TECHNICAL PAPER
RAC-TP-[illegible]

NOVEMBER [illegible]

RESEARCH
ANALYSIS
CORPORATION

Improved Models To Measure Army Personnel Readiness

by
Betty W. Holz
Paul D. Phillips

RAC

PREPARED FOR THE
DEPARTMENT OF THE ARMY
[illegible]
Copy ______ of 100

55

SPECIAL PROJECTS
TECHNICAL PAPER RAC-TP-381
Published November 1969

Improved Models To Measure Army Personnel Readiness

by
Betty W. Holz
Paul D. Phillips

RAC Research Analysis Corporation
McLean, Virginia

BLANK PAGE

FOREWORD

This paper has been made possible by applying RAC's own research funds to an unsolved and nagging problem faced by Army managers, particularly at the Department of the Army level and during times of high personnel turnover—namely, how to measure the readiness of Army units. Army regulation 220-1* addresses the same problem. The work here is intended to show how the models prescribed in AR 220-1 to measure the personnel aspects of unit readiness might be improved. The work was under the joint direction of Mr. Arnold Proschan, head of the Resource Analysis Department, and BG Paul Phillips. The main substance of the work was done by Mrs. Betty Holz of Mr. Proschan's department and GEN Phillips.

Hugh M. Cole
Vice President
Operational Systems Group

*Dept of Army, "Unit Readiness," AR 220-1, Apr 69.

ACKNOWLEDGMENTS

The help is gratefully acknowledged of Mr. Lee G. Wentling, whose original thought resulted in the model that accounts for the effects on readiness of personnel turbulence, and Mr. William B. Blakemore, a programmer of outstanding ability, who developed the FORTRAN program for handling data for the model that handles military occupational specialty (MOS) match.

The assistance of those who helped in the development of a logic to rate 32 hypothetical units for personnel readiness is also gratefully acknowledged: GEN H. K. Johnson, MG David B. Parker, COL Charles E. Preble, and Messrs Robert H. Cole, Robert J. Faust, Irving Heymont, John T. Newman, Daniel Parker, Norman W. Parsons, and Dean T. Vanderhoef.

Finally the typing assistance of Mrs. Peggy H. MacDonald, who cheerfully completed many drafts and the final version of the paper, is gratefully acknowledged.

CONTENTS

Tables

Problem

To develop models that will reflect the impact of personnel turnover and military occupational specialty (MOS) mismatch on the readiness of Army units.

Facts

The Army readiness reporting system[1] covers personnel, training, and logistics. For each, a readiness condition (REDCON) is reported by the unit commander. There are four REDCONS, defined as follows:

REDCON 1 (C1): Fully ready. Unit is fully capable of performing the full table(s) of organization and equipment (TOE) mission for which organized or designed.

REDCON 2 (C2): Substantially ready. Unit is capable of performing the full TOE mission for which organized or designed but has minor deficiencies that reduce its ability to conduct sustained operations.

REDCON 3 (C3): Marginally ready. Unit has major deficiencies of such magnitude as to limit severely its capability to perform the full TOE mission for which organized or designed but is capable nonetheless of conducting limited operations for a limited period.

REDCON 4 (C4): Not ready. Unit is not capable of performing the missions for which it is organized or designed.

For personnel, the system requires a report on strength, MOS match, deployability, and leadership. The strength indicator is the ratio of operating strength to full TOE strength expressed in percent; the MOS indicator is the ratio of authorized MOSs being filled by qualified persons, who make up the operating strength to the total MOS spaces authorized, also expressed in percent. The Army system then assigns a personnel REDCON based on the lower of these two indicators. Deployability and leadership do not influence REDCON.

For training, the system requires reports on the percentage of personnel turnover by grade and rank and on the percentage of personnel stabilized for the past 3 months, but these enter only subjectively in the overall training REDCON, which is based on a determination by the unit commander of the highest level of proficiency at which his unit is capable of operating effectively in the performance of its TOE mission. The determination is based on an evaluation of training completed; qualification, experience, and number of personnel assigned; and rate of personnel turnover. However, no definitive guidance is supplied by the system for weighing these bases in arriving at the training REDCON.

Thus the current system does not modify in a reproducible way either the personnel or training REDCON because of personnel turnover, nor does it take into account the relative importance of missing MOSs in arriving at the personnel REDCON. As a result, units can appear to be more ready for combat than in fact they are.

For logistics, the system bases REDCON on equipment on hand and equipment deployability.

This paper is not concerned with logistics readiness or with training readiness except insofar as the latter is affected by personnel turnover.

Discussion

The two models presented in this paper give added insights into unit readiness as it is affected by personnel turnover and by MOS mismatch, which means the lack of some authorized skills in the operating strength of the unit. The two models have been designed to help answer the following two problems:

(1) Determine the personnel readiness of a given set of Army units at the end of a period, given their authorized (or TOE) strength,[a] their beginning and end strengths, and their losses and gains during the period, or estimate future readiness, given authorized and beginning strengths and estimated losses and gains during the future period.

The model developed for this problem is called the "strength-turbulence indicator."

(2) Determine the personnel readiness of a given set of Army units at the end of a period, given their authorized (or TOE) strength by MOS and their operating strength by MOS.

The model developed for this problem is identified as the "MOS indicator (proposed)" and, eventually, as the "proportional MOS indicator."

Strength-Turbulence Indicator

The concept underlying the strength-turbulence indicator is that the actual operating strength on the date that readiness is measured is not necessarily the effective strength of the unit, which is probably somewhat less. The authors show how the effective strength of a unit can be derived from its operating strength, and then propose, in simplest terms, that the

$$\text{Strength-turbulence indicator} = 100 \times \frac{\text{effective strength}}{\text{authorized (or TOE) strength}}$$

SUMMARY

In developing effective strength, operating strength is degraded to account for the following variables: administrative processing time for gains (new men) and for early future losses, the arrival time of each gain during the reporting period, the learning (or orientation) time and rate of learning for each gain by MOS and grade, and the effect on learning time of the ratio of gains to end strength. The result is a model of such complexity and of such demanding data input as to be worthless.

Five simplifying assumptions are made, each of which is examined in detail and three of which are tested for sensitivity:

(1) Gains to a unit arrive during the period between reports in a uniform random distribution.

(2) The learning time for a gain to a unit varies in a simple way as the ratio of gains to end strength changes.

(3) The rate of learning for a gain for all MOSs, grades/ranks, and positions is uniform over time.

(4) The number of different categories of gains (by MOS, grade/rank, etc) can be limited to five, and a single category will suffice in normal circumstances.

(5) Personnel being processed for early departure can be ignored because they can be held and reassimilated quickly in event of an emergency.

With these assumptions the strength-turbulence model becomes:

$$\text{Strength-turbulence indicator} = 100\left[\frac{E - \dfrac{G\,(t_1 + c_0 k t_2)}{T}}{A}\right] = 100 \times \frac{\text{effective strength}}{\text{authorized strength}}$$

where E = the end strength of the unit

G = the gains during the period

t_1 = the time required for administrative processing of gains

t_2 = the learning orientation time for a typical gain

k = a parameter describing the shape of the learning curve: $1/2$ (0.5 in tables and calculations) for a linear curve and $2/3$ for a quadratic curve

c_0 = a multiplier of the learning/orientation time based on the ratio G/E

T = the length of the period between readiness reports

A = the authorized (or TOE) strength

Finally, the results of readiness computations using the strength indicator in AR 220-1[1] and the strength-turbulence indicator developed in this paper are displayed for 44 cases for which imaginary but realistic data have been developed.

A comparison of the results suggests that the strength-turbulence model will add to the understanding of personnel readiness measurement and reporting in the field and at the Department of the Army (DA).

SUMMARY

MOS Indicator (Proposed)

The concept underlying the proposed MOS indicator is that it is possible, in principle, to assign relative values to the MOSs in a unit, which would then permit degrading the personnel readiness of the unit when some MOSs are missing. Since it is important not to charge field units with complex reporting burdens, the method of choosing relative values for MOSs must be simple. Three methods are examined and examples given, together with advantages and disadvantages.

(1) By skill level. This method presumes that all MOSs of a given skill level, of which there are five, are equally valuable to the unit, but that low-skill-level MOSs are less valuable than high-skill-level MOSs. For officers, grade levels are used instead of skill levels.

(2) By relative fill of each MOS, ignoring skill level. This method would weight each three-character MOS in a unit. The authors briefly discuss and point out the infeasibility of doing this on an individual MOS basis and develop and discuss instead a model that is based on the assumption that each man in a given MOS has a value to the unit that is inversely proportional to the number of men with that MOS authorized in the unit. This assumption gives a higher readiness rating to understrength units that are understrength mostly in low skills, because these usually are authorized in larger numbers than are high-skill MOSs. This tendency is generally consistent with the way the Army structured the understrength columns of the new G-series TOE.[a]

(3) A combination of skill level and relative fill for each MOS. This method combines (1) and (2) above, using the four-character MOS for enlisted men and MOS combined with grade for officers. The MOS indicator is then based on the concept that the value of a given man in a given MOS is inversely proportional to the number of men authorized the unit in that MOS and directly proportional to the skill level of the MOS.

The resultant model is as follows:

$$\text{MOS indicator (proposed)} = \frac{100}{\sum_{i=1}^{M} W_i}\left[\sum_{i=1}^{M}\left(\frac{W_i}{N_i}\right)\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right]$$

where $O_{i,j}$ = the number of men in the operating strength of the jth MOS of skill-level i (or grade-level i for officers)

$A_{i,j}$ = the number of men authorized in the jth MOS of skill-level i (or grade-level i for officers)

N_i = the total number of different MOSs of the ith skill level

W_i = the weight (or relative value) of the ith skill level (or grade-level i for officers)

M = the number of skill levels (or grades for officers) and the expression $1/\Sigma_{i=1}^{M} W_i$ outside the brackets is simply a normalizing factor so that one need not bother making $\sum_{i=1}^{M} w_i = 1$

It is of note that the only data needed for the model are the authorized (or TOE) and operating strength for a unit by MOS and grade. These data are now being reported by units, consolidated at theater headquarters, and reproduced in the OPO-45 report.[4] Of course the user must also assign relative values to each of the skill levels and officer grades although the authors believe grades can be consolidated into three categories as is done in AR 220-1 for reporting personnel turnover.

Imaginary but realistic data were developed for 10 cases of a unit consisting of 20 MOSs. The proposed model and the model in AR 220-1 for MOS indicator were applied to the data. Comparison of the results shows that the proposed model does give insights to MOS match that are not available with the relatively crude but simple percentage model of AR 220-1.[1]

A computer program to handle the model has also been developed and is available at RAC.

Application of the Models

To demonstrate the usefulness of the models, the authors developed a set of gain/loss data by MOS (and grade for officers) for an infantry division (App A) and computed the readiness indicators and the kind of displays possible if the two personnel-readiness indicators proposed in this paper are combined with those now in use. The accompanying tabulation summarizes the results.

Indicator	TOE rating	REDCON rating
Strength (AR 220-1)	95	C-1
Strength-turbulence	88	C-2
MOS (AR 220-1)	95	C-1
MOS (proposed)	85	C-2

From this tabulation the following conclusions can be made about the division. The A infantry division, at 95 percent of TOE (or authorized strength) has had enough personnel turnover to reduce its effective strength to 88 percent and hence to the rating C-2. From the standpoint of skills, the division is at 95 percent on a gross percentage basis, but there is a shortage of those skills authorized in relatively small numbers and in the higher skill levels.

Conclusion

The models developed for measuring the effect of personnel turnover and MOS mismatch on unit readiness provide insights not now available to the field or the DA. Neither requires collecting or reporting new data from the field. They should be considered for inclusion in an early revision of AR 220-1.[1]

BLANK PAGE

Improved Models To Measure Army Personnel Readiness

RAC

ABBREVIATIONS

CONUS	continental United States
DA	Department of the Army
MOS	military occupational specialty
OJT	on-the-job training
REDCON	readiness condition
TOE	table(s) of organization and equipment

INTRODUCTION

For a number of years the Army has had a readiness-reporting system for units.[1] The purpose of the system is threefold: to inform the DA and commanders at all levels of the readiness of units, to assist commanders in making the most effective use of available resources, and to determine requirements for additional resources. The system requires quarterly reports in the areas of personnel, training, and logistics from almost all units that make out a morning report. A REDCON is reported by each unit commander for each of the three areas. There are four REDCONs, defined as follows:

REDCON 1 (C1): Fully ready. Unit is fully capable of performing the full TOE mission for which organized or designed.

REDCON 2 (C2): Substantially ready. Unit is capable of performing the full TOE mission for which organized or designed but has minor deficiencies that reduce its ability to conduct sustained operations.

REDCON 3 (C3): Marginally ready. Unit has major deficiencies of such magnitude as to limit severely its capability to perform the full TOE mission for which organized or designed but is capable nonetheless of conducting limited operations for a limited period.

REDCON 4 (C4): Not ready. Unit is not capable of performing the mission for which it is organized or designed.

For each of the four REDCONs, specific criteria and measures are provided in the three areas of personnel, training, and logistics.

For personnel, four measures are specified: deployable personnel, leadership-balance data, strength indicator, and MOS indicator. The last two are used to establish the personnel REDCON and are the two primarily addressed in this paper.

For training, three measures are specified: level of training (refresher, squad/crew, unit proficiency, field exercises, operational readiness, technical proficiency, and annual service practice), personnel stabilized for 3 months, and personnel turnover. The first establishes the basic training REDCON. The unit commander uses the other two to modify the basic training REDCON on the basis of his judgment of their effect on his unit's readiness.

For logistics the REDCON is based on equipment on hand and equipment deployability.

This paper is concerned with improving the insights available to commanders in the field and managers at the DA on unit readiness as it is affected by strength, personnel turnover, and MOS. The paper is not concerned with any aspect of logistics and is concerned with training only to the extent that personnel turnover affects it. Since strength and MOS fix the personnel REDCON in the current Army system, added insights in these two fields should be welcome; since personnel turnover is today applied only subjectively to modify the basic training REDCON, an objective reproducible way of applying the effects on readiness of personnel turnover should be useful.

To assist the model builders in establishing the effects on readiness of personnel turnover, hypothetical gain/loss data on a set of 32 units were provided to 11 active and retired officers at RAC who held ranks from lieutenant colonel to general. No assumptions were provided. The officers were asked to rank the 32 units for readiness and to explain the logic they used. No two officers used the same criteria, but general agreement was obtained on the following points:

Personnel stability is essential to unit readiness and has its greatest benefit in training and development of teamwork.

Understrength is bad.

Overstrength above 5 to 10 percent is bad.

Loss in readiness is caused by loss of teamwork when veteran personnel leave.

Gains are not fully useful on arrival.

A unit starting with a higher strength can handle equal losses and replacement gains better than one starting with a lower strength.

Despite the fact that gains create problems, losses without replacements is not as good as losses with replacements. [Though this point may seem obvious, some senior officers believe losses (small) without replacements would provide a more ready unit in the short term.]

This study is part of a larger effort[5] to develop a system for portraying the relation among time, cost, and readiness as the Army strength and structure undergo downward adjustments. Since readiness plays such a major role in this larger study, it was deemed essential to undertake a study that would refine present ways of measuring personnel readiness to take account of the large turnover rates likely during a phasedown in strength and the probably significant mismatch in MOS.

Two models are presented: One model provides a measure that shows the effect of personnel turnover on personnel readiness. The other model provides a refined measure for the MOS indicator, a measure that takes account of the relative importance to readiness of various MOSs.

STRENGTH-TURBULENCE MODEL

BACKGROUND

Since mid-1965, when the Army began to expand for Vietnam without mobilizing, excessive personnel turnover in Army units has had a deleterious effect on readiness, owing in large part to the 2-year draft law and 1-year tours in Korea and Vietnam. Excessive personnel turnover is called "turbulence" and is defined as follows: personnel turnover of such magnitude and frequency as to conflict with or interrupt the normal sequence of training (individual-crew/team-company-battalion-brigade-division) and require extended training schedules and sometimes repetitive starts, which tend to prevent completion of the training cycle and hence lower a unit's readiness.

In periods of force structure and strength stability in the Army, the rate of personnel turnover is low enough to mask its effect on readiness, and it has habitually been ignored. In short the training cycle is not interrupted by what has been defined as turbulence. In wartime such conditions do not exist. The latest demonstration of turbulence began in 1965 with the Vietnam buildup and will not end until the war is over and the Army has again become relatively stabilized. Turbulence is particularly severe under policies that continue the 2-year draft and the 1-year short tour, particularly when only about one-third of the Army is in the continental United States (CONUS). Each year the Army processes and trains between 200,000 and 250,000 officers and enlisted accessions to replace those it loses from a trained population of about 1.3 million; each year the Army moves to Vietnam alone some 360,000 to replace those whose tours are over. Such flows into, within, and out of the Army preclude effective training in many units and make important the measurement of the effect of turbulence on unit readiness.

The latest revision of the unit-readiness reporting system (AR 220-1,[1]) requires a report on rates of personnel loss by grade and rank but does not specify acceptable rates or provide definitive guidance as to the effect these rates have on REDCON ratings. The model used in AR 220-1 for this computation is as follows:

$$\frac{\text{Gross losses for reporting period}}{\text{operating strength at end of reporting period}} \times 100.$$

The model is applied to all personnel in aggregate and to five subsets of personnel: E-1 to E-4, E-5 to E-9, warrant officers, 01,02 (first and second lieutenants), and 03 to 05 (captains, majors, and lieutenant colonels).

As noted in the introduction the resultant data are applied subjectively by the unit commander in arriving at the overall unit training REDCON.

In the current Army system the models used to compute the strength and MOS indicators are:

$$\text{Strength indicator} = \frac{\text{operating strength at end of reporting period}}{\text{full TOE strength}} \times 100.$$

$$\text{MOS indicator} = \frac{\text{personnel at end of reporting period qualified and occupying an authorized MOS}}{\text{total MOS at full TOE}} \times 100.$$

The personnel REDCON for the unit is the lesser of the two C-ratings found by entering the accompanying tabulation on the basis of the results of the above two models.

Strength	MOS	REDCON rating
≥ 95	≥ 86	C-1
≥ 85	≥ 77	C-2
≥ 75	≥ 68	C-3
< 75	< 68	C-4

PARAMETERS OF PROBLEM

A model that provides an objective measure of the effects of personnel turbulence on unit readiness should have these characteristics:

A logical (real-world) basis.
Simplicity.
No new requirement for different or new data from the field.
A way to insert military judgment explicitly and reproducibly.
A way to estimate future readiness.
The ability to measure readiness at a point in time.

The problem can now be restated as follows:

Determine the readiness of a set of Army units at the end of a period, given their authorized,[6] beginning, and end strengths and their losses and gains during the period, or estimate readiness at the end of a future period, given estimated losses and gains during the period.

It is clear that the best measure of personnel readiness in a unit is one that shows how effective the people are who make up the operating strength of the unit. This suggests that the quality, quantity, and training level of the operating personnel should be measured against some standard. The standard for quantity is either authorized strength or full TOE, as covered earlier. Quality would seem to depend on the proportion of "veterans" or "old timers" in the unit who are not scheduled to leave in the near future and on the match of MOS in the operating strength to those authorized or to full TOE. (MOS match is subject to several definitions and is discussed later in this paper.)

Considering personnel turnover (but not MOS match) it can be surmised that the operating strength at the instant of readiness measurement will be less than fully effective under any of the following conditions: (1) if any personnel are undergoing administrative processing for early departure, (2) if any new personnel (gains) are undergoing administrative processing, and (3) if any new personnel have not been assimilated as fully trained members of the unit. It is important to note that losses during the period since the last report have nothing to do with the condition of effectiveness being measured, viz, that of the operating strength at the end of the period.

In its crudest form personnel readiness can be measured by strength, viz, operating strength/authorized strength. To account for turbulence, it is necessary to degrade the operating strength for those persons who are not fully effective. Thus turbulence will be measured by the effect it produces.

Degrading Operating Strength

Let E = the operating strength of a unit at the end of the period when readiness is to be measured and A = the authorized strength of the unit. Then readiness = $100\ (E/A)$ is the crudest measure.

The first improvement to this crude measure would be to degrade the end strength by all personnel undergoing administrative processing into or out of the unit because they are not participating in training and contribute nothing to unit readiness.
Thus

$$\text{Readiness} = 100\left(\frac{E-P}{A}\right) \tag{1}$$

where P = the total number of personnel undergoing administrative processing.

In Eq 1 we define all personnel undergoing administrative processing as P. Let us now break P into its two components.
Thus

$$P = G_{t_1} + L_{t_3}$$

where G_{t_1} = the gains to the unit within time t_1 of the end of the reporting period
t_1 = the administrative time required for gains
L_{t_3} = the losses to the unit within time t_3 after the end of the reporting period
t_3 = the administrative time required for losses

There may, however, be personnel in the resultant end strength who are not fully effective because, although completely processed into the unit, they are undergoing a learning process. Such learning must always take place for a new man whether he is a leader or one of the led, and most men in a unit are both. This learning involves orientation to the unit's operating procedures, the names and abilities of his seniors and subordinates, tne precise bounds of his job, and the teamwork that makes him an effective member of a crew, squad, or fireteam and permits integration of these small elements into a ready whole unit. In addition to the learning, which must always take place, it is sometimes necessary to accomplish on-the-job training (OJT), refresher, or even MOS training in lieu of school training. Complicating the measurement of the learning process are the certainty that the learning times for the same grade and MOS are different for different people; the probability that the learning time and shape of the learning curve are different for each different MOS, rank/grade; and position within the unit; and the probability that learning time is dependent in some way on the proportion of veterans in the unit to newcomers in the unit. Complicating the measurement of the effect on readiness of the learning process is the certainty that gains do not arrive uniformly distributed over time during the readiness reporting period.

Thus the normal pattern of effectiveness for a new man will include a standardized period of zero effectiveness during administrative in-processing, a nonstandardized period of increasing effectiveness (the so-called learning period), and finally full contribution. The proportion of a fully effective man that each new man contributes to unit readiness will depend on when he arrived in relation to the end of the reporting period, the length of the administrative processing time, the length of his learning period, and the shape of his learning curve.

To handle and eventually to make simplifying assumptions about some of the complications just discussed, it is necessary to develop the model in more detail. Let us look at the contribution to end strength made by gains.

Let $G =$ the gains for the entire period since the last readiness report, $T =$ the length of the reporting period in days, and $g_{s,t}$, $s = 1, 2, \ldots n =$ the number of gains of the s th category that arrive on the tth day before the end of the reporting period. The n categories, $s = 1, 2, \ldots n$, are defined so that normal learning time and the rate of learning or learning curve can be specified for each category. For example, the categories might be defined to separate gains on the basis of MOS, grade/rank, position, whether OJT is required, or other individual differences.

The total gains can be evaluated in terms of $g_{s,t}$ thus

$$G = \sum_{s=1}^{n} \sum_{t=1}^{T} g_{s,t} .$$

Let $t_{2,s}, s = 1, 2, \ldots n =$ the normal learning time for the s th category of gains

$c_0 =$ a multiplier that varies the learning time as the ratio of gains to end strength changes

$f_s(t, c_0 t_{2,s}) =$ the function defining the effective strength that each gain of the sth category contributes to the unit at time t days before the end of the period

with

$$0 \leq f_s(t, c_0 t_{2,s}) \leq 1 .$$

If a linear learning curve is assumed, the fractional effectiveness of each gain equals the fraction of training time completed. Thus, in this case

$$f_s(t, c_0 t_{2,s}) = (t - t_1) / c_0 t_{2,s} .$$

for

$$t_1 \leq t \leq t_1 + c_o t_{2,s}.$$

To summarize, the effective strength contributed by each gain of category s is

$$0 \text{ if } t \leq t_1;$$

$$f_s(t, c_o t_{2,s}) \text{ if } t_1 \leq t \leq t_1 + c_o t_{2,s};$$

$$1 \text{ if } t \leq t_1 + c_o t_{2,s}.$$

The effectiveness of all gains at the end of the reporting period is

$$G - G_{t_1} - \sum_{s=1}^{n} \sum_{t=t_1}^{t_1+c_o t_2} g_{s,t} f_s(t, c_o t_{2,s}).$$

We can now improve Eq 1 by writing

$$\text{Strength-turbulence} = 100 \left[\frac{B - L + G - G_{t_1} - L_{t_2} - \sum_{s=1}^{n} \sum_{t=t_1}^{t_1+c_o t_2} g_{s,t} f_s(t, c_o t_{2,s})}{A} \right] \quad (2)$$

where B = the operating strength at the beginning of the period and L = losses during the period.

We have thus modified end strength ($E = B - L + G$) by degrading gains in great detail.

SIMPLIFYING ASSUMPTIONS

Equation 2 is too detailed and complex to be of any practical use. For example, it would require assigning a learning time for each of the 1400-odd four-character MOSs, a learning time based on an MOS to each gain, a learning curve based on the ratio of gains to veterans in the operating strength, and a separate effectiveness measure at the end of the reporting period based on these and on his date of arrival.

To make Eq 2 into a useful model, we propose five simplifying assumptions.

(1) Gains to a unit occur uniformly over the period between readiness reports.

In fact, of course, gains do not arrive uniformly, but the results derived under the assumption of a uniform rate of arrival represent the expected value of the readiness measure that would be obtained under the assumption of a uniform random distribution of arrivals. And since there is no attempt by the Army to time arrivals to units on particular dates of the month, the assumption of a uniform random distribution of actual arrivals seems reasonable.[7]

This assumption permits us to degrade end strength due to unassimilated gains very simply.

The number of arrivals per unit of time is G/T. When broken out by each category of gains, the number of arrivals per unit of time for category $s = g_s/T$, where g_s = the total number of gains of the s th category.

To account for administrative time, we must subtract $(G/T)t_1$ people from end strength.

To account for learning time, we must subtract $\Sigma_{s=1}^{n} (g_s/T)\, c_e k_s t_{2,s}$ people from end strength, where k_s = a factor whose value depends on the shape of the learning curve for the s th category of gains. A further discussion of k_s occurs later.

Thus our end strength E must be degraded by $(G/T)t_1 + \Sigma_{s=1}^{n} (g_s/T)\, c_e k_s t_{2,s}$ to account for ineffective newcomers and by L_{t_3} to account for personnel who are out-processing. Our model becomes

$$\text{Strength-turbulence} = 100 \left[\frac{B - L + G - (G/T)t_1 - \sum_{s=1}^{n} (g_s/T)\, c_e k_s t_{2,s} - L_{t_3}}{A}\right] \quad (3)$$

or since

$$B - L + G = E$$

$$\text{Strength-turbulence} = 100 \left[\frac{E - (G/T)t_1 - \sum_{s=1}^{n} (g_s/T)\, c_e k_s t_{2,s} - L_{t_3}}{A}\right] \quad (4)$$

The sensitivity of the strength-turbulence indicator to this assumption of uniform gains is displayed in Tables 1 and 2.

Given: Unit authorized and TOE strength are 100.
Reporting period T is 3 months.
Administrative time t_1 is 1 week.
Linear learning curve k is 0.5.
Constant learning time for all gains, t_2 is 6 weeks.
Constant c_e is 1.
Constant number of men preparing to leave L_{t_3} is 5.

TABLE 1

Value of Strength-Turbulence Indicator for Various Conditions of Arrival: Linear Learning Curve

(T = 3 months)

Case	E	G	Condition of arrival: Uniform arrival	All earlier than $T - (t_1 + t_2)$	All uniformly within $t_1 + t_2$ of end of T	All within t_1 of end of T	One-third on 1st day of each month	One-third on last day of each month
1	100	9	92	95	90	86	94	90
2	100	21	88	95	83	74	91	84
3	100	30	86	95	78	65	90	80
4	90	9	82	85	80	76	84	80
5	90	21	78	85	73	64	81	74

Given: Unit authorized TOE and end strength =100

T = 1 month
t_1 = 1 week
t_2 = 4 weeks
k = 0.5
L_{t_3} = 0
G = 8

TABLE 2

Value of Gains and Strength-Turbulence Indicator for Various Conditions of Arrival: By Day of Month

Value	Uniform Arrival	Arrival of all gains on						
		1st	5th	10th	15th	20th	25th	30th
8 gains	2.0	6.3	5.1	3.7	2.9	1.1	0.0	0.0
Indicator	94	98	97	96	95	93	92	92

The results in Tables 1 and 2 suggest that except in extreme cases the assumption of uniform random distribution of arrivals appears to be acceptable. However, one would expect that there would be greater sensitivity to the assumption concerning the distribution of arrivals if the ratio t_2/T were larger or if the rate of learning increased with time, e.g., in the case of the quadratic learning curve, rather than being uniform as in the case of the linear learning curve. This is illustrated in Table 3, which is computed with all values the same as for Table 1 except that there is a quadratic learning curve ($k = ^2/_3$), and $T = 2$ months. The values in Table 3 reinforce the suggestion that the assumption of uniform random distribution of arrivals appears to be acceptable.

TABLE 3

Value of Strength-Turbulence Indicator for Various Conditions of Arrival: Quadratic Learning Curve

(T = 2 months)

Case	E	G	Condition of arrival					
			Uniform arrival	All earlier than $T-(t_1+t_2)$	All uniformly within t_1+t_2 of end of T	All within t_1 of end of T	One-half on 1st day of each month	One-half on last day of each month
1	100	9	89	95	89	86	92	87
2	100	21	82	95	80	74	87	77
3	100	30	76	95	74	65	84	69
4	90	9	79	85	79	76	82	77
5	90	21	72	85	70	64	77	67

(2) The second simplifying assumption is that learning time $t_{2,s}$ varies in a simple way as the ratio of gains G to end strength E changes.

Although it is possible arbitrarily to devise a set of multipliers c_0, based on a set of ranges for all possible ratios of G/E, it is nearly impossible to imagine the sort of field test or questionnaire that would permit one to check the values. Table 4 is a simplified presentation based on the following rationale.

The Army seems able to maintain a satisfactory (though probably not optimal) training readiness with personnel turnover approaching 100 percent/year; Vietnam and Korea are examples. Any turnover that exceeds that rate for any readiness report period will either keep training at a standstill or will cause a restart at some lower level. The values for c_0 in Table 4 provide that turnover rates of 100 percent/year or less will not result in a penalty to learning times of gains, that rates between 100 and 200 percent will double the learning time, and that rates exceeding 200 percent will force recycling, automatically resulting in a rating of C-4 for the unit.

TABLE 4

Value of Learning-Time Multiplier c_0 for Various Reporting Periods

(Ratios of gains to end strength G/E)

Length of reporting period, months	G/E[a]	c_0
1	$\leq 1/12$	1
	$> 1/12$ and $< 1/6$	2
	$> 1/6$	REDCON C-4
3	$\leq 1/4$	1
	$> 1/4$ and $< 1/2$	2
	$> 1/2$	REDCON C-4
12	$\leq 1/1$	1
	$> 1/1$ and $< 2/1$	2
	$> 2/1$	REDCON C-4

[a]In computing G/E in cases where $E > A$, ignore any gains that make the unit overstrength. Otherwise the unit may be severely penalized for learning time simply because gains made the unit overstrength.

The following hypothetical cases show the sensitivity of the strength-turbulence indicator to the application of the multiplier c_0 from Table 4 (see Table 5).

Given:

Unit authorized and TOE strengths are 100.
Reporting period T is 3 months.
Administrative time t_1 is 0.
Linear learning curve k is 0.5.
Constant learning time t_2 is 4 weeks.
Constant number of men preparing to leave, L_{t_3}, is 0.

TABLE 5

Sensitivity of Strength-Turbulence Indicator to Learning-Time Multiplier

Case	G	E	G/E	Strength-turbulence indicator[a]		REDCON rating[b]	
				With c_o	Without c_o	With c_o	Without c_o
1	5	100	< 1/4	99.2	99.2	C-1	C-1
2	20	100	< 1/4	96.7	96.7	C-1	C-1
3	30	100	> 1/4	90.0	95.0	C-2	C-1
4	20	90	< 1/4	86.7	86.7	C-2	C-2
5	21	80	> 1/4	73.0	76.5	C-4	C-3
6	51	100	> 1/2	na[c]	91.5	C-4	C-2

[a]Strength-turbulence indicator =

$$\frac{100\left[E-(G/T)(t_1 + c_o k_n t_{2,s}) - L_{t_3}\right]}{A}$$

$$= E - \frac{G}{3}[0 + (c_o \times 0.5 \times 1)] - 0 \qquad (4)$$

$$= E - \frac{G}{6}c_o$$

[b]C-1 $\geq$ 95   C-3 $\geq$ 75

C-2 $\geq$ 85   C-4 < 75

[c]Not applicable.

It should be noted that in Table 4 both the learning-time multiplier of 2 and the range over which it is applied are subject to the judgment of the user. It is believed that the values in Table 4 will reasonably reproduce, albeit in a simplified way, the experience of many units whose readiness summaries were reviewed during the Vietnam war.

(3) The third simplifying assumption is that the learning curve for all MOSs, grades/ranks, and positions is linear; i.e., the rate of learning is uniform. An alternative assumption has been examined (Table 3), that the learning curve is quadratic; i.e., the rate of learning increases as a linear function of time. (See Figs. 1 and 2.) Of course any number of other arbitrary assumptions could be made and the model tailored accordingly. The number of different duties in the Army is of such magnitude as to prevent any feasible field test of learning curves. The authors accept that any man arriving with a usable MOS is properly trained in that MOS and, once oriented to the peculiarities of his superiors and subordinates and of the unit operating procedures, that he will function effectively. It is proposed that, in the absence of evidence to the contrary, the linear learning curve and a value for k of 0.5 be used.

(4) The fourth assumption is that the number of categories of gains and the number of associated values for $t_{2,s}$, s = 1, 2, . . . n, can be limited to a maximum of 5 and that a single value will suffice for all usual circumstances.

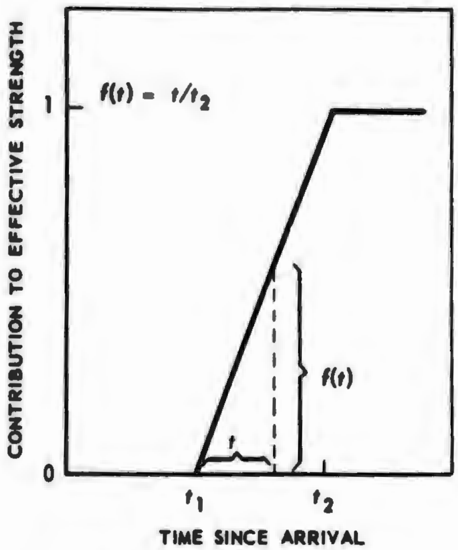

Fig. 1—Linear Learning Curve

Using the assumption of a linear learning curve

$$k(t_2) = t_2 - \int_0^{t_2} (t/t_2)\,dt$$
$$= (1/2)\,t_2$$

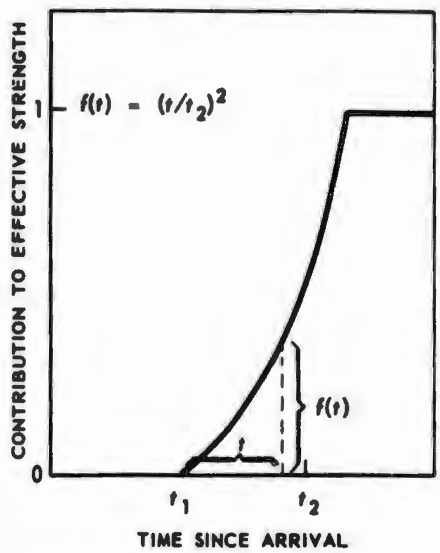

Fig. 2—Quadratic Learning Curve

Using the assumption of a quadratic learning curve

$$k(t_2) = t_2 - \int_0^{t_2} (t/t_2)^2\,dt$$
$$= (2/3)\,t_2$$

The effect of this assumption is to reduce n to a maximum of 5 and usually to 1. In the case of certain skills or leadership positions, two learning times are involved for new accessions: the time for a man to learn his job and the names, abilities, and characteristics of his subordinates and superiors and the time for his subordinates and superiors to adjust to his abilities, characteristics, and method of operating. The simplest way of accommodating these facts is to select for t_2 the greater of the two times, since they obviously run simultaneously. The practical effect of accepting a single value for t_2 is to accept that it takes the same length of time for personnel of all MOSs, grade/rank, and position to learn their job. If one accepts that the Army training and schooling system awards MOSs only when earned, he must accept that the time t_2 need accommodate only nonskill orientation and learning for a gain who has an MOS usable in the unit. We know, however, that OJT is frequently required because personnel distribution problems do not always provide the right man for the right job at the right time. When men are undergoing OJT of a length exceeding an average t_2, it can be taken into account as will be demonstrated. In fact the model can handle a different t_2 for each of the 1400-odd four-character MOSs and can take account of OJT and occupational retraining, but this would place an enormous data-collecting effort on the Army and a very large reporting burden on the units.

The following example demonstrates the sensitivity of the strength-turbulence indicator to varying assumptions regarding the length of t_2.

Given:

Unit authorized and TOE strength are 100.

Reporting period T is 3 months.

Administrative time for gains t_1 is 1 week.
Linear learning curve k is 0.5.
Uniform rate of gains over time T.
Constant number of men preparing to leave L_{t_3} is 5.
Gains of 20 during the period.
End strength is 100.
The following learning times, t_2:

Average, 4 weeks;
E-1 to E-4 and MOS skill levels 1 and 2, 3 weeks;
E-5 to E-9 and MOS skill levels 3 to 5, 6 weeks;
OJT, variable.

TABLE 6

Value of Strength-Turbulence Indicator: Reporting Period, 3 Months

Case	Distribution of 20 gains		OJT		Value of strength-turbulence indicator[a]	
	E-1 to E-4 and skill levels 1 and 2	E-5 to E-9 and skill levels 3–5	Number required	t_2	Using average t_2	Using variable t_2
1	5	5	10		90	89
			(5)	8		
			(4)	6		
			(1)	3		
2	15	5	0		90	90
3	Not controlling		20		90	87
			(10)	8		
			(10)	6		

[a]Based on

$$\left[\frac{E - \sum_s g_s \dfrac{(t_1 + kc_e t_{2,s})}{T} - L_{t_3}}{A}\right]100$$

or, using the given values

$$\left[\frac{100 - \sum_s g_s \dfrac{(1 + \frac{1}{2} t_{2,s})}{13} - 5}{100}\right]100$$

where t_2 values vary from 3 to 8 weeks as in the given data, and g_s = the gains for each category with a different t_2.

It would be expected that greater variability in the strength-turbulence indicator would have been revealed in Table 6 if the length of the reporting period had been less. To illustrate, Table 7 gives data for the same three cases with the only change being the reduction of the length of the reporting period from 3 to 2 months.

TABLE 7

Value of Strength-Turbulence Indicator: Reporting Period, 2 Months

Case	Using average t_2	Using variable t_2
1	85	85.5
2	85	87.0
3	85	84.0

The values in Tables 6 and 7 suggest that for all likely distributions of gains and reasonable times for OJT, an average value for t_2 will suffice.

(5) The last simplifying assumption is that personnel being processed for early departure can be ignored in degrading end strength. This assumption eliminates the term L_{t_3}. The rationale is that, although these people are not training with the unit and are all looking forward to discharge or to their next assignment, they are physically available to the unit in event of an emergency, are well trained, and can be reassimilated with no loss of time.

WRITING THE MODEL

With these assumptions, we can now write and summarize the model for the strength-turbulence indicator as

$$100\left[\frac{E-\frac{G\,(t_1+c_0kt_2)}{T}}{A}\right] \tag{5}$$

where E = end strength of a unit

G = gains to the unit since the last reporting period

A = the authorized (or TOE) strength of the unit

T = the time length of the report period

t_1 = the administrative time required for a new man during which he contributes zero effectiveness to the unit

t_2 = the learning time, during which the new man contributes increasing effectiveness

k = a parameter defining the rate of learning, 0.5 for uniform (straight line) learning over period t_2, and $2/3$ for a quadratic learning curve

c_0 = a parameter defining the length of learning based on T and on the ratio of G/E.

The recommended values of c_0 are shown in the accompanying tabulation.

T	G/E	c_0	G/E	c_0	G/E	Unit is
1	≤ 1/12	1	> 1/12 and < 1/6	2	> 1/6	C-4
3	≤ 1/4	1	> 1/4 and < 1/2	2	> 1/2	C-4
12	≤ 1/1	1	> 1/1 and < 2/1	2	> 2/1	C-4

The model permits different administrative and learning times to be applied, e.g., if experience dictates that combat service support units have an easier time assimilating new men than do combat units, or that a unit above 95 percent strength can assimilate a new man in 3 weeks but that a unit below 95 percent takes 4 weeks, or the user can decide that some average value of t_1 and t_2 will suffice for all units of all types. Obviously some centralized control will be required to ensure that the values used for t_1 and t_2 are realistic for the theater or kind of unit in question.

The current readiness reporting system requires entries showing the percentage of personnel stabilized over the past 3 months and makes the statement, "If a man has been with his unit for three months or longer, it is assumed that he has absorbed unit training for the purpose of presenting data. . . .assumptively, he has learned to operate as part of the team."[1]

Table 8 shows how simple it is to handle the factor $\left(\frac{t_1 + c_o k t_2}{T}\right)$ used to degrade gains. The table provides for learning times up to the 3 months suggested in the current Army regulations on unit readiness.

TABLE 8

Values of $(t_1 + c_o k t_2)/T$ for Various Reporting Periods

Administrative time, weeks	Learning time, weeks	$(t_1 + c_o k t_2)/T$[a] for reporting periods of		
		1 month	3 months	12 months
0	0	0	0	0
1	1	3/8	3/26	3/104
1	2	1/2	2/13	1/26
1	3	5/8	5/26	5/104
1	4	3/4	3/13	3/52
1	6	1	4/13	4/52
1	8	5/4	5/13	5/52
1	12	7/4	7/13	7/52
0	1	1/8	1/26	1/104
0	2	1/4	1/13	1/52
0	3	3/8	3/26	3/104
0	4	1/2	2/13	2/52
0	6	3/4	3/13	3/52
0	8	1	4/13	4/52
0	12	3/2	6/13	3/26

[a]Linear learning curve $k = 0.5$; $c_o = 1$; and G/E rates less than 100 percent/year. A similar table can easily be constructed if G/E lies between 100 and 200 percent/year (for which $c_o = 2$) and for such additional values for administration time and learning time as are of interest. If G/E exceeds 200 percent/year, the unit is automatically marked C-4 for the reporting period.

Example 1:

A unit is authorized 100 manpower spaces (full TOE)
Its end strength is 95
It has received 18 gains over the past 3 months
It requires 1-week administrative time and a 6-week learning period for new men to become fully effective

Its strength-turbulence indicator is:

$$\left[\frac{95-(18\times 4/13)}{100}\right]100 = 89 \text{ percent}$$

The current Army system would rate the unit C-1 (95 percent) on strength; this model would rate the unit C-2 on the combination of strength and turbulence (assuming the same correspondence between the numerical value of the indicator and the REDCON as prescribed in AR 220-1[1]).

Tiebreaker

If the relative strength-turbulence of a number of units is of interest, it may be useful to have a tiebreaker because the model will not distinguish, for example, between the units shown in the accompanying tabulation (assumes 100 authorized strength, 2-week administrative time, 2-week learning time, 1-month reporting period).

Unit	B	E	L	G	Model score	$\frac{G+L}{B+E}$	Tiebreaker ranking
1	120	100	20	0	100	0.091	2
2	100	100	0	0	100	0.0	1

The suggested tiebreaker ($G+L/B+E$) is based on the notion that the higher the turnover in proportion to strength during the month, the lower will be readiness at the end of the month. It seems reasonable, when judging among units with the same score, to favor the units with the least disruption whether by gains or losses.

Tests

A set of 44 cases was set up and tested using Eq 5. Losses were limited to 20 percent of beginning strength, and reporting periods of 1 and 3 months were assumed. This produces loss rates of up to 240 percent/year. Table 9 shows the results. With the same turbulence spread over 3 months, many of the rankings change, showing that strength influences the outcome more than for the shorter period. This is logical since the losses are probably not excessive over a 3-month period (limited to 20 percent) when one realizes that turnover in Vietnam and Korea is 100 percent/year.

Comparison of Model with AR 220-1[1]

Table 9 reveals that the proposed strength-turbulence model will result in lower indicator ratings than the strength indicator of AR 220-1.[1] For the 1-month reporting period the model differs with AR 220-1 in 25 of the 44 cases (sometimes by three steps). However, as might be expected, when the same turnover is spread over a 3-month reporting period, strength has a greater influence on the strength-turbulence indicator, and the model differs with AR 220-1 in only 11 of the 44 cases. Note also how radically the rankings change between the 1- and 3-month reporting periods, also reflecting the increased influence of end strength on the results for the longer reporting period. The accompanying tabulation illustrates the point.

Case	E	G	Ranking among 44 cases	
			1 month	3 months
5	100	0	5	10
22	110	20	22	7
28	70	0	28	43
32	110	30	32	9

Predicting Readiness

It is often desirable to focus resources and attention on a group of units whose current and future readiness is of concern, for example, on two or three United States Strategic Army Force divisions. In such cases it is important to set realistic readiness goals so that the resource commitment can be estimated or, conversely, to determine the readiness likely to result from given resource commitments. The model proposed can be used for these purposes.

Example 1

The X armored division is now at 78 percent personnel readiness, considering strength and past turbulence. Its strength is 10,500. Over the next 3 months, losses are expected to be 1200 and gains to be 2000. Authorized strength is 13,500. What will the strength-turbulence indicator show readiness to be at the end of the 3-month period if gains require 1 week for administrative purposes and 4-weeks learning time?

$$\text{Readiness value} = \left[\frac{E - G\dfrac{(t_1 + c_0 k t_2)}{T}}{A}\right]$$

$E = 10{,}500 - 1200 + 2000 = 11{,}300$

$T = 3;\ t_1 = 1;\ t_2 = 4;\ k = 0.5$ (linear learning); $c_0 = 1$

Readiness = 100 [11300 − 2000 (3/13)]/13500 = (10839/13500) = 80 percent or C-3.

Example 2

If all data are as stated in Example 1 and it is desired to raise the X armored division from C-3 (78 percent) to C-2 (85 percent) by the end of the next 3 months, how many gains are required?

$$85 = 100\left[\frac{E - G\dfrac{(1+2)}{13}}{13500}\right]$$

$$E = B - L + G$$

$$85 = 100\left(\frac{10500 - 1200 + G - \dfrac{3G}{13}}{13500}\right)$$

$$G = 2840.$$

Thus, presuming that gains arrive uniformly throughout the period, 840 more gains must be programmed into the division than now planned.

TABLE 9

Comparison of Strength-Turbulence Model with AR 220-1[1,a]

(44 test cases)

Case rank	Strength: Beginning	Strength: End	Losses	Gains	1 month (T = 1): c_e[b]	1 month: Value	1 month: $\frac{L+G}{B+E}$	1 month C-rating: AR 220-1	1 month C-rating: Model	1 month: Disagreement[c]	1-month rank	3 months (T = 3): c_e[b]	3 months: Value	3 months: $\frac{L+G}{B+E}$	3-month rank	3 months C-rating: AR 220-1	3 months C-rating: Model	3 months: Disagreement[d]
1	120	115	6	1	1^e	114	—	C-1	C-1	—	1	1	115	—	1	C-1	C-1	—
2	120	115	12	7	1^e	108	—	C-1	C-1	—	2	1	113	—	2	C-1	C-1	—
3	110	105	6	1	1^e	104	0.05	C-1	C-1	—	3	1	105	0.06	4	C-1	C-1	—
4	110	104	6	0	1^e	104	0.04	C-1	C-1	—	4	1	104	0.03	6	C-1	C-1	—
5	100	100	0	0	1	100	0.0	C-1	C-1	—	5	1	100	0.0	10	C-1	C-1	—
6	110	100	10	0	1	100	0.05	C-1	C-1	—	6	1	100	0.05	11	C-1	C-1	—
7	120	100	20	0	1	100	0.09	C-1	C-1	—	7	1	100	0.09	12	C-1	C-1	—
8	110	99	11	0	1	99	0.05	C-1	C-1	—	8	1	99	—	14	C-1	C-1	—
9	110	105	11	6	1^e	99	0.08	C-1	C-1	—	9	1	103	—	8	C-1	C-1	—
10	120	115	24	19	1^e	96	—	C-1	C-1	—	10	1	109	—	3	C-1	C-1	—
11	100	100	5	5	1	95	0.05	C-1	C-1	—	11	1	98	0.05	15	C-1	C-1	—
12	100	110	5	15	1^e	95	0.09	C-1	C-1	—	12	1	105	0.1	5	C-1	C-1	—
13	90	90	0	0	1	90	0.0	C-2	C-2	—	13	1	90	0.0	23	C-2	C-2	—
14	100	90	10	0	1	90	0.05	C-2	C-2	—	14	1	90	0.05	24	C-2	C-2	—
15	110	88	22	0	1	88	—	C-2	C-2	—	15	1	88	—	25	C-2	C-2	—
16	90	100	0	10	2	82	0.05	C-1	C-3	xx	16	1	97	0.05	16	C-1	C-1	—
17	100	100	10	10	2	82	0.10	C-1	C-3	xx	17	1	97	0.10	17	C-1	C-1	—
18	80	80	0	0	1	80	0.0	C-3	C-3	—	18	1	80	0.0	35	C-3	C-3	—
19	90	80	10	0	1	80	0.06	C-2	C-3	x	19	1	80	0.06	36	C-3	C-3	—
20	100	80	20	0	1	80	0.11	C-3	C-3	—	20	1	80	0.11	37	C-3	C-3	—
21	80	80	4	4	1	76	—	C-3	C-4	x	21	1	79	—	38	C-3	C-3	—
22	100	110	10	20	2^e	75	0.14	C-1	C-3	xx	22	1	104	0.14	7	C-1	C-1	—
23	110	105	22	17	2^e	75	0.17	C-1	C-3	xx	23	1	100	0.18	13	C-1	C-1	—
24	90	90	9	9	2	74	0.10	C-2	C-4	xx	24	1	87	0.10	27	C-2	C-2	—
25	90	100	5	15	2	74	0.11	C-1	C-4	xxx	25	1	95	—	18	C-1	C-1	—

RAC

26	80	90	0	10	2	72	0.08	C-2	C-4	xx	26	1	87	0.08	26	C-2	C-2	—
27	100	90	20	10	2	72	0.16	C-2	C-4	xx	27	1	87	0.16	28	C-2	C-2	—
28	80	70	0	10	1	70	—	C-4	C-4	—	28	1	70	—	43	C-4	C-4	—
29	80	90	4	14	2	65	—	C-2	C-4	xx	29	1	86	—	29	C-2	C-2	—
30	80	82	8	10	2	64	0.10	C-3	C-4	x	30	1	77	0.10	39	C-3	C-3	—
31	90	82	16	10	2	64	0.15	C-3	C-4	x	31	1	77	0.15	40	C-3	C-3	—
32	100	110	20	30	C-4[e]	—	—	C-1	C-4	xxx	32	1	101	—	9	C-1	C-1	—
33	90	100	9	19	C-4	—	—	C-1	C-4	xxx	33	1	94+	—	19	C-1	C-2	x
34	80	100	0	20	C-4	—	—	C-1	C-4	xxx	34	1	94	0.11	20	C-1	C-2	x
35	100	100	20	20	C-4	—	—	C-1	C-4	xxx	35	1	94	0.20	21	C-1	C-2	x
36	80	100	4	24	C-4	—	—	C-1	C-4	xxx	36	1	93	—	22	C-1	C-2	x
37	80	90	6	18	C-4	—	—	C-2	C-4	xx	37	1	84	0.15	32	C-2	C-3	x
38	90	90	1[illegible]	18	C-4	—	—	C-2	C-4	xx	38	1	84	0.20	33	C-2	C-3	x
39	80	100	8	28	C-4	—	—	C-1	C-4	xxx	39	2	85	0.20	30	C-1	C-2	x
40	90	100	18	28	C-4	—	—	C-1	C-4	xxx	40	2	85	0.24	31	C-1	C-2	x
41	80	100	16	36	C-4	—	—	C-1	C-4	xxx	41	2	81	—	34	C-1	C-3	xx
42	80	80	16	16	C-4	—	—	C-3	C-4	x	42	1	75	—	42	C-3	C-3	—
43	80	90	16	26	C-4	—	—	C-3	C-4	x	43	2	76	—	41	C-2	C-3	x
44	80	70	16	6	2	39	—	C-4	C-4	—	44	1	68	—	44	C-4	C-4	—

[a]Given:
Unit authorized and TOE strength are 100.
Administrative learning time t_1 is 1 week.
Linear learning curve, k is 0.5.
Constant learning time t_2 is 6 weeks.

[b]See Table 4.

[c]Total: 53. X's indicate number of steps away from agreement.

[d]Total: 11.

[e]In each case, gains excess to full strength are excluded in computing G/E.

SUMMARY OF MODEL FEATURES

The model provides a strength-turbulence indicator at a point in time (a snapshot of readiness) for Army units. This is consistent with current practice and contrasts with depicting average readiness over some specified past period.

The model is continuous, so that the time period over which turbulence occurs can be of any length.

The model presumes that the losses and gains, which both create turbulence, occur uniformly over the time period for which data are available.

The model assumes that any amount of personnel turnover is undesirable.[a]

If applied to aggregations of units, (e.g., to a division) the aggregation is treated as a single unit.

The model does not differentiate among kinds of turbulence, or distinguish turbulence by underlying cause; the value of MOS manpower spaces where turbulence occurs are not weighted. Thus a loss-gain transaction involving a jeep driver or cook will have the same effect as one involving a first sergeant or a missile radar repairman. (This simplifying assumption can be dropped—as shown—but to do so requires assigning relative values to MOSs or at least to groups of MOSs and also requires that gains be reported in the same groupings.)

The model has the following advantages:

It is simple.

It is applicable over any period of time.

It permits turbulence to be measured by its result, viz, lowered effectiveness of personnel.

It permits experience and judgment to be applied in military terms, i.e., to how long it takes a new accession to start contributing to unit effectiveness and how long after contributing he becomes a fully effective member of the unit.

It is flexible enough to permit weighting gains and losses by MOS, grade/rank, or position if such is desirable (and if data are reasonably available).

In conclusion, the strength-turbulence model can be used to show the effect of personnel turnover on unit readiness.

A MODEL FOR MEASURING MOS MATCH

BACKGROUND

The MOS indicator[9] now used by the Army to measure the skills available in a unit treats all MOSs as equally valuable to the unit; it does not differentiate on the basis of relative importance of MOS or on the basis of relative fill. Thus a unit authorized 10 sergeants of a given MOS and 90 privates of a given MOS would be rated 90 percent if it had no sergeants and 90 privates or if it had 10 sergeants and 80 privates. The example also holds for low- and high-skill levels among MOSs.

This chapter describes a model that takes into account the relative importance of MOSs[10] when measuring the skill available to a unit that does not have all authorized or all TOE MOSs in its operating strength.

PARAMETERS OF PROBLEM

The objective is to design a model that will measure the quality of the MOS strength in a unit rather than simply the percentage fill. Thus a logical system must be devised to put a value on each MOS missing from the ideal distribution of MOSs for the unit being assessed. The ideal distribution of MOSs is taken to be either that shown in the full TOE or that authorized, with, however, no penalty to be assessed or any enhancement to be granted for overstrength in any MOS.[11] As in the case of the strength-turbulence model, either TOE or authorized strength can be used. To avoid complications and to facilitate comparisons with the REDCON ratings of AR 220-1,[1] we will use authorized strength equal to TOE in the examples. To ease the reporting burden and keep computations uncomplicated, the system that assigns values to missing MOSs must also be simple.

The problem, then, resolves itself into defining a simple system for degrading readiness (as measured by an MOS indicator) when the operating strength of a unit fails to include all the authorized (or all the TOE) MOSs. Such a mismatch will always occur if a unit is understrength and is likely to occur when a unit is at strength or is overstrength.

In increasing order of complexity, the following suggest themselves as bases for degrading readiness, as measured by MOS match: skill level; relative fill of each MOS, ignoring skill level; or a combination of skill level and relative fill for each MOS.

Skill Level. The fourth character of the enlisted men's four-character MOS indicates the skill level of the MOS. The characters are digits from 1 (low) to 5 (high). Suggested here is weighting the MOS in a unit solely on skill level.

Let $W_1 \ldots W_5$ = the relative weights assigned to skill levels 1 to 5

where $\sum_{i=1}^{5} W_i = 1$

A_i = the number of manpower spaces authorized the i th skill level

O_i = the operating strength of the ith skill level

Then

$$\text{MOS indicator} = 100 \sum_{i=1}^{M} W_i \left(\frac{O_i}{A_i}\right) \qquad (6)$$

where $\sum_{i=1}^{M} W_i = 1$

Example 1:

Given a unit with authorized = TOE strength = 100 enlisted men

Skill level	Actual weight W[a]	Authorized A	Operating O
1	0.150	50	40
2	0.175	20	22
3	0.200	10	8
4	0.225	15	10
5	0.250	5	3
Total		100	83

[a]Examples used in this paper assign relative values to skill levels as shown in the following tabulation.

Skill level	Relative value	Weight
1	0.6	0.150
2	0.7	0.175
3	0.8	0.200
4	0.9	0.225
5	1.0	0 250

Military judgment might dictate the use of different relative values.

Applying Eq 6, MOS indicator for enlisted men =

$$100 \left[0.150\left(\frac{40}{50}\right) + 0.175\left(\frac{20}{20}\right) + 0.200\left(\frac{8}{10}\right) + 0.225\left(\frac{10}{15}\right) + 0.250\left(\frac{3}{5}\right)\right] = 75.5$$

This system will not hold for officers since skill level is not differentiated except by presumption on the basis of rank. However, the same principle can be applied to officers. We can assign relative values to officers and warrant officers for each rank, or we can group them (as does AR 220-1[1] for measuring personnel turnover) into three groups: warrant officers; lieutenants (0-1 and 0-2); and captains, majors, and lieutenant colonels (0-3 to 0-5).

In the example given, the unit is authorized six officers.

Rank	Weight W		Authorized A	Operating O
	Actual	Relative		
Warrant officers	0.30	0.8	2	1
0-1 and 0-2	0.33	0.9	3	2
0-3 to 0-5	0.37	1.0	1	1

Applying Eq 6

$$\text{MOS indicator for officers} = 100\,[0.3\,(1/2) + 0.33\,(2/3) + 0.37\,(1/1)\,] = 74.2$$

It now is necessary to combine the value of the indicator for enlisted men and officers. It is proposed that this be done on the concept that enlisted men as a group and officers as a group contribute equally to the readiness of a unit. (It might also be done on the basis of the proportion of officers and enlisted men authorized in the unit, which would mean that each person in the unit, whether officer or enlisted, contributes equally to readiness.) More formally

$$\text{MOS indicator} = 1/2\ (\text{MOS}_O + \text{MOS}_E) \tag{7}$$

where MOS_O is the value of the MOS indicator for officers, and MOS_E is the value of the MOS indicator for enlisted men. Applying Eq 7, MOS indicator $= \frac{1}{2}\,(74.2 + 74.5) = 74.9$ or 75 or C-3, assuming the same correspondence between numerical value of the indicator and the readiness rating as that prescribed in AR 220-1. Note that AR 220-1 would compute the MOS indicator to be $[(83 - 2 + 4)/100]\ 100 = 85$ or C-2.

This system would be simple, but it is still relatively crude because it does not weight the value of the skill (MOS) itself for either enlisted men or officers but only the value of the skill level (or rank, in the case of officers).

Relative Fill of Each MOS, Ignoring Skill Level. There are some 460 three-character enlisted MOSs. In an infantry division, one would expect to find something in excess of 250 of these, depending on the mix of maneuver battalions. In an infantry battalion, for example, there are 29; in a 155-mm howitzer field artillery battalion (SP) there are 25. What is suggested here is a system that weights the three-character MOSs in a unit.

There appear to be two ways to do this, only one of which seems simple enough to be feasible. The first method, which is quite complex because of the number of MOSs to be weighted, assigns a relative value to each MOS and from this devises a relative weight. Complicating the problem is the probability that the same MOS in different units should have a different value, and there are some 600 different TOE units. In addition, even in units with the same TOE, the value of the MOS might be different depending on the location of the units and the relative fill of other MOSs in the unit.

The second possible way of weighting MOS is to assume that each man in a given MOS has a value inversely proportional to the number of men with that MOS authorized for the unit.

Let

N = the number of different three-character MOSs in a unit
A_j = the total number of spaces authorized in the jth MOS
O_j = the total operational strength in the j th MOS.

Then

the value of the j th MOS = $100/N$ (i.e., all three-character MOSs in the unit are considered equally important)
the value of any one man in the j th MOS = $1/A_j$
the value of all men in the j th MOS if $O_j \le A_j = (100/N) \times (1/A_j) \times O_j$
the value of all men in all MOSs is

$$\text{MOS indicator} = \frac{100}{N} \sum_{j=1}^{N} \left(\frac{O_j}{A_j}\right) \qquad (8)$$

The quantity $100\,(O_j/A_j)$, $j = 1, 2, \ldots N$ represents the percentage fill for each three-character MOS, and the MOS indicator is the average value of this set of numbers for the unit.

Example 2:

Given a unit with authoriz-d u TOE strength = 150; MOS a-d operating strength as shown in the following chart.

MOS	Authorized A	Operating O
1	20	16
2	10	12
3	8	7
4	15	12
5	3	2
6	6	4
7	35	30
8	1	1
9	18	16
10	34	31
Total	150	131

Applying Eq 8

$$\text{MOS indicator} = \frac{100}{6}\left(\frac{16}{20}+\frac{10}{10}+\frac{7}{8}+\frac{12}{15}+\frac{2}{3}+\frac{4}{6}+\frac{30}{35}+\frac{1}{1}+\frac{16}{18}+\frac{31}{34}\right) = 84.7 \text{ or C-2}$$

again assuming the same correspondence between numerical value of the indicator and the readiness rating. Note that the MOS indicator in AR 220-1 would be 129/ 150 = 86 + or C-1.

This system would be relatively simple and has the advantage of handling officers and enlisted men in a single computation. However, it is still somewhat crude in that it does not differentiate among skill levels. Thus, in the example, MOS 1 is authorized 20 spaces. In actual fact these might be distributed across skill levels about as shown.

Level	Authorized A	Operating 0		
		Case 1	Case 2	Case 3
1	8	8	20	0
2	5	5	0	0
3	2	2	0	0
4	4	4	0	0
5	1	1	0	20
Total	20	20	20	20

Equation 8 would give the same results for all three cases of operating strength.

In addition, there is some question as to whether weighting MOSs in inverse proportion to their frequency is justified. Such weighting might imply (1) that the best understrength unit is one where every subordinate echelon is understrength by the same amount or (2) that the best understrength unit eliminates subordinate echelons in proportion to its understrength. The fact that either implication is possible provides a certain desirable flexibility in how one can organize an understrength unit.

The problem of distributing the strength of an understrength unit was faced by the Army in developing its newest (G-series) set of TOE. The TOE format requires a grade and an MOS distribution (presumably the "best") for each of three levels of personnel fill (100, 90, and 80 percent) corresponding to REDCONs 1, 2, and 3. A dilemma: should high grade/ skill manpower spaces be provided so that expansion in emergency would be easy or should across-the-board reductions be taken to keep as much mission capability as possible in peacetime? The first procedure would make sense for the strategic reserve in CONUS; the second, for units deployed overseas. A review of a number of tank, armored cavalry, infantry, and artillery TOE suggests that the choice made was to lean toward keeping the high grade/ skill manpower spaces and to remove a disproportionate share of lower-skill spaces. For example, the difference between a 100 percent infantry company and a 90 percent infantry company is 19 spaces. All 19 spaces were removed from the lowest skill level.

This tends to be the general pattern, but there are significant exceptions. For example, in a 105-mm howitzer battery, the difference between a 90 and an 80 percent unit is 12 spaces. Of these, 6 were removed from skill-level 4 from a base of 27 skill-level-4 spaces. Only 6 were removed from skill-level 1 from a base of 53 skill-level-1 spaces.

The TOE examined strongly suggest that understrength is best absorbed if it is in low-skill levels. But there was no consistent, simple rule followed in devising the distribution of skill levels when the TOE were designed for various fill levels. Rather their distribution was tailored for each type of unit, following no discernible pattern from unit to unit.

Weighting MOSs in inverse proportion to their frequency produces results that are generally consistent with the concept that the "best" understrength units are those that are understrength in low skills. This is true because there are many more low skills (1 and 2) than there are high skills (4 and 5) in most units. (In certain highly skilled small technical units this is not true.)

Finally the fact that the total strength in each MOS is valued the same can introduce some apparent anomalies. To illustrate, if the authorization for MOS-1 is 2 and for MOS-2 is 50, the same penalty to the MOS indicator will occur for a shortage of 1 in MOS-1 as for a shortage of 25 in MOS-2. However, this does not appear to be too serious a weakness since, if the shortage in MOS-1 is carried over into a shortage in total strength of the unit, this will be reflected in the strength-turbulence model discussed earlier.

<u>A Combination of Skill Level and Relative Fill for Each MOS.</u> Suggested here is some way of assessing the contributions made by each four-character enlisted MOS and by each MOS and grade for officers. Since there are about 1400 four-character enlisted MOSs, the problem of assessing the contribution and assigning a value to each MOS/skill level for enlisted men and each MOS/grade for officers that will apply in all units under all understrength conditions is even more intractable than outlined under system 2.

A feasible system of handling each MOS and skill level would be to combine the concepts of systems 1 and 2, viz, to accept that the value of a given man in a given MOS is inversely proportional to the number of such MOSs authorized for the unit and also that his value is directly proportional to the skill level of the MOS. Such a combination would be somewhat more complex to compute than either of the systems discussed earlier, but it would also take into acoount both fill by individual MOS and the relative value of each skill level.

We will develop two models, one for enlisted men by MOS and skill level and one for officers by MOS and grade. The resultant MOS indicator must then be combined, for which Eq 7 is recommended.

Let

$A_{i,j}$ = the authorized strength for the jth MOS (either officer or enlisted) of the ith skill level (enlisted) or ith grade (officers)

$O_{i,j}$ = the operating strength for the jth MOS (either officer or enlisted) of the ith skill level (enlisted) or ith grade (officers)

N_i = the number of different MOSs at the ith skill level (enlisted) or ith grade (officers)

Then

$$\frac{100}{N_i}\left[\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right]$$

is the MOS indicator corresponding to Eq 8 for the ith skill level (enlisted) or ith grade (officers).

Let W_i be the weight assigned to the ith skill level (enlisted) or ith grade (officers). The weight W_i corresponds to judgment concerning the relative importance of the strength (fill) of the ith skill level (enlisted) or grade (officers) to the readiness of the unit. Then the measures for each skill level or grade can be combined as follows:

$$\text{MOS indicator} = \frac{100}{\sum_{i=1}^{M} W_i}\left[\sum_{i=1}^{M}\left(\frac{W_i}{N_i}\right)\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right]$$

where M is the number of skill levels (i.e., 5) for enlisted or grades for officers. (For simplicity, we propose that officer grades be grouped into the same three categories as in AR 220-1, although all grades can be assessed if the user is able to weight their relative importance.) If the weights are chosen so that the sum equals one, the quantity $\Sigma_{i=1}^{M} W_i$ in the denominator outside the brackets is not needed.

Note that with the MOS indicator for each skill level (enlisted men) or grade (officers) representing the average percentage fill of the MOS corresponding to that skill level or grade, the overall measure is the weighted average percentage fill for the entire unit where the weights are assigned on the basis of the relative importance of the strength of each skill level or grade to the readiness of the unit.

To summarize

$$\text{MOS indicator for enlisted men} = \frac{100}{\sum_{i=1}^{5} W_i}\left[\sum_{i=1}^{5}\left(\frac{W_i}{N_i}\right)\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right] \qquad (9)$$

$$\text{MOS indicator for officers} = \frac{100}{\sum_{i=1}^{3} W_i}\left[\sum_{i=1}^{3}\left(\frac{W_i}{N_i}\right)\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right] \qquad (10)$$

and

$$\text{MOS indicator for the unit} = 1/2\ (MOS_O + MOS_E). \qquad (7)$$

It should be understood that the purpose of W_i is to provide a way of assigning a relative weight to each of the five skill levels for enlisted men and to each of the three groups of grade level for officers. This means, for example, that different values of W_i for different skill levels would penalize differently the lack of a single man in each of two MOSs of different skill levels even though the number of spaces authorized each of the two MOSs were the same.

To test and to compare the model to AR 220-1[1], imaginary data within what might be found in the real world were devised for 10 cases. Equation 9 was used (all enlisted MOSs) with the values shown for W_i:

Skill level	Value W_i
1	0.6
2	0.7
3	0.8
4	0.9
5	1.0

These values are believed to be reasonable, but they are purely arbitrary. Military judgment may suggest other values. The results are shown in Table 10.

TABLE 10

Test Cases of Proposed MOS-Indicator Model

MOS	Authorized number	Operating strength by case									
		1	2	3	4	5	6	7	8	9[a]	10
Sample Data											
TOE number											
11A1	30	30	30	30	30	15	15	25	30	31	30
11B1	50	50	33	67[a]	50	25	35	42	7	51	53[a]
71A1	6	5	6	5	0	3	6	5	6	7	4
11D2	20	20	20	20	20	10	20	17	20	21	27[a]
31B2	8	7	8	7	0	4	8	7	8	9	8
44C2	7	6	7	6	0	4	7	6	7	8	0
64B2	6	5	6	5	6	3	6	5	6	7	4
71B2	6	5	8	5	6	3	6	5	6	7	4
11A3	9	8	9	6	9	5	9	8	9	10	9
31F3	7	6	7	6	7	3	7	6	7	8	3
71C3	5	4	5	4	0	3	5	4	5	6	5
76K3	3	3	3	3	0	1	3	2	3	4	3
91B3	5	4	5	4	0	3	5	4	5	6	5
11C4	10	9	10	9	0	5	10	6	10	11	17[a]
11D4	1	0	1	0	0	0	1	1	1	2	1
91B4	4	4	4	4	4	2	4	3	4	5	4
94B4	5	4	5	4	5	2	5	4	5	6	5
11D5	2	0	2	0	0	1	2	2	2	3	2
11F5	2	0	2	0	2	1	2	2	2	3	2
11G5	1	0	1	0	1	1	1	1	1	2	1
Total	167	170	170	167	140	94	157	157	144	207	167
Comparative Results											
MOS indicator											
Model	—	62	98	62	56	51	96	67	96	100	90
AR 220-1	—	91	91	91	75	50	84	84	77	100	91
REDCON (C-)											
Model	—	4	1	4	4	4	1	1	1	1	1
AR 220-1	—	1	1	1	3	4	2	2	2	1	1

[a]Overstrength.

The most striking feature of the results that the model gives is that sometimes they are higher and sometimes they are far lower than the results from AR 220-1. For example, consider Cases 1 and 2, which AR 220-1 computes at 91 percent and the model computes at 62 and 98 percent respectively, even though both cases have the same operating strength. The reason for the difference, of course, is that the understrength in Case 1 is almost all in MOSs with low authorizations and high skills, whereas in Case 2 all the understrength is in the MOS with the highest authorization and lowest skill. The results seem to accord with the general scheme followed by the Army in designing the 90 and 80 percent columns of the G-series TOE; viz, to retain the higher-skill levels (which exist in smaller numbers) and to remove a disproportionate share of low-skill levels.

APPLICATION

The computational effort would be laborious if done by hand. We have developed a computer program in FORTRAN for the CDC 6400 computer that can compute and print out the MOS indicator for 1000 units varying in size from 2 to 20,000 and including all 1400 four-character MOSs in less than an hour of computer time.[12] This program was written, debugged, and tested at RAC in 6 man-hours using about 120 effective seconds of computer time. Similar programs could be written for computers used by the Army in the field or at the DA.

An idea of the burden of preparing data for the computer can be derived from Table 11 and the following discussion.

TABLE 11

Number of Different Four-Digit MOSs for Typical Units

Kind of unit	Number of different MOS		
	Officer	Enlisted	Total
Infantry division base	118	324	442
Infantry battalion	16	53	69
Infantry rifle company	1	17	18
Airborne battalion	15	48	63
Infantry mechanized battalion	16	53	69
Howitzer battalion (105-mm SP)	14	45	59

It takes one input card for each 16 MOSs to show authorized strength and one input card for each 16 MOSs to show operating strength. Table 12 shows the number of cards that would have to be prepared at the end of each reporting period for some of the units in Table 11.

There seem to be no data-collecting or computational barriers to the proposed model. All the data needed for each unit are the authorized and operating strength by MOS for enlisted men and by MOS and grade for officers. (The OPO-45 report[4] contains the data consolidated by command.)

TABLE 12

Number of Computer Cards for Typical Units

Kind of unit	Number of cards	
	First report	Subsequent reports
Infantry division	56	28 + 1[a] for each MOS with changed authorization
Infantry battalion	9	5 + 1[a] for each MOS with changed authorization
Artillery battalion (105-mm SP)	8	4 + 1[a] for each MOS with changed authorization

[a]This is the maximum. If changed authorizations occur, it is likely that several will occur among the 16 MOSs on a single card. Only one card need be punched for all such changes.

It would probably not be wise to substitute the proposed model for the model in AR 220-1; it would be better to use both on a limited number of units of most concern, e.g., all divisions or all units controlled by the Office of the Secretary of Defense. Table 13 depicts the kinds of insights possible when both are used.

TABLE 13

MOS Match: Results of Two Models

Division	MOS indicator		Remarks
	AR 220-1	Proposed	
X infantry	84	96	Unit MOS shortage is made up primarily of those authorized in large numbers, hence probably low-skilled personnel
Y infantry	86	85	Unit MOS shortage is about proportional to authorized strengths by MOS and skill
Z armored	96	71	Unit is nearly up to strength in MOS but shortages exist in some key MOS that are authorized the unit in relatively small numbers and probably in high skills

CONCLUSION

The proposed model can provide a refined view of MOS match in units to supplement the raw percentage model of AR 220-1.[1]

Appendix A

EXAMPLE OF READINESS REPORTING FOR THE A INFANTRY DIVISION

Tables

Given:

The A infantry division consisting of a division base and nine infantry battalions with authorized and operating strengths by MOS. (See Table A4 for extract.)

Authorized strength (full TOE)	= 15574
Operating strength	= 14805
Gains since last report	= 3680
Reporting period	= 3 months
Administrative time for new arrivals	= 1 week
Training time	= 6 weeks
Linear learning curve	

Determine

(1) Strength indicator
(2) Strength-turbulence indicator
(3) MOS indicator (AR 220-1)
(4) MOS indicator (proposed model)

Solution

(1) Strength indicator $= 100\left(\frac{E}{A}\right) = 100 \times \frac{14805}{15574} = 95$

(2) Strength-turbulence $= 100\left[\frac{E - G\,\frac{(t_1 + c_e k t_2)}{T}}{A}\right]$

$$= 100\left\{\frac{14805 - 3680\,\frac{1 + [1 \times (1/2) \times 6]}{13}}{15574}\right\}$$

$$= 88$$

(3) MOS indicator (AR 220-1) $= 100 \times \frac{\text{authorized MOS in operating strength}}{\text{total MOS}}$

$$= \frac{14805 - 83^*}{15574} = 95$$

*Overstrength MOS.

(4) MOS indicator (proposed model) = (1/2) (MOS_O + MOS_E) = 85*

where

MOS_o = MOS indicator for officers =

$$\frac{100}{\sum_{i=1}^{3} W_i}\left[\sum_{i=1}^{3}\left(\frac{W_i}{N_i}\right)\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right]$$

and $W_i^\dagger$ = 1.0 for 0-3 and above
= 0.9 for 0-1 and 0-2
= 0.8 for warrant officers

MOS_E = MOS indicator for enlisted =

$$\frac{100}{\sum_{i=1}^{5} W_i}\left[\sum_{i=1}^{5}\left(\frac{W_i}{N_i}\right)\sum_{j=1}^{N_i}\left(\frac{O_{i,j}}{A_{i,j}}\right)\right]$$

and $W_i^\dagger$ = 1.0 for skill-level 5
= 0.9 for skill-level 4
= 0.8 for skill-level 3
= 0.7 for skill-level 2
= 0.6 for skill-level 1

Table A1 is a display table for the A infantry division; from it the following conclusions can be drawn about the division: The division is at 95 percent in gross strength, but enough of that strength is ineffective because of personnel turnover to reduce the division to C-2. In skills, the division has 95 percent of TOE (or authorized), but there is a shortage in the higher-skill levels and among those skills authorized in relatively small numbers to reduce the division to C-2.

TABLE A1

Readiness Summary

Indicator	Rating	C-rating
Strength (AR 220-1)	95	C-1
Strength-turbulence	88	C-2
MOS (AR 220-1)	95	C-1
MOS (proposed)	85	C-2

*Solved using the RAC CDC 6400 computer.

†Arbitrary values. Military judgment may dictate a weight for each grade and skill level or a value of 1.0 for all.

Overall personnel readiness is C-2. The number 85 is for the division as a whole. Actually the computations shown in Table A2 were also made.

TABLE A2

MOS Indicator: Proposed Model

Unit	Category	MOSs handled	MOS indicator
Division base	Officers	117	81
Division base	Enlisted men	318	90
9 infantry battalions	Officers	16	69
9 infantry battalions	Enlisted men	53	91
Entire division	Officers	117	79
Entire division	Enlisted men	324	90
Entire division	Officers and enlisted men	441	85

These seven computations required ¼ effective minute of computer time on the computer. As mentioned earlier the only input that the model requires is the authorized and operating strength of a unit by MOS and weights to be assigned to skill levels and grades. The output format displays the readiness indicator for the unit as a whole, the total number of different MOSs handled, total authorized and operating strengths (including the overstrength ignored in the computation), and the same set of data for each skill-level and officer-grade grouping. Thus a much more detailed table than Table A2 can be provided.

Using data like those in the example, a summary display table (Table A3) can be prepared.

TABLE A3

Readiness Report Summary as of (Date)

Unit	Strength data			Readiness indicators				C-rating[c]
	Table of organization/ table of distribution	Authorized	Operating	Strength, percent	Strength-turbulence, percent	MOS indicator		
						Crude,[a] percent	Proportional,[b] percent	
A	xx.x	xx.x	xx	xx	xx	xx	xx	C-X
B	xx.x	—	—	—	—	—	—	—
C	xx.x	—	—	—	—	—	—	—

[a]AR 220-1 model.[1]
[b]Model proposed in this paper.
[c]Based on lowest of the four indicators.

Table A4 presents an extract of input data by MOS.

TABLE A4

Input Information by MOS

MOS	Authorized strength	Operating strength	MOS	Authorized strength	Operating strength	MOS	Authorized strength	Operating strength
				Officers, 115 MOSs				
00002	3	3	06201	4	3	03100	17	19
00221	1	1	09100	2	1	03500	1	1
00606	1	1	201A0	1	2	04015	1	1
00694	1	1	51154	1	1	04415	1	1
01330	1	1	57314	8	8	04512	2	1
01982	2	1	62162	1	1	04808	1	1
02136	2	1	671C0	5	5	05310	19	21
02260	3	3	721A0	2	2	06103	5	3
02900	24	22	00200	17	15	09301	10	8
03150	8	8	00420	1	0	286A0	1	1
03606	1	1	00660	5	4	51199	2	2
04200	5	5	01183	3	3	60210	1	1
04470	1	1	01342	5	3	632A0	1	1
04514	1	1	02010	2	1	711A0	6	5
04880	1	1	02183	5	5	781A0	9	8
06200	104	94	02516	2	1	00220	8	7
06500	1	1	03005	1	1	00600	4	3
09310	2	1	03170	4	5	00692	1	0
441A0	4	3	04010	27	29	01204	20	18
57010	1	1	04400	1	1	01981	24	21
621A0	1	1	04510	4	3	02110	21	20
671B0	2	1	04800	13	12	02210	1	1
71542	2	3	05000	2	2	02625	2	1
961A0	1	1	07423	1	1	03129	1	1
00030	2	2	09110	7	6	03506	15	14
00400	1	1	211A0	4	3	04130	1	1
00607	1	1	51193	26	26	04419	2	1
01154	3	3	59301	11	11	04513	1	1
01331	25	23	831A0	11	12	04815	1	1
01983	7	6	66301	1	1	05505	3	2
02162	18	17	741B0	1	1	06105	2	1
02430	1	1	00210	6	4	09309	2	1
03000	5	7	00500	2	1	421A0	4	4
03160	2	2	00663	2	1	52162	17	17
04000	2	2	01193	102	96	61204	11	10
04210	1	1	01542	18	15	64823	7	7
04490	1	0	02030	4	3	713A0	1	1
04530	1	0	02200	4	4	941A0	5	5
04960	2	1	02624	4	3			
				Enlisted Men, 316 MOSs[a]				
02B20	1	1	12A10	123	121	31L40	3	2
02E30	4	3	12B50	7	7	31Z40	6	6
02K30	1	0	12D60	2	1	35E20	2	1
03C20	1	1	13D20	40	41	36C10	70	68
11B10	100	98	17B10	3	3	41C20	8	8
11B4E	1	1	26B30	6	3	43K20	2	2
11C40	9	7	31B20	13	12	44E20	10	10
11D40	55	50	31E40	3	3	45F20	18	17
11E50	1	1	31H50	5	5	45H40	1	1

TABLE A4 (continued)

MOS	Authorized strength	Operating strength	MOS	Authorized strength	Operating strength	MOS	Authorized strength	Operating strength
51H20	4	3	11B4P	6	8	41J20	2	2
52B20	87	85	11D1Q	5	5	34B20	2	2
54E20	3	3	11E10	36	34	45B20	6	6
55G20	1	0	11F40	11	11	45G40	1	1
56C40	3	3	12B20	103	100	51A10	3	3
57F20	11	10	12C40	36	40	51N40	6	5
62B40	4	4	13A10	30	28	52D40	1	1
63B20	181	165	13E20	104	100	55A10	2	2
63C50	3	3	17B40	4	4	56B20	17	15
63H40	19	19	26C30	7	7	57A10	25	22
64A10	155	145	31C40	5	5	62B20	43	40
67A10	28	25	31F50	3	2	62F30	6	5
02B30	6	5	31J20	10	8	63C20	72	70
02F30	3	2	31M40	44	40	63G20	17	18
02L20	1	0	34C20	2	2	63Z40	11	11
03Z50	1	1	35G20	1	1	64C40	22	20
11B1P	7	7	36F20	10	8	67N20	81	80
11B40	73	63	41F20	1	1	02D30	3	3
11D10	41	43	44B20	6	8	02J30	10	9
11D50	6	5	45A10	15	12	02N30	1	1
11F20	8	8	45G30	10	8	05C40	56	55
12B2N	9	9	45Z40	1	1	11B20	136	120
12C30	46	45	51N20	10	9	11C20	18	20
13A1N	4	4	52D20	12	10	11D2Q	5	5
13D40	16	14	54E50	1	1	11E40	29	25
17B20	20	18	56A10	45	43	11G50	8	7
26C20	1	1	56D40	3	3	12B40	85	80
31C20	18	20	62A10	11	13	12D40	3	3
31F40	14	15	62E30	10	10	13D2N	20	18
31J10	1	1	63F50	3	2	13Z50	42	40
31M20	62	80	63F40	4	4	26B20	4	3
31Z50	6	6	63K30	2	2	26W40	1	1
35E30	1	1	64C20	3	3	31E20	26	26
36C40	25	20	67N2F	54	52	31H40	40	38
41E20	1	0	02D20	1	1	31L20	7	7
44A10	2	2	02H30	1	1	31Q30	5	4
44Z40	4	3	02M30	3	4	35D20	1	1
45G20	12	10	05C20	124	128	36B20	15	13
45J20	11	10	11B2F	31	30	41C10	1	1
51H40	2	1	11C10	16	20	43A10	1	1
52B30	1	1	11D20	73	71	44C20	10	8
54E40	14	12	11E20	65	63	45C20	9	8
55Z50	1	1	11F50	11	11	45H20	6	6
56D20	8	6	12B4N	3	3	51G20	1	1
57F40	5	5	12C50	1	1	52A10	27	25
62E20	46	50	13B40	270	268	54D20	4	4
63B40	36	34	13E40	74	72	55B20	3	3
63F20	15	18	22A10	1	1	56C20	23	20
63J20	1	1	26D30	1	1	57E40	1	1
64B20	147	137	31D20	12	12	62B30	9	9
67H40	1	1	31G40	7	5	63A10	186	184
02C30	2	2	31K20	5	4	63C40	12	10
02G30	2	2	31Q20	8	6	63H20	129	110
02L30	3	4	35C20	4	4	63Z50	7	6
05B20	91	88	36A10	304	285	64C50	4	3
11B2E	2	1	36G20	8	8	67N40	14	12

[a]Only 195 MOSs listed here.

REFERENCES AND NOTES

1. Dept of Army, "Unit Readiness," AR 220-1, Apr 69.
2. ______, "Dictionary of United States Army Terms," AR 320-5, Feb 63, defines authorized strength as the total of the personnel spaces contained in current personnel authorization vouchers issued by a higher headquarters to a subordinate element.

   AR 220-1 is based on measuring both the strength and the MOS indicator against the full TOE as the standard. This measurement shows how ready units are for combat. If, however, the standard taken is the authorized strength, the results show how well the manpower and personnel programs are being managed. To avoid confusion and to facilitate comparison, the examples in this paper presume that authorized and full TOE strengths are the same. The models developed, however, are indifferent as to which standard is used.
3. The G-series TOE have four columns: full TOE, the so-called 90 and 80 percent columns corresponding roughly to 90 and 80 percent of full TOE and to REDCONs C-2 and C-3, and a column for a cadre unit.
4. Dept of Army, Office of Personnel Operations, "The Inventory and Projection of Army Strengths," OPO-45, monthly report.
5. "Army Manpower Phasedown Planning System," a RAC institutional research project undertaken during 1969.
6. TOE strength should be substituted for authorized strength if readiness comparisons with the C-rating system of AR 220-1 are desired. If this is the case, "TOE strength" can be substituted for "authorized strength" wherever it appears in connection with the strength-turbulence model. To avoid confusion and to facilitate comparisons with the current system, the examples used in the paper presume that authorized strength equals TOE strength.

   TOE strength gives a clear picture of combat readiness. The use of authorized strength, however, gives the best insight into how well personnel resources are being managed and is probably of more interest at the DA level. The model is indifferent to which is used.
7. The Army does attempt to minimize the accounting transactions on personnel during the last 3 days of the month by assigning as few EDCSAs (effective date of change for strength accountability) during those days as possible. However, EDCSA is a paper accounting procedure, having little to do with physical reporting dates since leave, temporary duty, delays enroute, and the like almost always occur during permanent change of station. Thus there are two typical morning report entries covering people whose EDCSA has occurred before they join and for those who join before their EDCSA occurs, namely, "assigned, not joined" and "joined pending EDCSA." It is also true that special cases can occur. For example, if a unit is formed in a short-tour oversea area during 1 month, all members will rotate that same month a year hence. A 3-month readiness report that assumed uniform distribution would be biased. However, oversea commanders in practice do not permit a mass exodus. Instead, as in Vietnam, they combine policies of cross-transfers among similar units and shortened and lengthened tours to smooth the turnover over a reasonable time period. The validity of the assumption as to uniform random distribution of gains can be tested by making a statistical analysis of arrival dates using the morning reports of a set of typical CONUS units.

8. One can conceive of situations where no personnel turnover is less desirable than some, if only to avoid staleness and promotion stagnation. Such a time seems remote today. But in WWII, personnel turnover caused by the necessity to cadre new units improved promotion opportunities and morale and made cadred units more ready than those held stable.

9. AR 220-1 MOS indicator $= \left(\dfrac{\text{personnel at end of reporting period qualified and occupying an authorized MOS}}{\text{total MOS spaces authorized by TOE}} \right) \times 100$

10. The relative importance or value of interest here involves the contribution that the MOS makes to readiness. The value of the MOS—measured by the time, effort, and cost of supplying a replacement for a missing MOS—may be of interest in some management sense (e.g., it may be feasible to design understrength TOE, which are more cost-effective than others, though perhaps less ready); but readiness, as measured by an MOS indicator, is all that is considered in this paper.

11. AR 220-1 directs the unit commander to consider as qualified, when in his judgment they can perform the required duties: personnel awarded secondary MOSs, additional MOSs, and those performing duties to meet MOS requirements of the unit. It also directs that personnel who are overstrength in a specific skill and who do not meet the foregoing criteria not be considered as MOS-qualified. The authors propose the same set of rules be followed in the model developed.

12. Estimate based on experience in handling the various cases covered in this paper. For example, it took $\frac{1}{4}$ min. of computer time to handle the seven computations involving 442 different MOS and 15,000+ personnel in the readiness reporting example. The FORTRAN program is available at RAC.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Research Analysis Corporation McLean, Virginia 22101	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

IMPROVED MODELS TO MEASURE ARMY PERSONNEL READINESS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical paper

5. AUTHOR(S) (First name, middle initial, last name)

Betty W. Holz
Paul D. Phillips

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1969	46	12

8a. CONTRACT OR GRANT NO. DAHC19-69-C-0017 b. PROJECT NO. 009.212 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) RAC-TP-381 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Army Institutional Research

13. ABSTRACT Two models for improving insights into the combat readiness of Army units are proposed. One model permits the effects of personnel turnover (turbulence) to be included in ~~the~~ strength indicator, ~~of AR 220-1.~~ The other model permits a more sophisticated look to be taken at the match between authorized and in-hand skills and skill levels and to modify the MOS indicator ~~of AR 220-1~~ accordingly. Neither model requires units to report information not now being reported. Both models are simple in concept and operation, though one requires a simple computer program that is available ~~at RAC.~~

DD FORM 1 NOV 65 1473

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Readiness Measurement Models						