2)	DPSK5 (b_3)	R	R^2
122X0(G)	171	.42160	.00022	.07991**	.03750	.3373	.1138
272X0(G)	172	.38805	.00136*	.07297**	.01776	.3118	.0972
328X0(E)	67	.16423	.00384**	.09732	-.01195	.4375	.1914
423X5(E)[1]	218	.37853	.00163**	.03374	.04917*	.4111	.1690
423X5(M)[1]	218	.29161	.00226	.04056	.04699*	.4449	.1979
426X2(M)	197	.38404	.00168**	.07303**	-.01383	.3129	.0979
492X1(A)	125	.48486	.00015	.04695*	.10134**	.4748	.2254

[1] Note that 423X5 appears twice in the table-- once for the Electronics AI requirement and once for the Mechanical AI requirement.

*p < .05.

**p < .01.

A minimal qualifying score on the AFQT is required for enlistment. For this reason, the regressions described above were rerun with AFQT as the APT variable. The regressions using AFQT as APT are comparable to those using the selector AIs. These regressions are summarized in Table 6. The regression coefficients for AFQT and LTAFMS are similar to the coefficients based on use of the selector AI. Like Table 5, Table 6 indicates that productive capacity varies directly with experience and aptitude.

Table 6. Regressions of Productive Capacity Using AFQT

AFS	N	(b_0)	APT (b_1)	LTAFMS (b_2)	DPSK5 (b_3)	R	R^2
122X0	171	.42597	.00003	.08226^b	.03718	.3363	.1131
272X0	172	.42389	.00091	.07201^a	.02061	.2840	.0807
328X0	67	.28121	.00262^b	.09668	-.00421	.4535	.2057
423X5	218	.46158	.00025	.03364	.05985^b	.3457	.1195
426X2	197	.45980	.00108^b	.06994$_b$	-.01004	.2759	.0761
492X1	125	.38701	.00223^b	.03819	.09987^b	.5524	.3052

^{a} p < .05.

^{b} p < .01.

Attrition Module

The attrition function estimated by Carpenter et al. (1989) is used in this demonstration as a substitute for attrition influenced by AFQT and length of service. The function was estimated as:

$$r(x,t) = b_0 + b_1 \ln [(t + s(x)) / (48 - t)] + b_4 \qquad (18)$$

Table 7. Cost Estimates in Dollars by Month of Service

TAFMS	122X0	272X0	328X0	423X5	426X2	492X1
1	3,154	2,992	2,539	2,655	2,901	2,275
2	3,154	2,992	2,539	2,655	2,901	2,275
3	2,811	2,992	2,539	2,655	2,901	2,275
4	1,584	2,992	2,539	2,655	2,308	1,757
5	1,584	2,992	2,539	2,655	1,584	1,584
6	1,584	2,211	2,539	2,055	1,584	1,584
7	1,584	1,584	2,539	1,584	1,584	1,584
8	1,584	1,584	2,405	1,584	1,584	1,584
9	1,584	1,584	1,584	1,584	1,584	1,584
10	1,584	1,584	1,584	1,584	1,584	1,584
11	1,584	1,584	1,584	1,584	1,584	1,584
12	1,741	1,741	1,741	1,741	1,741	1,741
13	1,741	1,741	1,741	1,741	1,741	1,741
14	1,741	1,741	1,741	1,741	1,741	1,741
15	1,741	1,741	1,741	1,741	1,741	1,741
16	1,741	1,741	1,741	1,741	1,741	1,741
17	1,741	1,741	1,741	1,741	1,741	1,741
18	1,741	1,741	1,741	1,741	1,741	1,741
19	1,741	1,741	1,741	1,741	1,741	1,741
20	1,741	1,741	1,741	1,741	1,741	1,741
21	1,741	1,741	1,741	1,741	1,741	1,741
22	1,741	1,741	1,741	1,741	1,741	1,741
23	1,741	1,741	1,741	1,741	1,741	1,741
24	1,741	1,741	1,741	1,741	1,741	1,741
25	1,741	1,741	1,741	1,741	1,741	1,741
26	1,741	1,741	1,741	1,741	1,741	1,741
27	1,741	1,741	1,741	1,741	1,741	1,741
28	1,741	1,741	1,741	1,741	1,741	1,741
29	1,741	1,741	1,741	1,741	1,741	1,741
30	1,741	1,741	1,741	1,741	1,741	1,741
31	1,741	1,741	1,741	1,741	1,741	1,741
32	1,741	1,741	1,741	1,741	1,741	1,741
33	1,741	1,741	1,741	1,741	1,741	1,741
34	1,741	1,741	1,741	1,741	1,741	1,741
35	2,081	2,081	2,081	2,081	2,081	2,081
36	2,081	2,081	2,081	2,081	2,081	2,081
37	2,081	2,081	2,081	2,081	2,081	2,081
38	2,081	2,081	2,081	2,081	2,081	2,081
39	2,081	2,081	2,081	2,081	2,081	2,081
40	2,081	2,081	2,081	2,081	2,081	2,081
41	2,081	2,081	2,081	2,081	2,081	2,081
42	2,081	2,081	2,081	2,081	2,081	2,081
43	2,081	2,081	2,081	2,081	2,081	2,081
44	2,081	2,081	2,081	2,081	2,081	2,081
45	2,081	2,081	2,081	2,081	2,081	2,081
46	2,081	2,081	2,081	2,081	2,081	2,081
47	2,081	2,081	2,081	2,081	2,081	2,081
48	2,081	2,081	2,081	2,081	2,081	2,081

Note. Includes costs associated with permanent change of station.

where $s(x) = \exp(b_2 + b_3 x)$,

$r(x,t)$ = probability of an airman with an AI score of x remaining in the service after t months (t = 1 to 48),

x = AI score, and

b_0, b_1, b_2, b_3, b_4 = parameters to be estimated.

Cost Module

Cost data for fiscal year 1988 were used for each AFS. Costs included recruitment and training costs, as well as military compensation for the first 48 months of active duty. Cost was modeled as a function of time in service, but not aptitude, because cost data were not available by aptitude level. Thus, the cost module is constant across aptitude levels. The cost module includes average initial recruiting and training costs in the first 8 months of service. Military pay is included through the first term, with increases following an average promotion schedule. Table 7 presents the cost estimates for each AFS over the first 48 months of service.

Model Integration

Carpenter et al. (1989) estimated two intermediate functions enroute to determining optimal standards. These functions were expected first term productive capacity and expected first term cost. A similar process was followed for this demonstration.

Expected First Term Productive Capacity

Expected productive capacity was defined as:

$$P(x) = \sum_{t=0}^{48} r(x,t)\, p(x,t) \tag{19}$$

where $P(x)$ = expected first term productive capacity for an individual with an aptitude score of x,

x = aptitude score,

$r(x,t)$ = probability of an individual with an aptitude score of x remaining in the service after t months, and

$p(x,t)$ = productive capacity for an individual with an aptitude score of x and t months experience.

This is the same formulation defined by Carpenter et al. (1989). Based on regression results shown in Tables 5 and 6 and the attrition functions, expected productive capacity was calculated for each AFS. Tables 8 and 9 present average expected first-term productive capacity using AFQT and relevant aptitude scores, repectively. Expected productive capacity increases with aptitude and varies among the AFSs in both cases.

Table 8. Expected Average First Term Productive Capacity Based on AFQT

AFQT Decile	122X0	272X0	328X0	423X5	426X2	492X1
0 - 9	.44	.42	.38	.37	.44	.34
10 - 19	.46	.44	.41	.39	.47	.37
20 - 29	.47	.47	.45	.41	.49	.40
30 - 39	.49	.49	.48	.42	.52	.43
40 - 49	.51	.52	.52	.44	.55	.46
50 - 59	.53	.54	.56	.46	.57	.49
60 - 69	.54	.57	.60	.47	.60	.53
70 - 79	.56	.59	.64	.49	.62	.56
80 - 89	.57	.61	.67	.50	.65	.59
90 - 99	.58	.63	.71	.51	.67	.62

Table 9. Expected Average First Term Productive Capacity Based on Relevant Aptitude Score

Sel AI Decile	122X0 (G)	272X0 (G)	328X0 (E)	423X5 (E)	423X5 (M)	426X2 (M)	492X1 (A)
0 - 9	.43	.40	.31	.32	.28	.40	.41
10 - 19	.45	.43	.34	.35	.31	.43	.43
20 - 29	.47	.45	.39	.37	.33	.46	.45
30 - 39	.49	.48	.48	.43	.36	.40	.49
40 - 49	.51	.51	.47	.42	.39	.52	.48
50 - 59	.53	.53	.52	.45	.42	.55	.50
60 - 69	.55	.56	.57	.48	.46	.58	.52
70 - 79	.56	.59	.62	.50	.49	.61	.53
80 - 89	.58	.61	.66	.53	.52	.64	.55
90 - 99	.59	.64	.71	.55	.55	.66	.56

Expected First-Term Cost

As defined by Carpenter et al. (1989), expected cost was:

$$C(x) = \sum_{t=0}^{48} r(x,t)\, c(x,t) \tag{20}$$

where
x = aptitude score,
t = time in service (months),
$r(x,t)$ = probability that an individual with an aptitude score of x is still in the service after t months, and
$c(x,t)$ = cost to the Air Force of an individual at aptitude score x in month t.

Table 10 presents expected first-term (48 month) cost by AFS calculated from this formula. For these cost computations, the assumptions are: (a) all AFSs have the same retention rates by month, (b) promotion rate (and pay) is the same for all AFSs, (c) differences in expected first-term cost reflect differences in AFS training costs, and (d) there is an inverse relationship between aptitude and attrition rate.

Table 10 shows higher costs for higher aptitude levels. This is a result of lower attrition among higher aptitude individuals prior to month 48. With lower attrition, more individuals remain in the service collecting pay and compensation. There is no cost associated with airmen who have attrited from service since they no longer receive military pay. Thus, higher aptitude levels were associated with higher cost over the first term. However, these expected first term costs are deceptive. They do not reflect the fact that another airman must be brought into the service, trained, and paid to fill the slot left by the attrited airman.

As attrition occurs the expected costs defined by Carpenter et al. (1989) are associated with the remaining fraction of an airman. To know costs associated with one full airman (productive unit) at the end of 48 months, a mathematical adjustment to the expected cost function is necessary. The adjustment must consider accessions necessary to leave one full airman at the end of 48 months. This adjustment involves the reciprocal of the probability of continuing in service to the end of month 48. If an airman's probability of completing 48 months service is 0.75, 1.33 accessions are necessary to retain one full airman at month 48. This productive unit adjusted cost computation can be expressed as:

$$C(x) = [\ 1/\ r(x,48)] \sum_{t=0}^{48} r(x,t)\ c(x,t) \tag{21}$$

where
x = aptitude level,
t = time in months,
C(x) = expected first term cost for an individual at aptitude level x,
r(x,t) = probability that an individual with aptitude level x is in service after t months,
c(x,t) = cost of an individual with aptitude level x in month t, and
1/r(x,48) = recruits necessary to retain one airman in month 48.

Table 10. Expected First Term Cost in Dollars Based on AFQT

AFQT Centile	122X0	272X0	328X0	423X5	426X2	492X1
0 - 9	60,736	63,386	63,085	61,824	60,956	58,909
10 - 19	63,155	65,893	65,587	64,283	63,383	61,273
20 - 29	65,567	68,397	68,086	66,737	65,804	63,632
30 - 39	67,950	70,864	70,553	69,158	68,195	65,965
40 - 49	70,290	73,289	72,977	71,538	70,546	68,261
50 - 59	72,557	75,633	75,327	73,845	72,823	70,494
60 - 69	74,702	77,847	77,551	76,030	74,978	72,613
70 - 79	76,670	79,871	79,590	78,029	76,953	74,567
80 - 89	78,390	81,627	81,361	79,776	78,680	76,284
90 - 99	79,772	83,025	82,776	81,172	80,066	77,673

Thus, if $r(x_1,48)$ is 0.50, 2 recruits with aptitude x_1 must enter the Air Force to retain one full airman at month 48. Aptitude levels with lower attrition rates will entail lower expected first term cost for a full airman at month 48. Table 11 presents expected first term full investment costs. These are Table 10 costs adjusted to provide a full airman in month 48 (Flamholtz, 1985).

Table 11. Expected First Term Full Investment Cost in Dollars Based on AFQT

AFQT Centile	122X0	272X0	328X0	423X5	426X2	492X1
0- 9	183,398	191,400	190,491	186,683	184,062	177,881
10- 19	176,445	184,095	183,240	179,597	177,082	171,187
20- 29	170,455	177,812	177,004	173,497	171,071	165,425
30- 39	165,195	172,279	171,523	168,132	165,790	160,369
40- 49	160,516	167,365	166,652	163,366	161,101	155,883
50- 59	156,284	162,910	162,251	159,058	156,857	151,841
60- 69	152,378	158,793	158,189	155,086	152,941	148,117
70- 79	148,728	154,937	154,392	151,364	149,277	144,648
80- 89	145,309	151,309	150,816	147,878	145,846	141,405
90- 99	142,144	147,940	147,497	144,639	142,668	138,404

Integration of Expected Productive Capacity and Expected Cost

Expected productive capacity and expected full investment cost are integrated by summing the ratio of expected full investment cost to expected productivity over the entire 48 months. This summation of the ratios is expressed as:

$$[1/\ r(x,48)] \sum_{t=0}^{48} [(r(x,t)\ c(x,t))\ /\ (r(x,t)\ p(x,t))] \qquad (22)$$

where r(x,t) = probability that an aptitude level x person is in service at month t,
p(x,t) = productive capacity of an aptitude level x person at month t,
c(x,t) = cost of an aptitude level x person at t months of service,
1/r(x,48) = number of recruits necessary to retain one airman to the 48th month of service.

This computation yields the expected full investment per productive unit over the first 48 months of service. Table 12 presents these expected full investment costs per productive unit based on AFQT. Expected full investment cost per productive unit based on relevant aptitude scores are in Appendix B. These costs are consistently less for higher aptitude levels across all AFSs. This is because attrition in the first 48 months is lower for high aptitude levels and productive capacity is higher for high aptitude levels. An unequivocal direct relationship exists between expected full investment per productive unit and aptitude.

Table 12. Expected First Term Full Investment Cost Per Productive Unit in Dollars Based on AFQT

AFQT Centile	122X0	272X0	328X0	423X5	426X2	492X1
0 - 9	8,789	9,518	10,729	10,429	8,718	11,007
10 - 19	8,128	8,677	9,458	9,606	7,934	9,753
20 - 29	7,560	7,958	8,405	8,898	7,263	8,707
30 - 39	7,066	7,336	7,523	8,284	6,685	7,825
40 - 49	6,635	6,795	6,778	7,747	6,182	7,075
50 - 59	6,254	6,320	6,143	7,275	5,742	6,432
60 - 69	5,921	5,904	5,598	6,860	5,355	5,879
70 - 79	5,628	5,539	5,131	6,495	5,017	5,403
80 - 89	5,375	5,223	4,732	6,179	4,724	4,995
90 - 99	5,165	4,955	4,396	5,914	4,476	4,650

Simultaneous Application of the TTP Model to Six Career Fields

To demonstrate the simultaneous application of the TTP model to multiple specialties, 633 hypothetical recruits were allocated to the six career fields. In executing this allocation, total full investment cost per productive unit was minimized across the AFSs. The Ford-Fulkerson Primal-Dual Algorithm (Seplo, Deo, & Kowalik, 1983) was used to determine the optimal allocation. Once the optimal allocation was determined, minimum cut score standards were identified. The standards are the lowest aptitude score allocated to each specialty. The following examples illustrate.

Simultaneous Application Based on AFQT

Assume the AFQT aptitude measure is sufficient to estimate productive capacity (and thus cost per productive unit) across AFSs. The equations for computing productive capacity were summarized in Table 6. For this analysis, the AFQT aptitude level distribution of the available manpower pool is assumed to be:

AFQT level	Available cases
90-99	11
80-89	62
70-79	85
60-69	71
50-59	84
40-49	97
30-39	75
20-29	88
10-19	49
0- 9	11

The AFSs were assumed to require:

AFS	Required manning
122X0	83
272X0	131
328X0	145
423X5	45
426X2	115
492X1	114

This simulated aptitude distribution is proportional to the actual distribution of 1988 Air Force recruit aptitudes. Also, the simulated manning requirements are approximately proportional to the actual requirements in 1988. Table 13 presents the allocation of the 633 recruits across the six AFSs.

Since, in this instance, supply equals demand, 633 individuals were allocated to 633 manning slots across six AFSs. The total supply is allocated with no surplus, and no AFSs undermanned. The aptitide cut-off scores established in this example are:

AFS	AFQT Cut-off
122X0	0
272X0	40
328X0	50
423X0	30
426X0	20
492X1	70

Table 13. Allocation of the Manpower Pool Based on AFQT

To AFS	From AFQT level	Number of recruits	Cost/ productive unit	Average cost/prod unit
122X0	0 - 9[a]	11	$ 8,789	
122X0	10 - 19	49	$ 8,128	
122X0	20 - 29	23	$ 7,560	
				$ 8,058
272X0	40 - 49[a]	77	$ 6,795	
272X0	50 - 59	54	$ 6,320	
				$ 6,599
328X0	50 - 59[a]	30	$ 6,143	
328X0	60 - 69	71	$ 5,598	
328X0	70 - 79	44	$ 5,131	
				$ 5,569
423X5	30 - 39[a]	25	$ 8,284	
423X5	40 - 49	20	$ 7,747	
				$ 8,045
426X2	20 - 29[a]	65	$ 7,264	
426X2	30 - 39	50	$ 6,685	
				$ 7,012
492X1	70 - 79[a]	41	$ 5,403	
492X1	80 - 89	62	$ 4,995	
492X1	90 - 99	11	$ 4,650	
				$ 5,108
	Total Personnel = 633			

[a] Designates the aptitude level which is used as the cutoff score for the AFS.

These cut-off scores minimize productive unit costs when aptitude level, manpower pool aptitude distribution, manning requirements, and cost per productive unit within each AFS are all considered. AFSs receiving the most low aptitude recruits exhibit the highest average expected cost per productive unit. Conversely, AFSs allocated the highest aptitude recruits reflect the lowest average expected cost per productive unit. For example, AFS 122X0, was allocated the lowest average aptitude recruits, but exhibited the highest average productive unit cost ($ 8,058.00). By contrast, AFS 492X1 was allocated the highest average aptitude recruits, but exhibited the lowest average productive unit cost ($ 5,108.00).

The example presented in Table 13 established minimal cut-off scores with no constraints other than total cost per productive unit. However, one rarely chooses to let cost alone drive choice of cut-off scores. One may wish to maintain minimum manning levels in particular AFSs or to establish a minimum level of productivity as a factor in setting aptitude cut-offs. To examine implications of these factors, two additional restrictions are imposed: (1) a minimum manning requirement of 90% for each AFS, and (2) a minimum acceptable average first term productive capacity of .50 for each individual in each AFS.

Under restriction (1) AFS 122X0, for example, is assigned a minimum manning requirement of 75 recruits (vice the 83 desired). Imposition of the minimum manning restriction calls for a two step sequential allocation process by the algorithm. First, personnel are allocated across AFSs to meet minimum manning requirements while minimizing total expected cost per productive unit. Then remaining personnel are allocated across AFSs while minimizing their total expected cost per productive unit. Constraint (2) uses the expected productive capacity estimates to set the minimum aptitude level which assures expected productive capacity of 0.50 or better for each individual allocated to a given AFS.

Table 14 presents the allocation of the 633 cases to the six AFSs with constraints (1) and (2) imposed. Constraints for this allocation are:

AFS	Desired Manning	Minimum Manning	Minimum Aptitude
122X0	83	75	40
272X0	131	118	40
328X0	145	131	40
423X5	45	41	80
426X2	115	104	30
492X1	114	103	50
Total	633	572	--

Results of this allocation do not satisfy all the constraints. Outcomes, compared with the constraints, are summarized below:

	Manning				Minimum Aptitude	
AFS	Desired	Minimum	Obtained	Shortage	Mandated	Obtained
122X0	83	75	75	8	40	40
272X0	131	118	77	54	40	50
328X0	145	131	131	14	40	60
423X5	45	41	0	45	80	--
426X2	115	104	104	11	30	30
492X1	114	103	98	16	50	70
Total	633	572	485	148		

Because of the minimum aptitude constraints, 148 cases are not assignable. The remaining 485 cases are not adequate to satisfy the minimum manning requirement. Consequently, no AFS was allocated more than its minimum manning requirement. AFS 426X2, which had the highest aptitude requirement, was allocated 0 applicants (and fell short of its minimum manning requirement by 41 cases). AFSs 272X0 and 492X1 also fall short of their minimum manning. Cases suitable for allocation are assigned such that cost per productive unit is minimized. This explains the failure of the algorithm to assign cases to AFS 426X2.

Table 14. Allocation of the Manpower Pool Based on AFQT, With Minimum Manning Requirements of 90%, and Minimum Acceptable Productive Capacity Levels of 0.50

To AFS	From AFQT Level	Number of Recruits	Cost/ Prod Unit	Average Cost/Prod Unit
122XO	40 - 49[a]	75	$ 6,635	
				$ 6,635
272X0	50 - 59[a]	77	$ 6,320	
				$ 6,320
328X0	60 - 69[a]	71	$ 5,598	
328X0	70 - 79	60	$ 5,131	
				$ 5,384
426X2	30 - 39[a]	75	$ 6,685	
426X2	40 - 49	22	$ 5,742	
426X2	50 - 59	7	$ 5,403	
				$ 6,515
492X1	70 - 79[a]	25	$ 5,403	
492X1	80 - 89	62	$ 4,995	
492X1	90 - 99	11	$ 4,650	
				$ 5,060
122X0	Shortage	8		
272X0	Shortage	54		
328X0	Shortage	14		
423X5	Shortage	45		
426X2	Shortage	11		
492X1	Shortage	16		
	Total Personnel =	410		

[a] Designates the aptitude level which is used as the cutoff score for the AFS.

The policy maker faced with these outcomes has three options (or some combination of them):

(1) Obtain a larger applicant pool. This would mitigate or eliminate the shortage of assignable personnel. New aptitude cut-offs can then be established by rerunning the TTP model with the same constraints. In the present example, the larger applicant pool must contain at least 87 more cases with an aptitude level of 30 or higher to satisfy the minimum manning requirement. At least 148 more applicants with qualifying aptitude scores would be necessary to meet desired manning.

Without an adequately larger qualified applicant pool, (2) manning minimums can be reduced, or (3) minimum acceptable productive capacity (thus, minimum aptitude cut-offs) can be dropped. In the present instance, minimum manning (option 2) would have to drop to 485 or less. Option 3 would require dropping the minimum aptitude level for one or more AFSs to 0.

Simultaneous Application Based on Relevant Aptitude Scores

Capability to set cut-off scores on the Air Force's four selector AIs with the TTP model is important. For each AFS, a particular AI has been identified as the appropriate score for that job. The data used in the previous example were also used in this example. However, the four AIs were used instead of the single AFQT, and the most relevant AI was identified as the selector for each AFS. For this example, each of the four AIs were divided into four aptitude levels as follows:

Aptitude level	Score range
1	01 - 25
2	26 - 50
3	51 - 75
4	76 - 99

Tables 15 and 16 show average expected productive capacity by score quartile on AFQT and on the relevant aptitude Index, respectively.

Table 15. Expected Average First Term Productive Capacity By Quartile Based on AFQT

AFQT Quartile	122X0	272X0	328X0	423X5	426X2	492X1
01 - 25	.45	.43	.40	.38	.46	.36
26 - 50	.48	.49	.47	.41	.51	.42
51 - 75	.53	.56	.59	.46	.59	.52
76 - 99	.57	.61	.67	.50	.66	.58

Table 16. Expected Average First Term Productive Capacity by Quartile Based on Relevant Aptitude Score

Sel AI Quartile	122X0 (G)	272X0 (G)	328X0 (E)	423X5 (E)	423X5 (M)	426X2 (M)	492X1 (A)
01 - 25	.45	.42	.33	.34	.30	.42	.42
26 - 50	.49	.48	.46	.43	.36	.50	.47
51 - 75	.54	.55	.56	.47	.47	.56	.51
76 - 99	.60	.63	.65	.54	.54	.63	.55

There are 256 possible combinations of the four aptitude levels across the four AIs. We can identify each of the 256 cells by aptitude level of the four AIs (in a fixed order - Mechanical, Administrative, General, Electronic). Thus, an airman in aptitude level 1231 has scores in the following ranges: Mechanical, 1 through 25; Administrative, 26 through 50; General, 51 through 75; Electronic, 1 through 25. In this example, no subject is assigned to an AFS unless he/she meets or exceeds a stated minimum score on the AI appropriate for that AFS. In each AFS, productive capacity estimates are computed from the appropriate equation summarized in Table 5. For AFS 423X5, the Mechanical AI equation is used.

Distribution of the 633 hypothetical recruits on the 256 aptitude level cells is presented in Appendix A. Again, this distribution is proportional to the actual distribution of 1988 recruit aptitudes. Expected costs per productive unit by AFS and the 256 aptitude cells are presented in Appendix B. Minimum acceptable manning levels are set at 90% for all six of the AFSs. A minimum average productive capacity level (over 48 months of service as presented in Table 9) of 0.50 was imposed for each of the AFSs. Constraints imposed on the allocation problem are summarized below:

	Manning		Aptitude	
AFS	Desired	Minimum	Apt Index	Minimum
122X0	83	75	General	25
272X0	131	118	General	25
328X0	145	131	Elect	50
423X5	45	41	Elect	75
426X2	115	104	Mech	25
492X1	114	103	Admin	50
Total	633	572		

Results of the minimized cost per productive unit allocation of the 633 cases under the stated constraints are presented in Appendix D. The unconstrained allocation is presented in Appendix C.

With constraints imposed, the allocation outcome is:

	Manning				Aptitude		
AFS	Desired	Min	Obt	Short	Index	Min	Obt
122X0	83	75	83	0	Gen	25	25
272X0	131	118	131	0	Gen	25	50
328X0	145	131	131	14	Elect	50	50
423X5	45	41	41	4	Elect	75	75
426X2	115	104	112	3	Mech	25	25
492X1	114	103	103	11	Admin	50	50
Total	633	572	601	32			

Four AFSs have assignment shortages: 328X0 with 14, 423X5 with 4, 426X2 with 3, and 492X1 with 11. However, in every instance minimum manning was achieved. In only one AFS, 272X0, was it possible to establish a cut-off score above the minimum average productive capacity level of 0.50. The cut-off score established for an AFS is a function of manpower pool aptitude distribution, the pool's size, minimum manning requirements, and minimum acceptable average productive capacity for each AFS.

A cut-off score for each AFS is set on only one aptitude score. Individuals qualified for a particular AFS may be unqualified for one or more other AFSs. For example, 86 (64.7%) of the 131 people allocated to AFS 328X0 had an aptitude score less than 51 on one or more of the three non-relevant AIs (M, A, or G). Fourteen (10.7%) of the 71 cases allocated to AFS 328X0 had scores below 26 on one or more of the non-relevant AIs. Individuals with an adequate relevant AI score but low scores on non-relevant AIs are still viable candidates for the AFS. If a single aptitude score were used to establish qualification for all AFSs, fewer of these individuals could be allocated to an AFS, and manning shortfalls would be larger. This is demonstrated in Appendices E and F. Use of multiple, differential scores for classification to AFSs permits fuller utilization of the available manpower pool.

V. CONCLUSIONS AND RECOMMENDATIONS

The TTP model establishes relationships between productive capacity and aptitude. It also estimates the level of aptitude and experience needed to yield a specified level of job performance. The model minimizes the overall full investment cost of manning AFSs within the limitations of a defined manpower pool and specified set of allocation constraints.

Integration of the TTP Model

The TTP Model was integrated using the Carpenter et al (1989) approach with two fundamental exceptions:

1. Expected cost per productive unit calculation was modified. The Carpenter et al. (1989) method computed cost for the fraction of a worker remaining in service at month 48. The modified method computes cost of a full worker at month 48. If probability of retention to the 48th month of service is .33, three people must be accessed to have one airman at the 48th month, and cost must be adjusted accordingly. This adjustment assumes that the expected cost per productive unit is the full investment cost of retaining a full worker to month 48.

2. A linear function was used for the model's productive capacity module since the linear specification yielded the highest R^2 values and the best t-statistics (Stone, 1989).

The model was extended to a multiple AFS and multiple aptitude paradigm. This necessitated changes, especially in the specification of the objective function to be minimized. Previously, Carpenter et al. (1989) selected the aptitude score which minimized expected cost per productive unit given that score's distribution aptitude score in the manpower pool. With multiple AFSs, each with a particular relevant aptitude score, the objective function becomes minimum total manning cost across all AFSs.

The primary factors affecting the expected full investment cost per productive unit are aptitude level, attrition and productive capacity. Expected full investment cost per productive unit decreases as aptitude increases. Thus, establishing a particular AFS's cut-off score through the TTP model without considering the simultaneous impact on other AFSs produces an inflated answer. The available pool must simultaneously accommodate the needs of all AFSs. The minimization of expected full investment cost per productive unit will almost always assign the highest aptitude groups first.

The TTP model permits specification of policy constraints such as designation of the appropriate aptitude score, minimum acceptable productive capacity, and minimum acceptable manning level for each AFS. Establishing a minimum acceptable aptitude score for all AFSs (e.g., G equal to 40 or above) reduces the size of the available manpower pool. This could result in manning shortfalls if the overall aptitude minimum is set too high. Similarly, establishing separate minimum aptitude levels and aptitude indexes (i.e., M, A, G, or E) for each AFS reduces available manning, but not as severely as does a single aptitude score and minimum for across all AFSs.

The distribution of aptitude scores in the available manpower pool directly affects costs and cut-off scores in all AFSs. The Ford-Fulkerson Primal-Dual Algorithm (Seplo et al., 1983) is used to allocate personnel to competing AFSs in ways that minimize the total expected cost per productive unit.

The TTP model establishes cut-off scores for AFSs without regard to their importance to the overall mission readiness of the force. Incompatability between lowest cost per productive unit and AFS criticality can arise in application of the TTP model. This is because an AFS with high cost per productive unit may help minimize total cost by taking lower ability people. Thus, the allocation could set a low cut-off score for Air Traffic Controllers, while setting a high cut-off score for less critical jobs. Personnel planners might consider such an allocation inappropriate. The TTP model allows planners to set constraints such as minimum acceptable productivity and manning levels for the AFSs as one way of off-setting this problem.

By specifying these constraints and allocating the expected applicant pool against manning needs, several objectives of value are accomplished. (1) One can determine whether acceptable manning is achievable from the available manpower pool. (2) If not, the system can be exercised to determine necessary trade-offs. (3) While policy judgment determines acceptable minimums, one can establish standards that exceed this bare minimum if the applicant pool is adequate.

The TTP model applications in this paper utilized productive capacity estimates based upon data accumulated in the Air Force's JPMS project. These data were not designed to yield optimal productive capacity indicators. Thus, future research on the model should be based upon measures specifically designed as productive capacity indicators.

Development of appropriate productive capacity measures involves:

1. Developing a set of important job tasks and standards/guidelines/factors by which to define the optimal performance. This requires systematic use of Air Force job survey data (Comprehensive Occupational Data Analysis Program (CODAP)) and panels of job experts (experienced Non-Commissioned Officers). It is anticipated that observable time (t^*) and quality of work (q^*) factors by which performance can be judged will be identified. Finally, these materials should be prepared as a set of instructional materials from which worker performance can be compared and rated. In addition, appropriate rating forms for supervisor rating of workers should be developed.

2. For at least two AFSs, ratings (yielding t and q) should be collected on a sample of workers who are also administered the JPMS project job performance measures. For each of these workers, productive capacity indicators (t^*/t and q/q^*) should be computed.

3. These productive capacity indicators should be validated against the job performance measures (or productive capacity estimates based upon them).

4. The TTP model should be applied to these data, and the outcomes should be compared to those based on estimates of productive capacity from the JPMS project measures.

5. If the model still looks adaquately promising, the more direct productive capacity measures should be developed for a broad spectrum of AFSs. This would allow test/job performance linkage work across the broader spectrum of jobs using the TTP model.

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GLOSSARY FOR APPENDIXES A - F

MAG&E aptitude levels are presented as series of four digits. The first digit indicates the score level of M, the second digit indicates the score level of A, the third digit indicates the score level of G, and the fourth digit indicates the score level of E. MAG&E score levels are as follows:

SCORE LEVEL	M, A, G OR E PERCENTILE
1>	0 and < 26
2>	25 and < 51
3>	50 and < 76
4>	75 and < 100

APPENDIX A: DISTRIBUTION OF MAGE

MAGE	Freq	MAGE	Freq	MAGE	Freq	MAGE	Freq
2211	4	2122	1	3442	9	3343	10
1221	5	1222	4	4442	7	4343	3
2221	18	2222	31	2213	7	3443	6
3221	2	3222	8	3213	4	4443	21
2321	6	2322	20	3313	3	3214	2
3321	3	3322	16	2223	14	3314	2
1231	9	3422	1	3223	10	2224	2
2231	17	4422	1	2323	5	3224	10
3231	2	1232	3	3323	24	3324	11
2331	9	2232	18	4323	3	4324	5
3331	5	3232	6	3423	2	3424	1
3431	1	2332	12	4423	4	4424	7
1241	3	3333	24	2233	7	3234	2
2241	5	4332	2	3233	6	3334	10
2341	6	3432	6	2333	5	4334	6
3341	3	4432	3	3333	29	3434	2
3441	2	2242	5	4333	6	4434	21
2212	14	3242	2	3433	6	3344	3
3212	3	2342	6	4433	14	4344	3
2312	3	3342	14	2243	2	3444	1
3312	2	4342	1	3243	2	4444	28
1221	5	3442	9	2343	2	4343	3
2221	18	2222	31	2213	7	3443	6
3221	2	3222	8	3213	4	4443	21
2321	6	2322	20	3313	3	3214	7
3321	3	3322	16	2223	14	3314	2
1231	9	3422	1	3223	10	2224	2
2231	17	4422	1	3323	24	3224	10
3231	2	1232	3	4323	3	3324	11
2331	9	2232	18	3423	2	4324	5
3331	5	3232	6	4423	4	3424	1
3431	1	2332	12	2233	7	4424	7
1241	3	3333	24	3233	6	3234	2
2241	5	4332	2	2333	5	3334	10
2341	6	3432	6	3333	29	4334	6
3341	3	4432	3	4333	6	3434	2
3441	2	2242	5	3433	6	4434	21
2212	14	3242	2	4433	14	3344	3
3212	3	2342	6	2243	2	4344	3
2312	3	3342	14	3243	2	3444	1
3312	2	4342	1	2343	2	4444	28

Total Number = 633

APPENDIX B: EXPECTED FULL INVESTMENT COST PER PRODUCTIVE UNIT

MAGE level	AFS 122X0	AFS 272X0	AFS 328X0	AFS 423X5	AFS 426X2	AFS 492X1
1111	8,389	9,291	11,972	12,677	8,939	8,479
1112	8,009	8,870	9,380	12,102	8,534	8,094
1113	7,666	8,490	7,640	11,584	8,168	7,748
1114	7,372	8,165	6,402	11,139	7,855	7,451
1121	8,317	8,786	11,974	12,679	8,941	8,480
1122	7,940	8,388	9,382	12,104	8,535	8,096
1123	7,600	8,028	7,641	11,585	8,170	7,749
1124	7,308	7,720	6,403	11,141	7,856	7,452
1131	8,252	8,339	11,984	12,689	8,948	8,487
1132	7,878	7,961	9,389	12,113	8,542	8,102
1133	7,540	7,620	7,647	11,594	8,176	7,755
1134	7,251	7,327	6,408	11,149	7,862	7,457
1141	8,214	7,963	12,032	12,740	8,984	8,521
1142	7,840	7,600	9,425	12,160	8,575	8,133
1143	7,503	7,273	7,675	11,637	8,206	7,783
1144	7,214	6,993	6,430	11,188	7,890	7,483
1211	7,660	8,484	10,932	11,575	8,162	7,694
1212	7,342	8,131	8,599	11,094	7,823	7,375
1213	7,053	7,811	7,028	10,657	7,515	7,084
1214	6,803	7,534	5,908	10,279	7,249	6,833
1221	7,594	8,022	10,933	11,577	8,163	7,696
1222	7,279	7,689	8,600	11,095	7,824	7,376
1223	6,992	7,386	7,029	10,658	7,516	7,085
1224	6,744	7,124	5,909	10,281	7,250	6,834
1231	7,534	7,614	10,941	11,585	8,170	7,701
1232	7,221	7,297	8,607	11,103	7,830	7,381
1233	6,936	7,010	7,034	10,666	7,521	7,090
1234	6,690	6,761	5,913	10,288	7,255	6,839
1241	7,497	7,268	10,982	11,628	8,200	7,730
1242	7,184	6,964	8,637	11,142	7,857	7,407
1243	6,900	6,689	7,058	10,702	7,546	7,114
1244	6,655	6,451	5,932	10,321	7,278	6,861
1311	7,052	7,810	10,063	10,655	7,514	7,040
1312	6,781	7,510	7,942	10,246	7,225	6,770
1313	6,534	7,236	6,511	9,872	6,962	6,523
1314	6,319	6,998	5,488	9,548	6,733	6,308
1321	6,991	7,385	10,064	10,657	7,515	7,041
1322	6,723	7,101	7,943	10,248	7,226	6,770
1323	6,477	6,842	6,512	9,874	6,963	6,523
1324	6,264	6,617	5,488	9,549	6,734	6,309
1331	6,935	7,009	10,071	10,664	7,520	7,046
1332	6,669	6,739	7,949	10,254	7,231	6,775
1333	6,425	6,493	6,516	9,880	6,967	6,528
1334	6,214	6,280	5,492	9,555	6,738	6,313
1341	6,899	6,688	10,105	10,700	7,545	7,070
1342	6,633	6,430	7,974	10,288	7,255	6,797
1343	6,390	6,194	6,536	9,911	6,[illegible]89	6,548
1344	6,179	5,990	5,508	9,584	6,758	6,332
1411	6,549	7,253	9,346	9,896	6,978	6,498

APPENDIX B: (Continued)

MAGE level	AFS 122X0	AFS 272X0	AFS 328X0	AFS 423X5	AFS 426X2	AFS 492X1
1412	6,315	6,994	7,396	9,542	6,729	6,266
1413	6,100	6,756	6,079	9,217	6,499	6,052
1414	5,912	6,548	5,134	8,933	6,299	5,866
1421	6,492	6,858	9,347	9,897	6,979	6,499
1422	6,260	6,613	7,397	9,543	6,729	6,267
1423	6,047	6,388	6,079	9,218	6,500	6,053
1424	5,861	6,191	5,135	8,934	6,300	5,867
1431	6,440	6,509	9,353	9,903	6,983	6,503
1432	6,210	6,276	7,402	9,549	6,734	6,270
1433	5,998	6,062	6,083	9,223	6,504	6,057
1434	5,814	5,875	5,138	8,939	6,304	5,870
1441	6,405	6,209	9,382	9,934	7,005	6,524
1442	6,175	5,986	7,424	9,578	6,754	6,289
1443	5,964	5,782	6,101	9,250	6,523	6,074
1444	5,780	5,603	5,152	8,965	6,322	5,887
2111	8,009	8,870	11,429	10,694	7,971	8,094
2112	7,661	8,485	8,974	10,230	7,625	7,743
2113	7,347	8,137	7,322	9,811	7,312	7,426
2114	7,076	7,837	6,146	9,449	7,043	7,152
2121	7,940	8,388	11,431	10,696	7,972	8,096
2122	7,596	8,024	8,975	10,232	7,626	7,744
2123	7,284	7,694	7,323	9,812	7,313	7,427
2124	7,016	7,411	6,147	9,450	7,044	7,153
2131	7,878	7,961	11,440	10,704	7,978	8,102
2132	7,536	7,615	8,982	10,239	7,632	7,750
2133	7,226	7,303	7,328	9,819	7,318	7,432
2134	6,960	7,033	6,151	9,457	7,049	7,158
2141	7,840	7,600	11,484	10,745	8,009	8,133
2142	7,498	7,269	9,015	10,277	7,660	7,779
2143	7,189	6,969	7,354	9,854	7,344	7,458
2144	6,923	6,711	6,172	9,489	7,072	7,182
2211	7,342	8,131	10,477	9,803	7,307	7,375
2212	7,049	7,807	8,256	9,412	7,015	7,080
2213	6,782	7,511	6,758	9,056	6,749	6,812
2214	6,551	7,255	5,689	8,747	6,519	6,580
2221	7,279	7,689	10,479	9,805	7,308	7,376
2222	6,988	7,382	8,257	9,413	7,016	7,081
2223	6,723	7,102	6,759	9,057	6,750	6,813
2224	6,494	6,860	5,690	8,748	6,520	6,581
2231	7,221	7,297	10,486	9,812	7,313	7,381
2232	6,932	7,006	8,263	9,420	7,021	7,086
2233	6,670	6,740	6,764	9,063	6,755	6,818
2234	6,442	6,510	5,693	8,754	6,524	6,585
2241	7,184	6,964	10,523	9,846	7,339	7,407
2242	6,896	6,685	8,291	9,452	7,045	7,110
2243	6,634	6,431	6,786	9,092	6,777	6,840
2244	6,407	6,211	5,711	8,781	6,545	6,606
2311	6,781	7,510	9,677	9,055	6,749	6,770
2312	6,530	7,232	7,649	8,720	6,499	6,519
2313	6,300	6,978	6,279	8,413	6,270	6,290

APPENDIX B: (Continued)

MAGE level	AFS 122X0	AFS 272X0	AFS 328X0	AFS 423X5	AFS 426X2	AFS 492X1
2314	6,100	6,756	5,298	8,146	6,071	6,090
2322	6,474	6,839	7,650	8,721	6,500	6,520
2323	6,246	6,598	6,280	8,414	6,271	6,291
2324	6,048	6,389	5,299	8,147	6,072	6,091
2331	6,669	6,739	9,684	9,062	6,754	6,775
2332	6,422	6,490	7,654	8,726	6,504	6,524
2333	6,196	6,261	6,283	8,419	6,275	6,295
2334	5,999	6,062	5,302	8,152	6,076	6,095
2341	6,633	6,430	9,716	9,091	6,776	6,797
2342	6,387	6,191	7,678	8,754	6,524	6,545
2343	6,161	5,973	6,302	8,445	6,294	6,314
2344	5,965	5,782	5,317	8,175	6,093	6,112
2411	6,315	6,994	9,011	8,432	6,285	6,266
2412	6,097	6,752	7,141	8,141	6,068	6,049
2413	5,896	6,530	5,876	7,873	5,868	5,850
2414	5,720	6,335	4,968	7,638	5,693	5,676
2421	6,260	6,613	9,012	8,433	6,285	6,267
2422	6,044	6,385	7,142	8,142	6,068	6,050
2423	5,845	6,174	5,876	7,874	5,869	5,851
2424	5,671	5,991	4,969	7,639	5,694	5,677
2431	6,210	6,276	9,018	8,438	6,289	6,270
2432	5,995	6,059	7,146	8,147	6,072	6,054
2433	5,798	5,859	5,880	7,878	5,872	5,854
2434	5,625	5,685	4,971	7,644	5,697	5,680
2441	6,175	5,986	9,045	8,464	6,308	6,289
2442	5,961	5,779	7,167	8,170	6,090	6,071
2443	5,764	5,588	5,896	7,901	5,889	5,871
2444	5,592	5,421	4,985	7,664	5,713	5,695
3111	7,666	8,490	10,940	9,172	7,158	7,748
3112	7,347	8,137	8,605	8,790	6,861	7,426
3113	7,058	7,816	7,033	8,444	6,590	7,133
3114	6,807	7,539	5,912	8,145	6,357	6,880
3121	7,600	8,028	10,941	9,173	7,160	7,749
3122	7,284	7,694	8,607	8,792	6,862	7,427
3123	6,997	7,391	7,034	8,445	6,591	7,134
3124	6,749	7,129	5,913	8,146	6,358	6,881
3131	7,540	7,620	10,950	9,180	7,165	7,755
3132	7,226	7,303	8,613	8,798	6,867	7,432
3133	6,941	7,015	7,039	8,451	6,596	7,139
3134	6,695	6,766	5,917	8,151	6,362	6,886
3141	7,503	7,273	10,990	9,214	7,191	7,783
3142	7,189	6,969	8,643	8,829	6,891	7,458
3143	6,905	6,693	7,063	8,480	6,618	7,163
3144	6,659	6,455	5,936	8,178	6,383	6,908
3211	7,053	7,811	10,064	8,438	6,586	7,084
3212	6,782	7,511	7,943	8,114	6,333	6,812
3213	6,534	7,237	6,512	7,818	6,102	6,564
3214	6,319	6,999	5,488	7,561	5,901	6,348
3221	6,992	7,386	10,066	8,439	6,587	7,085
3222	6,723	7,102	7,944	8,115	6,334	6,813

APPENDIX B: (Continued)

MAGE level	AFS 122X0	AFS 272X0	AFS 328X0	AFS 423X5	AFS 426X2	AFS 492X1
3223	6,478	6,843	6,513	7,819	6,103	6,564
3224	6,265	6,618	5,489	7,562	5,902	6,348
3231	6,936	7,010	10,073	8,445	6,591	7,090
3232	6,670	6,740	7,950	8,121	6,338	6,818
3233	6,426	6,494	6,517	7,824	6,106	6,569
3234	6,215	6,280	5,492	7,566	5,905	6,352
3241	6,900	6,689	10,107	8,474	6,613	7,114
3242	6,634	6,431	7,975	8,147	6,358	6,840
3243	6,391	6,195	6,537	7,848	6,126	6,589
3244	6,180	5,991	5,509	7,589	5,923	6,372
3311	6,534	7,236	9,324	7,817	6,101	6,523
3312	6,300	6,978	7,379	7,538	5,883	6,290
3313	6,086	6,741	6,065	7,282	5,683	6,076
3314	5,899	6,534	5,123	7,058	5,509	5,890
3321	6,477	6,842	9,325	7,818	6,102	6,523
3322	6,246	6,598	7,380	7,539	5,884	6,291
3323	6,034	6,374	6,066	7,283	5,684	6,077
3324	5,849	6,178	5,124	7,059	5,509	5,890
3331	6,425	6,493	9,331	7,823	6,106	6,528
3332	6,196	6,261	7,385	7,544	5,888	6,295
3333	5,985	6,049	6,070	7,287	5,687	6,081
3334	5,801	5,863	5,127	7,063	5,513	5,894
3341	6,390	6,194	9,360	7,847	6,125	6,548
3342	6,161	5,973	7,407	7,566	5,905	6,314
3343	5,951	5,769	6,087	7,308	5,704	6,098
3344	5,768	5,591	5,141	7,083	5,528	5,910
3411	6,100	6,756	8,704	7,298	5,696	6,052
3412	5,896	6,530	6,906	7,054	5,506	5,850
3413	5,708	6,322	5,688	6,829	5,330	5,664
3414	5,543	6,139	4,814	6,632	5,176	5,500
3421	6,047	6,388	8,705	7,299	5,696	6,053
3422	5,845	6,174	6,907	7,055	5,506	5,851
3423	5,659	5,978	5,689	6,830	5,331	5,665
3424	5,496	5,805	4,815	6,633	5,177	5,501
3431	5,998	6,062	8,711	7,303	5,700	6,057
3432	5,798	5,859	6,911	7,059	5,509	5,854
3433	5,613	5,672	5,692	6,834	5,334	5,668
3434	5,451	5,509	4,817	6,637	5,180	5,504
3441	5,964	5,782	8,736	7,324	5,716	6,074
3442	5,764	5,588	6,930	7,079	5,525	5,871
3443	5,580	5,409	5,708	6,853	5,348	5,683
3444	5,418	5,253	4,830	6,654	5,193	5,519
4111	7,372	8,165	10,520	7,990	6,484	7,451
4112	7,076	7,837	8,288	7,670	6,224	7,152
4113	6,807	7,539	6,784	7,378	5,988	6,880
4114	6,574	7,281	5,710	7,126	5,783	6,645
4121	7,308	7,720	10,521	7,991	6.485	7,452
4122	7,016	7,411	8,290	7,671	6,225	7,153
4123	6,749	7,129	6,785	7,379	5,989	6,881
4124	6,518	6,885	5,710	7,127	5,784	6,646

APPENDIX B: (Continued)

MAGE level	AFS 122X0	AFS 272X0	AFS 328X0	AFS 423X5	AFS 426X2	AFS 492X1
4131	7,251	7,327	10,529	7,997	6,490	7,457
4132	6,960	7,033	8,295	7,676	6,230	7,158
4133	6,695	6,766	6,789	7,384	5,993	6,886
4134	6,466	6,534	5,714	7,131	5,787	6 650
4141	7,214	6,993	10,566	8,025	6,513	7,483
4142	6,923	6,711	8,323	7,702	6,251	7,182
4143	6,659	6,455	6,812	7,408	6,012	6,908
4144	6,430	6,233	5,732	7,154	5,806	6,671
4211	6,803	7,534	9,708	7,374	5,984	6,833
4212	6,551	7,255	7,672	7,100	5,762	6,580
4213	6,319	6,999	6,298	6,849	5,559	6,348
4214	6,118	6,776	5,313	6,631	5,381	6,145
4221	6,744	7,124	9,709	7,375	5,985	6,834
4222	6,494	6,860	7,673	7,101	5,763	6,581
4223	6,265	6,618	6,298	6,850	5,559	6,348
4224	6,065	6,407	5,314	6,632	5,382	6,146
4231	6,690	6,761	9,716	7,379	5,989	6,839
4232	6,442	6,510	7,678	7,106	5,766	6,585
4233	6,215	6,280	6,302	6,855	5,563	6,352
4234	6,017	6,080	5,317	6,636	5,385	6,150
4241	6,655	6,451	9,747	7,403	6,008	6,861
4242	6,407	6,211	7,702	7,128	5,784	6,606
4243	6,180	5,991	6,321	6,875	5,580	6,372
4244	5,982	5,799	5,333	6,656	5,401	6,168
4311	6,319	6,998	9,017	6,849	5,558	6,308
4312	6,100	6,756	7,145	6,612	5,366	6,090
4313	5,899	6,534	5,879	6,394	5,189	5,890
4314	5,724	6,339	4,971	6,204	5,034	5,714
4321	6,264	6,617	9,018	6,849	5,559	6,309
4322	6,048	6,389	7,146	6,613	5,367	6,091
4323	5,849	6,178	5,880	6,395	5,190	5,890
4324	5,674	5,994	4,971	6,204	5,035	5,715
4331	6,214	6,280	9,024	6,854	5,562	6,313
4332	5,999	6,062	7,150	6,617	5,370	6,095
4333	5,801	5,863	5,883	6,399	5,193	5,894
4334	5,628	5,688	4,974	6,208	5,038	5,718
4341	6,179	5,990	9,051	6,874	5,579	6,332
4342	5,965	5,782	7,171	6,636	5,385	6,112
4343	5,768	5,591	5,900	6,417	5,207	5,910
4344	5,595	5,424	4,988	6,225	5,052	5,734
4411	5,912	6,548	8,437	6,408	5,200	5,866
4412	5,720	6,335	6,700	6,200	5,032	5,676
4413	5,543	6,139	5,524	6,008	4,876	5,500
4414	5,388	5,967	4,679	5,840	4,729	5,346
4421	5,861	6,191	8,438	6,409	5,201	5,867
4422	5,671	5,991	6,701	6,201	5,032	5,677
4423	5,496	5,805	5,525	6,009	4,876	5,501
4424	5,341	5,642	4,680	5,840	4,740	5,347
4431	5,814	5,875	8,442	6,412	5,204	5,870
4432	5,625	5,685	6,705	6,204	5,035	5,680

APPENDIX B: (Concluded)

MAGE level	AFS 122X0	AFS 272X0	AFS 328X0	AFS 423X5	AFS 426X2	AFS 492X1
4433	5,451	5,509	5,528	6,012	4,879	5,504
4434	5,298	5,354	4,682	5,844	4,742	5,350
4441	5,780	5,603	8,466	6,430	5,218	5,887
4442	5,592	5,421	6,723	6,221	5,049	5,695
4443	5,418	5,253	5,543	6,028	4,892	5,519
4444	5,266	5,105	4,694	5,859	4,754	5,363

APPENDIX C: ALLOCATION OF THE MANPOWER POOL BASED ON RELEVANT APTITUDE SCORES

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
122X0	1221	5	$ 7,594	
122X0	1222	4	7,279	
122X0	1231	9	7,534	
122X0	1232	3	7,221	
122X0	2122	1	7,596	
122X0	2221	18	7,279	
122X0	2231	17	7,221	
122X0	2232	18	[illegible]	
122X0	2331	8	6,669	$ 7,181
272X0	1241	3	7,268	
272X0	2233	7	6,740	
272X0	2241	5	6,964	
272X0	2242	5	6,685	
272X0	2243	2	6,431	
272X0	2331	1	6,739	
272X0	2332	12	6,490	
272X0	2333	5	6,261	
272X0	2341	6	6,430	
272X0	2342	6	6,191	
272X0	2343	2	5,973	
272X0	3242	2	6,431	
272X0	3243	2	6,195	
272X0	3333	29	6,049	
272X0	3341	3	6,194	
272X0	3342	14	5,973	
272X0	3343	10	5,769	
272X0	3441	2	5,782	
272X0	3442	9	5,588	
272X0	3443	6	5,409	6,172
328X0	2213	7	6,758	
328X0	2223	14	6,759	
328X0	2224	2	5,690	
328X0	3214	2	5,488	
328X0	3214	5	5,488	
328X0	3224	10	5,489	
328X0	3234	2	5,492	
328X0	3314	2	5,123	
328X0	3323	3	6,066	
328X0	3324	11	5,124	
328X0	3334	10	5,127	
328X0	3344	3	5,127	
328X0	3424	1	4,815	
328X0	3434	2	4,817	
328X0	3444	1	4,830	
328X0	4324	5	4,971	
328X0	4334	6	$ 4,974	
328X0	4344	3	4,988	
328X0	4424	7	4,680	
328X0	4434	21	4,682	

APPENDIX C: (Concluded)

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
328X0	4444	28	5,513	$ 5,273
423X5	4422	1	6,201	
423X5	4423	4	6,009	
423X5	4432	3	6,204	
423X5	4433	14	6,012	
423X5	4442	2	6,221	
423X5	4443	21	6,028	6,635
426X2	3212	3	6,333	
426X2	3213	4	6,102	
426X2	3221	2	6,587	
426X2	3222	8	6,334	
426X2	3223	10	6,103	
426X2	3231	2	6,591	
426X2	3232	6	6,338	
426X2	3233	6	6,106	
426X2	3312	2	5,883	
426X2	3313	3	5,683	
426X2	3321	3	6,102	
426X2	3322	16	5,884	
426X2	3323	1	5,684	
426X2	3331	5	6,106	
426X2	3332	24	5,888	
426X2	4323	3	5,190	
426X2	4332	2	5,370	
426X2	4333	6	5,193	
426X2	4342	1	5,385	
426X2	4343	3	5,207	
426X2	4442	5	5,049	5,901
492X1	2211	4	7,375	
492X1	2212	14	7,080	
492X1	2222	31	7,081	
492X1	2312	3	6,519	
492X1	2321	6	6,770	
492X1	2322	20	6,520	
492X1	3323	20	6,077	
492X1	3422	1	5,851	
492X1	3423	2	5,665	
492X1	3431	1	6,057	
492X1	3432	6	5,854	
492X1	3433	6	5,668	6,602

Total Personnel = 633

APPENDIX D: ALLOCATION OF THE MANPOWER POOL BASED ON RELEVANT APTITUDE SCORES, WITH MINIMUM MANNING REQUIREMENTS OF 90%, AND MINIMUM ACCEPTABLE PRODUCTIVE CAPACITY LEVELS OF .50

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
122X0	1222	4	$ 7,279	
122X0	2221	4	7,279	
122X0	2222	31	6,988	
122X0	2231	14	7,221	
122X0	2232	18	6,932	
122X0	2233	3	6,670	
122X0	2331	9	6,669	$ 6,997
272X0	1231	7	7,614	
272X0	1232	3	7,297	
272X0	1241	3	7,268	
272X0	2231	3	7,297	
272X0	2233	4	6,740	
272X0	2241	5	6,964	
272X0	2242	5	6,685	
272X0	2243	2	6,431	
272X0	2341	6	6,430	
272X0	2342	6	6,191	
272X0	2343	2	5,973	
272X0	3242	2	6,431	
272X0	3243	2	6,195	
272X0	3332	9	6,261	
272X0	3341	3	6,194	
272X0	3342	14	5,973	
272X0	3343	10	5,769	
272X0	3441	2	5,782	
272X0	344	9	5,588	
272X0	3443	6	5,409	
272X0	4442	7	5,421	
272X0	4443	21	5,253	6,097
328X0	2213	7	6,758	
328X0	2223	14	6,759	
328X0	2224	2	5,690	
328X0	2323	5	6,280	
328X0	2333	5	6,283	
328X0	3214	2	5,488	
328X0	3224	10	5,489	
328X0	3234	2	5,492	
328XO	3313	3	6,065	
328X0	3314	2	5,123	
328X0	3323	19	6,066	
328X0	3324	11	5,124	
328X0	3333	3	6,070	
328X0	3334	10	5,127	
328X0	3344	3	5,141	
328X0	3424	1	4,815	
328X0	3434	2	$ 4,817	
328X0	3444	1	4,830	

APPENDIX D: (Concluded)

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
328X0	4324	5	4,971	
328X0	4334	6	4,974	
328X0	4344	3	4,988	
328X0	4444	15	4,694	
328X0	shortage	14	-----	$ 5,628
423X5	4323	3	6,395	
423X5	4424	7	5,840	
423X5	4434	21	5,844	
423X5	4444	13	5,859	
423X5	shortage	14	-----	5,803
426X2	2212	11	7,015	
426X2	3212	3	6,333	
426X2	3213	4	6,102	
426X2	3221	2	6,587	
426X2	3222	8	6,334	
426X2	3223	10	6,103	
426X2	3231	2	6,591	
426X2	3232	6	6,338	
426X2	3233	6	6,106	
426X2	3312	2	5,883	
426X2	3321	3	6,102	
426X2	3322	16	5,884	
426X2	3331	5	6,106	
426X2	4332	2	5,370	
426X2	4333	6	5,193	
426X2	4342	1	5,385	
426X2	4343	3	5,207	
426X2	4422	1	5,032	
426X2	4423	4	4,876	
426X2	4432	3	5,035	
426X2	4433	14	4,879	5,883
492X1	2312	3	6,519	
492X1	2321	6	6,770	
492X1	2322	20	6,520	
492X1	2332	12	6,524	
492X1	3323	5	6,077	
492X1	3332	15	6,295	
492X1	3333	26	6,081	
492X1	3422	1	5,851	
492X1	3423	2	5,665	
492X1	3431	1	6,057	
492X1	3432	6	5,854	
492X1	3433	6	5,668	
492X1	shortage	11	-----	6,254

Total Personnel = 633

APPENDIX E: ALLOCATION OF THE MANPOWER POOL BASED ON RELEVANT APTITUDE SCORES WITH A MINIMUM G SCORE REQUIREMENT OF 25

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
122X0	1221	5	$ 7,594	
122X0	1222	4	7,279	
122X0	1231	3	7,534	
122X0	1232	3	7,221	
122X0	2221	10	7,279	
122X0	2231	17	7,221	
122X0	2232	18	6,932	
122X0	2233	7	6,670	
122X0	2331	9	6,669	
122X0	2332	7	6,422	$ 7,029
272X0	1231	6	7,614	
272X0	1241	3	7,268	
272X0	2241	5	6,964	
272X0	2242	5	6,685	
272X0	2243	2	6,431	
272X0	2332	5	6,490	
272X0	2333	5	6,261	
272X0	2341	6	6,430	
272X0	2342	6	6,191	
272X0	2343	2	5,973	
272X0	3242	2	6,431	
272X0	3243	2	6,195	
272X0	3333	29	6,049	
272X0	3341	3	6,194	
272X0	3342	14	5,973	
272X0	3343	10	5,769	
272X0	3441	2	5,782	
272X0	3442	9	5,588	
272X0	3443	6	5,409	
272X0	4442	2	5,421	
272X0	shortage	7	-----	5,851
328X0	2223	14	6,759	
328X0	2224	2	5,690	
328X0	2323	5	6,280	
328X0	3224	10	5,489	
328X0	3234	2	5,492	
328X0	3324	11	5,124	
328X0	3334	10	5,127	
328X0	3344	3	5,141	
328X0	3424	1	4,815	
328X0	3434	2	4,817	
328X0	3444	1	4,830	
328X0	4324	5	4,971	
328X0	4334	6	4,974	
328X0	4344	3	4,988	
328X0	4424	7	$ 4,680	
328X0	4434	21	4,682	
328X0	4444	28	4,694	

APPENDIX E: (Concluded)

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
328X0	shortage	14	-----	$ 4,087
423X5	4422	1	6,201	
423X5	4423	4	6,009	
423X5	4432	1	6,204	
423X5	4433	14	6,012	
423X5	4443	21	6,028	
423X5	shortage	4	-----	5,493
426X2	2122	1	7,626	
426X2	2221	2	7,308	
426X2	3221	2	6,587	
426X2	3222	8	6,334	
426X2	3223	10	6,103	
426X2	3231	2	6,591	
426X2	3232	6	6,338	
426X2	3233	6	6,106	
426X2	3321	3	6,102	
426X2	3322	16	5,884	
426X2	3331	5	6,106	
426X2	3332	24	5,888	
426X2	4323	3	5,190	
426X2	4332	2	5,370	
426X2	4333	6	5,193	
426X2	4342	1	5,385	
426X2	4343	3	5,207	
426X2	4432	2	5,035	
426X2	4442	5	5,049	
426X2	shortage	8	-----	5,504
492X1	2221	6	7,376	
492X1	2222	31	7,081	
492X1	2321	6	6,770	
492X1	2322	20	6,520	
492X1	3323	24	6,077	
492X1	3422	1	5,851	
492X1	3423	2	5,665	
492X1	3431	1	6,057	
492X1	3432	6	5,854	
492X1	3433	6	5,668	
492X1	shortage	11	-----	5,903

Total Personnel = 633

APPENDIX F: ALLOCATION OF THE MANPOWER POOL BASED ON RELEVANT APTITUDE SCORES WITH A MINIMUM G SCORE REQUIREMENT OF 50

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
122X0	1231	9	$ 7,534	
122X0	1232	3	7,221	
122X0	2231	17	7,221	
122X0	2232	18	6,932	
122X0	2233	7	6,670	
122X0	2331	9	6,669	
122X0	2332	12	6,422	
122X0	shortage	8	-----	$ 6,944
272X0	1241	3	7,268	
272X0	2241	5	6,964	
272X0	2242	5	6,685	
272X0	2243	2	6,431	
272X0	2333	5	6,261	
272X0	2341	6	6,430	
272X0	2342	6	6,191	
272X0	2343	2	5,973	
272X0	3242	2	6,431	
272X0	3243	2	6,195	
272X0	3333	4	6,049	
272X0	3341	3	6,194	
272X0	3342	14	5,973	
272X0	3343	10	5,769	
272X0	3441	2	5,782	
272X0	3442	9	5,588	
272X0	3443	6	5,409	
272X0	4443	21	5,253	
272X0	shortage	24	-----	5,943
328X0	3234	2	5,492	
328X0	3334	10	5,127	
328X0	3344	3	5,141	
328X0	3434	2	5,509	
328X0	3444	1	4,830	
328X0	4334	6	4,974	
328X0	4344	3	4,988	
328X0	4434	21	4,682	
328X0	4444	28	4,694	
328X0	shortage	69	----	4,825
426X2	3231	2	6,591	
426X2	3232	6	6,338	
426X2	3233	6	6,106	
426X2	3331	5	6,106	
426X2	3332	24	5,888	
426X2	3333	25	5,687	
426X2	4332	2	5,370	
426X2	4333	6	5,193	
426X2	4342	1	$ 5,385	
426X2	4343	3	5,207	
426x2	4432	3	5,035	

APPENDIX F: (Concluded)

To AFS	From Aptitude Group	Number of Recruits	Cost/ Productive Unit	Average Cost/Productive Unit
426X2	4433	14	4,879	
426X2	4442	7	5,049	
426X2	shortage	11	-----	$ 5,611
492X1	3431	1	6,057	
492X1	3432	6	5,854	
492X1	3433	6	5,668	
492X1	shortage	101	-----	5,784

Total Personnel = 633