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Optimizing Promotion Opportunity and In-Zone Range for the Unrestricted Marine Corps Reserve Officer Population

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APPLICATION AREAS: Manpower and Personnel
OR METHODS: Linear Programming, Multiobjective Optimization, Markov Processes

ABSTRACT

This paper illustrates the development of a five-year promotion plan and 10-year forecast for the unrestricted Marine Corps Reserve (MCR) colonel (O6) population using Markov chains and goal programming. A Markov chain model is used to represent the O5 and O6 MCR population. A goal program allows the specification of grade strength targets set by statutory limitations for the rank of O6. Using a linear program with promotion opportunity and in-zone time-in-grade (TIG) range as decision variables for a five-year planning horizon, the goals of the model are to meet grade strength targets and produce consistent promotion opportunity and in-zone values across the planning horizon. The entire unrestricted Reserve officer population is then modeled for an additional five years to monitor company and field grade officer strengths upon returning to the running mate system.

INTRODUCTION

The military drawdown of the 1990s resulted in an increased number of company and field grade officers transferring from the Active to Reserve component. This, combined with implementation of the Reserve Officer Personnel Management Act and greater than anticipated Post-9/11 retention, exacerbated a growing population of senior Marine Corps Reserve (MCR) officers. As a result, in July 2004 the MCR colonels in an active status[a] exceeded the statutory limitation of 490 and reached a peak of 660 in June 2008 as depicted in Figure 1.

Statutory limitations are congressionally mandated ceilings on controlled grades at the end of the fiscal year (September 30). During a time of war or declared national emergency, the President of the United States may temporarily suspend these limits for a period of up to two years.[b] The current waiver of this authority expired in February of 2010[c] and as of November 2011, an approval of an additional two-year waiver was not anticipated.

To reduce the MCR colonel population to meet the statutory limits, Headquarters Marine Corps, Manpower, and Reserve Affairs in 2008 initiated the following actions:

- Elicit voluntary retirements
- Reduce promotion opportunity
- Hold a Selective Retention Board (SRB)
- Reduce promotion zones (size of group to be considered for promotion) by decoupling from the running mate system

Voluntary retirements occur when an MCR colonel agrees to retire early from the Reserve component. However, because Congress had not authorized monetary incentives, this course of action did not nearly account for the necessary reduction in grade strength. Thus, in the precept for the Fiscal Year 2010 (FY10) and FY11 promotion boards, promotion opportunity was reduced by Headquarters Marine Corps from 52% to 42%.[d] (Note: this opportunity was chosen to remain consistent with Secretary of the Navy (SECNAV) guidance regarding opportunity and to avoid unfairly penalizing future in-zone populations.) Additionally, on October 14, 2008, 99 retirement-eligible colonels were selected by the SRB for involuntary retirement, or separation.[e] Lastly, the running mate system is a policy used for Reserve Naval officer promotions for the grades below flag officer rank in which Reserve officers are assigned running mates from the active duty list. When the Reserve officer's running mate is in-zone for promotion, the Reserve officer is also in-zone for promotion.[f] The Marine Corps abandoned this system for the FY11 unrestricted Reserve colonel promotion board in order to meet statutory limitations by 30 September 2010. These combined actions were necessary to meet the statutory limits; however, none of these measures involved a feasible long-term solution or identified consistent promotion opportunities and zones for the Marine Corps Total Force.[g] The Secretary of the Navy Instruction (SECNAVINST) 1420.1B states ''promotion zones will be designed to provide relatively similar promotion opportunity over a period of five years.'' Promotion zone is defined as the time frame for which officers are considered for promotion. The current zone is based off of the previous zone that was selected for promotion. Generally, colonels are in-zone sometime between five and seven years after promotion to lieutenant colonel. The promotion opportunity is defined as the percentage of people in-zone who can be chosen for promotion. The promotion opportunity is calculated by determining the number of officers selected

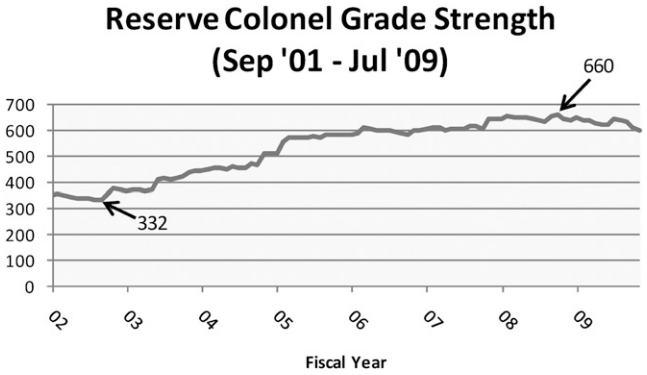

Figure 1. Graphical depiction of MCR colonel historical trends.

divided by the number of officers in the primary zone for promotion. Note: officers in the primary zone are senior to officers below zone for promotion and have not previously been passed over (also known as failing selection) for promotion to that grade.

This paper addresses both short-term and long-term planning for the Marine Corps Total Force with two main objectives. The first objective was to verify that the before mentioned actions would return the MCR colonel population to statutory limitations by September 30, 2010. The second objective was to identify annual promotion opportunities and zones that would maintain the MCR colonel population within statutory limits through 2015 (while returning to the running mate system) and then monitoring this population for an additional five years. Mathematical modeling of the MCR population provided a method for accomplishing these goals. We used goal programming optimization to minimize deviation from target strength numbers for a five-year planning horizon, where end strength was modeled through a Markov chain, by controlling the in-zone ranges and promotion opportunities.

MOTIVATION

The President of the United States may authorize a waiver that allows growth of controlled officer grades beyond the statutory limits during a time of war or declared national emergency to meet planned mobilization requirements. Exceeding the statutory limits in the MCR is not generally considered a fiduciary issue since only those officers on active duty or serving in a formal Selected Marine Corps Reserve (SMCR) (drilling) billet receive substantial monetary allowances. However, one often overlooked concern of promoting beyond statutory limitations is the incurrence of other manpower costs. Although excess pay and benefits are fiscally constrained by annual appropriations and marginal administrative costs are inconsequential, it would be a mistake to ignore increased future retirement obligations.

Contributions to the retired pay accrual account (RPA) fund Reserve retirements and are based on actuary tables and the base pay and compensation of the SMCR.[h] Increasing grade strength while maintaining constant SMCR paychecks results in cumulative actuarial losses to the fund and recoupment through future increases to the Reserve RPA rate and amortization schedule. In this section we sought to discover an approximate hidden future cost to the DoD based on exceeding statutory limits. We calculated the marginal cost of retirement per person as well as the current estimated cumulative marginal retirement cost and net present value of that total.

Unlike active duty retirees who immediately receive annuity payments, Reserve retirees are not eligible to receive retirement annuity payments until age 60. However, only 20 years of Reserve qualifying service is required instead of mandating 20 complete years of active duty service.[i] A qualifying year includes any

combination of active duty, inactive duty (drills), membership, funeral honors duty, and equivalent instruction in which one accumulates 50 retirement points. Generally, a member receives 1 point for each day of active duty, 1 point per drill, 1 point for each period of equivalent duty (paid or unpaid), 1 point for completion of funeral honors duty, and 15 membership points per year. For a full discussion of Reserve retirement credits and qualifications see Chapter 9 of Marine Corps Order 1001R.1K. Recently, the FY08 National Defense Authorization Act reduced the retirement age by three months for every 90 consecutive days on active duty operational support orders after January 28, 2008.[j] Notwithstanding this amendment, we assumed a retirement age of 60 years for cost calculations.

We calculated retirement annuities at a rate of 2½ percent of the active duty base pay of the highest rank satisfactorily held[k] for each cumulative period consisting of 360 retirement points.[l] Retirement in-grade for officers above the rank of major requires three satisfactory years of service (50 points per year) in that grade.

$$\text{Retirement Annuity} = \frac{\text{Retirement Points}}{360} * 2.5\% * \text{base pay} \qquad (1)$$

The active duty annual pay is based on the pay tables when retired pay is calculated (age 60) and subject to annual cost of living adjustments. We rounded down fractional years resulting from the 360 point calculations to the lower 30 day (month) period. For instance, 36,100 points would be rounded down to 36,090 points (equivalent to 10.25 years and an annuity of 25.625%).

Calculating Marginal Costs of Retirement

The marginal cost of exceeding statutory limitations for grade strength is calculated by taking the difference between annuity payments of the higher retired grade (plus additional retirement points earned by MCR colonels compared to lieutenant colonels) and then multiplying that annual amount by the cumulative overage of promotions and the average life expectancy beyond age 60.

$$MC = (O6_{\text{Ret. Annuity}} - O5_{\text{Ret. Annuity}}) * \%\,\text{Retiring} * \text{Overage} * \text{Life Expectancy} \qquad (2)$$

To perform these calculations, we made certain assumptions regarding the characteristics and behavior of MCR colonels and lieutenant colonels.

The average career retirement points accumulated by colonels and lieutenant colonels are independent of grade strength overages from October 1, 2001 (post 9/11)–April 30, 2009 (prior to SRB retirements)

- The percentage of colonels obtaining the minimum satisfactory service required for retirement in-grade is independent of grade strength overages during this same time period
- The average life expectancy of MCR colonels and lieutenant colonels is consistent with the data published by the US Department of Health and Human Services (United States Life Tables, 2004)

Using data obtained from the Total Force Data Warehouse (TFDW),[m] we calculated the average career retirement points credited for colonels and lieutenant colonels at retirement, the percentage of colonels meeting the service requirements for retirement in-grade, the average age at promotion to colonel, and the average cohort survival rates. The average career retirement credit points for lieutenant colonels are based on those officers passed over for promotion to colonel.

Table 1 incorporates retirement annuities based on 2009 Military Pay Tables published by the Defense Finance and Accounting Service, an average life expectancy of 79.31 years, which accounts for gender differences in the subject population, and the fiscal year promotions which exceeded statutory limitations accounting for cohort survival.

The average lifetime marginal cost per person in excess of the statutory limit was approximately $200,000. In addition to retirement cost calculations per person, Table 1 also accounts for the overall retirement marginal cost by SRB-induced savings due to the involuntary early retirement of 99 colonels during FY 2009 and

Table 1. Cumulative retirement costs of exceeding statutory limitations from FY04–08, adjusted for SRB savings.

Grade	Cohort	Career Points	Retirement Rate	Monthly Annuity	Retirement in Grade Probability	Monthly Marginal Cost	Lifetime Marginal Cost per Person	Cohort	Promotions over Statutory Limit	Cost per FY Cohort	Total Cost
LtCol	Base	4700.93	32.50%	$ 2,576.83				04	22	$ 4,345,237.72	
								05	71	$ 14,086,503.51	
					93.40%	$ 852.37	$197,511	06	22	$ 4,299,757.34	$33,566,188
Col	No SRB	5084.17	35.21%	$ 3,489.43				07	46	$ 9,125,948.09	
								08	23	$ 4,550,697.62	
	SRB	-190	-1.25%	$ (123.89)	100%	$(123.89)	$(28,707)	SRB	99	$ (2,841,956.59)	

accounts for the average career retirement point reduction for separated officers due to a shortened career. This is a conservative estimate and likely over-estimates any cost savings due to the SRB. It is important to note that the SRB resulted in relatively minor savings (less than $3 million dollars), reinforcing the principle that policy makers should address long-term health of manpower populations in advance through consistent planning vice more drastic, after-the-fact measures.

Net Present Value

The cumulative retirement cost of more than 33.5 million dollars will be paid out over a number of future years, beginning in less than nine years for the earliest recipients. Using a net present value calculation, we can determine the real cost to the government in 2009. However, the retirement annuities are not constant. The base pay calculation will increase annually according to congressionally-mandated military pay raises until age 60 based on the Employment Cost Index (ECI).[n] Additionally, monthly annuities will continue to increase according to congressionally mandated cost of living adjustments (COLA) based on the Consumer Price Index (CPI).[o]

$$\text{Net Present Value} = \sum_{t=1}^{(\text{Life Expectancy}-60)} \times \frac{\left[\dfrac{\text{Total Annual Marginal Cost}}{[1+(\text{D.R.}-\text{ECI})]^{\text{Ave Years to Retire}}}\right]}{[1+(\text{D.R.}-\text{COLA})]^{t}} \quad (3)$$

Introducing the government's current 30-year discount rate of 4.9%,[p] an annual ECI of 3.37%[q] until age 60, and a 3.1% COLA rate[r] thereafter, resulted in a cost to the government of more than 25.3 million dollars. Although exceeding the statutory limits doesn't have any immediate consequences to budget considerations, this illustrates the costs incurred at a later date through amortized RPA rate increases. Reducing the MCR colonel population to within the statutory limits will eliminate additional hidden future costs. This paper seeks to optimize zone range and promotion opportunity based on meeting specific grade strength targets.

LITERATURE REVIEW

Mathematical models are suitable for analyzing manpower planning decisions and have been effectively utilized in the manpower military community. Typically, military manpower model applications found in the literature are designed for a specific force (e.g., Army) and focus on either the enlisted or officer Corps, although there is some work found that includes evaluation of the entire force structure (see Workman 2009). A common theme found in the analysis of military manpower is to study strength as a function of time (for a fixed planning horizon) and select decision variables that can be influenced through changes in policy. Examples of decision variables include accessions per year, promotion rates, branch details, inventory, advancement, recruiting, and retention. This research used a Markov chain to predict the number of MCR colonels in an active status and an optimization model to control variables in order to achieve target strengths.

Several examples of optimization models used for evaluating military manpower requirements and/or personnel policy decisions are found in the literature. Charnes et al. (1975)

provide a review of manpower and personnel model (both military and civilian) research from 1967–1975. This review includes a discussion about analytical techniques used to model manpower systems and provides reference to several earlier works on manpower modeling for the Navy and Air Force.

Two of the authors on the review paper by Charnes et al. (Charnes and Cooper) joined with Bres and Burns to publish a paper on the use of goal programming in conjunction with Markov chains for planning officer accessions to the US Navy from a variety of commission sources (Bres et al. 1980). Mehlmann (1980) uses dynamic programming in conjunction with Markov chains in order to optimize recruitment and grade transitions strategies. Holz and Wroth (1980) use a goal programming model that determines the gains (accessions) that maintain the Army's operating force strength as closely as possible over a finite planning horizon. Zanakis and Maret (1981) combine a Markov chain with a goal programming optimization to assess the manning of an engineering plant in flux. They do not apply the work in their paper to a military setting, but reference applied military works of similar flavor. Collins et al. (1983) use a goal programming approach to optimize the mix of incoming enlisted recruits (within each of the military services) by specific personnel characteristics. Gass et al. (1988) present a Markov chain model of the US Army and an optimization model (goal programming linear model) to meet target end strength over a long-range planning period (7–20 years).

Thomas et al. (1997) describe their systems dynamics and network approach to modeling the US Army's enlisted personnel. Their network contains subsets of smaller models including several linear programs. Schrews (2002) presents a linear program that studies the Active Guard Reserve enlisted manpower policies directly influencing critical career fields. Gibson (2007) uses a linear program to determine the number of annual accessions and zone promotion rates for officers in the Army Competitive Category (a subset of the Army officer Corps) over a 40-year horizon.

Although the concept of Markov chain analysis and goal programming is not a new topic or application, this paper contributes to the literature and body of work in mathematical application in the military by providing: (1) an application of optimization for the Marine Corps Unrestricted Reserve manpower, (2) the simultaneous optimization of promotion zone range and promotion opportunity, and (3) the development of an Excel-based tool that can be used for future planning by informing policy decision makers. To the authors' knowledge, there were no optimization applications for planning target strengths in the MCR community, nor were there efforts to develop a long-term plan for meeting the statutory limits of the Marine Corps Unrestricted Reserve colonels. Edwards (1983), who provides a broad sampling of mathematical manpower planning models, states: "a common theme of successful application is that a good presentation of results and ease of use are more important to uses than theoretical sophistication." The model developed in this paper was based on an easy-to-use format within an Excel spreadsheet and provided to the M&RA Reserve Plans Section Head and Officer Promotion Planner for implementation. M&RA has incorporated this model in its planning process and is currently pursuing additional models to capture the Reserve enlisted and restricted officer populations. As a result, the FY12 unrestricted Reserve officer promotion plan was developed and approved by the Secretary of the Navy for implementation using this model.

MODEL FORMULATION

The goals of the research described in the introduction section were met through the modeling and analysis of the lieutenant colonel and colonel ranks in the MCR. This was done through a goal programming formulation with an embedded Markov chain. Next, we describe the flow of officers and data collection. We then present the Markov chain that we use to calculate the number of colonels by year and the goal programming optimization model and formulation.

Officer Flow and Data Collection

The flow in and out of senior company and field grade ranks (captain, major, lieutenant

colonel, and colonel) in the Marine Corps is shown in Figure 2. In this representation, promotion to General Officer is not specifically depicted, but can be counted as a portion of the exits. The dotted box in Figure 2 represents the segment of the population that was modeled. Modeling the officers at the O6 grade (colonel) through a Markov chain required the definition of four types of transitions. They are: remain in-grade, promote from lieutenant colonel to colonel, laterally transition from an inactive status to an active status, and laterally transition from an active status to an inactive status or exit the rank of colonel (either by promotion to general, natural attrition, retirement, or by involuntary action).

Markov chains specifically require the definition of nodes, the transition matrix, and the total number of entities within each node for an initial time period. Manpower models formulated via a Markov chain representation require taking inventory of the personnel in each class at equally spaced points in time. This type of data allows the definition of the nodes, the empirical calculation of elements in the transition matrix, and the total number of personnel in each node. For this paper, MCR officers by month from September 2001 to July 2009 were obtained from TFDW[m] on August 13, 2009.

The data collected included a unique identifier, officer rank, data of rank, and training category pay group by month. Additionally, planned and actual promotion opportunities for officers (above-, below-, and in-zone), 2004–2010 fiscal year promotion statistics, planned 2011 fiscal year promotion zones and opportunities, and the 2009 fiscal year SRB results summary from Headquarters Marine Corps, Manpower & Reserve Affairs were collected. The 2010 fiscal year colonel promotion board results and the planned schedule for effecting those promotions were also collected. Table 2 summarizes the strength, average time in-grade, and promotion zone opportunities for lieutenant colonels and colonels.

Markov Chain Model

The data collected in the previous section were used to generate a Markov chain that describes the number of MCR colonels as a function of time (in years). In manpower examples, this type of model is often called a cross-sectional model because the number of personnel in the organization is illustrated at discrete (and equal) time intervals thus providing a snapshot (or cross-section) of the organization. For the purposes of this study, we added a longitudinal aspect to the model in order to properly account for zone calculations. Instead of modeling the number of colonels as a single node, we expanded the nodes in the model to include time-in-grade (TIG) by month because zone ranges are defined in terms of months. Figure 3 illustrates an example of the O6 officer class expanded to include TIG.

We used the data collected during the years 2001–2009 to create the transition matrix and define the number of officers in each node in 2009. We determined strength, lateral growth, and attrition by TIG (in months) empirically using the data. Note that these data account for all categories of losses as part of the continuation rates from year to year. Lateral movement into the O5 and O6 populations was modeled as constant growth based on historical trends. Additional assumptions made include:

- Monthly growth and attrition by TIG is constant based on historical averages (Oct 2001–April 2009).
- The Active Reserve (AR) colonel population will be managed sufficiently as to not negatively impact Reserve colonel grade strength limits.[s] The AR colonel population is a subset of the entire Reserve population and managed as a separate competitive category.
- Marines are promoted throughout the year equally (monthly promotions = total selected / 12). Marines separated due to the 2009 fiscal year SRB are equally distributed across the eligible population.
- All promotions are effected from June 1st to May 1st of the fiscal year following the year of the promotion board.[t]

Using the data to populate the number in each node (O5 and O6 by TIG), the following equation describes the number in each class by year t:

$$x_i(t+1) = P' x_i(t) + r_i \lambda \qquad (5)$$

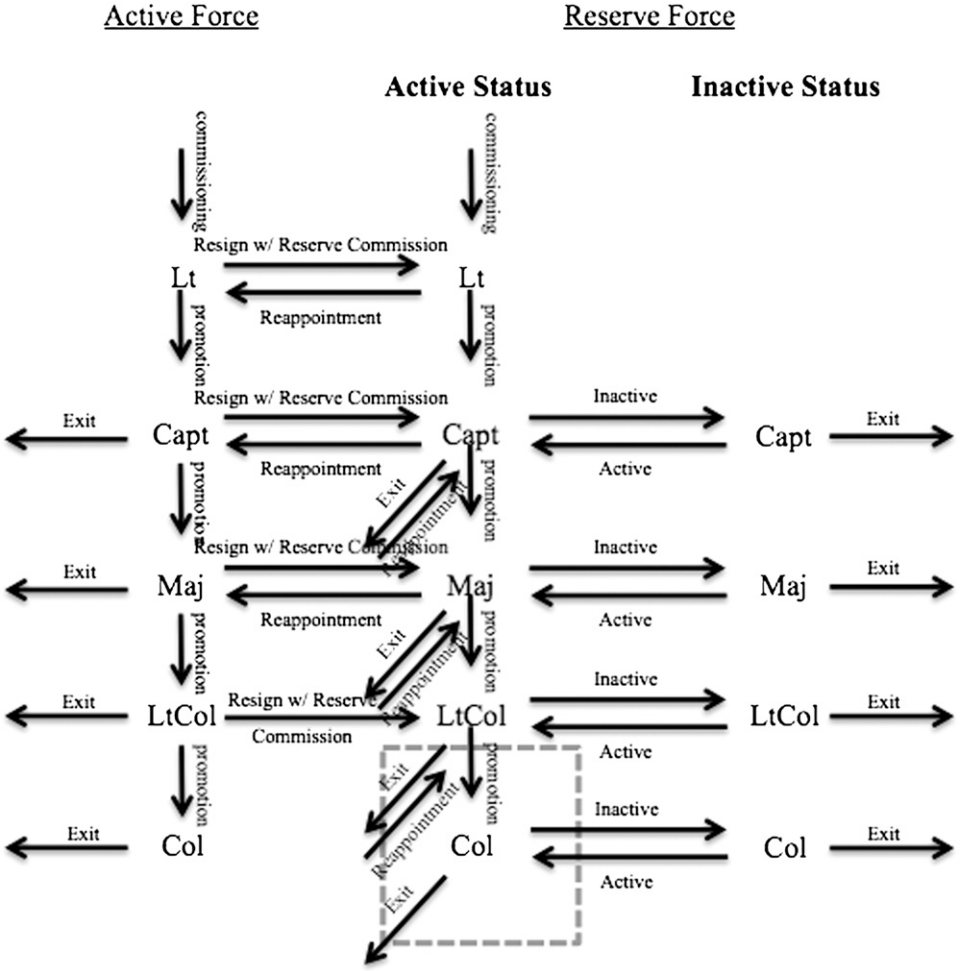

Figure 2. Marine Corps officers.

where, x_i is a column vector of grade strength by TIG (i varies from 0 to 108), t is time measured in months, P is the transition matrix, r_i represents four distinct column vectors incorporating lateral transfer and promotion proportions, and λ represents the monthly promotions and lateral transfers.

We made two additional assumptions to simplify the model, but we do not expect them to negatively impact the long-term results. There are 99 Marines who were not selected for retention on the FY09 Selective Retention Board and thus were separated beginning in April 2009. However, a small percentage of separations occurred as late as FY11 resulting in slightly inaccurate FY09 grade strength predictions. Also, all selections to O6 are made from the in-zone population. Although it is possible to be selected

Table 2. Summary of descriptive statistics.

Rank	Observations	Date	Strength	Average time in-grade
O6	50,629	September 2001	352	39.7
		April 2009	641	39.6
O5	143,547	September 2001	1514	35.0
		April 2009	1325	48.8

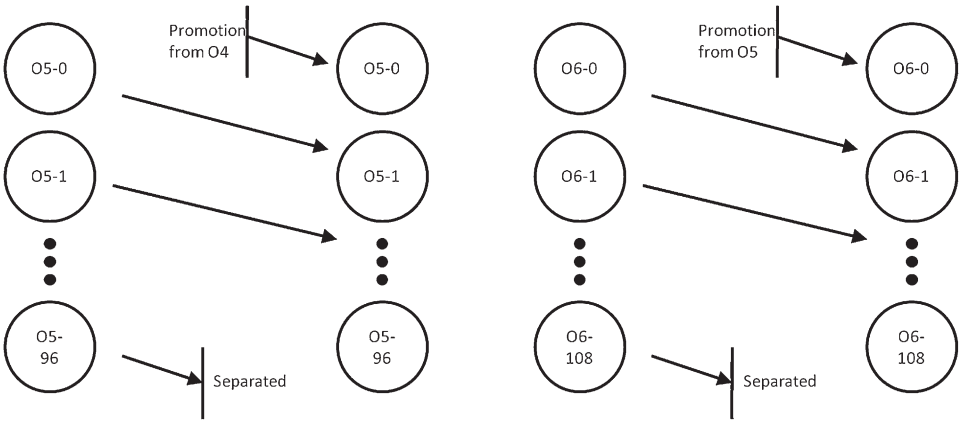

Figure 3. Flow of MCR colonels.

from above- or below-zone, this is not considered in this paper.

Goal Programming Model

Goal programming is used for multicriteria problems that have target levels to achieve rather than values to maximize or minimize (Rardin 1998). Manpower problems focused on target strength for a particular planning horizon are well-suited for formulation as a goal-programming problem. The targets of focus in this paper are the number of colonels in the MCR community for the end of fiscal years 2010–2014. The goals in priority order (highest to lowest) are:

- Meet the statutory limits for number of colonels at the end of fiscal years 2011–2014
- Create zone ranges that are consistent for fiscal years 2012–2015
- Create promotion opportunities that are consistent from 2012–2015

In addition to these goals, the Marine Corps plans to return to the running mate system by FY15. To account for this, we placed a hard constraint on the number of months to which the zones can sum in the years 2011–2015. Figure 4 shows the goal programming formulation based on these goals.

RESULTS

We validated our model through historical data checks and determined the plausibility of optimal results. The optimal solutions

Objective function:

Minimize $[\sum_{i=1}^{4}(O_i w_i + U_i w_i)]$

i = fiscal year in planning horizon[u]
j = deficiency variable (1, 3, 4)
O = Overage
U = Underage

Subject to:

$x_i(t+1) = P' x_i(t) + r_i \lambda \ \forall i$ %Markov chain constraint

$\sum_{i=1}^{5} Z_i - 58 = 0 \ \forall i$ %Running mate constraint

$E_i - 490 - O_{i1} + U_{i1} = 0 \ \forall i$ %Statutory limits goal

$Z_i - \left(\sum_{i=1}^{4} \frac{Z_i}{n}\right) - O_{i4} + U_{i4} = 0 \ \forall i$ %Consistent zone range goal

$P_i - \left(\sum_{i=1}^{4} \frac{P_i}{n}\right) - O_{i3} + U_{i3} = 0 \ \forall i$ %Consistent promotion opportunity goal

$.4 \leq P_i \leq .6 \ \forall i$ %Constraint on the promotion opportunity[v]

$12 \leq Z_i \leq 16 \ \forall i$ %Constraint on the zone range[w]

$O_i, U_i, x_i, E_i, Z_i, P_i \geq 0 \ \forall i$ %Nonnegativity constraint

Figure 4. Goal programming formulation.

conformed to expected behaviors given that the optimal zones and opportunities were within the range of expected values for the assumed transition matrix. Table 3 illustrates the optimal promotion solution (plan) assuming that the estimates of our transition matrix are valid. While the transition matrix elements are valid for historical data, these elements will vary in time.

The optimal solution, Table 3, met the highest priority goal of grade strength while meeting all model constraints to include returning to the running mate system. In the model, we placed weights on the goals in terms of their respective priorities. As a result of the highest priority given to achievement of statutory limits, the optimized results failed to achieve consistent zones ranges and consistent promotion opportunities across the planning horizon.

Because of the mismatch between promotion and fiscal years, there is some flexibility to exceed end strength during any given promotion year (May–June) and then adjust to the statutory limitation prior to the end of the fiscal year on September 30. We tested separate weighting schemes that prioritized consistent zone and opportunity resulting in a slight grade strength shortage. Overall, this analysis indicates that the maximum grade strength of 490 is achievable by allowing for relatively minor variance in promotion opportunities.

We conducted a sensitivity analysis to study the changes in the decision variables as a function of changes in the assumed transition matrix. The values for these optimized zones and promotion opportunities are in Table 4. Attrition rate was the focus of the sensitivity analysis. In the analysis, we varied attrition by 20% around the nominal value and then reran optimization.

In addition, in the sensitivity analysis we considered reprioritizing the goal programming. In the ES1:1 model shown in Table 4, we reduced the grade strength requirement to the lowest priority, and penalized deficiencies and overages equally. In the ES10:1 model, we gave implementation of a promotion plan that would meet or exceed statutory limitations the highest priority and weighted deficiencies using a factor of 10 compared to grade strength underages.

In both attrition rate cases, we achieved the overall objective of the promotion plan (to meet grade strength) as shown in FY14; however, a significant change to the FY12 zone (nine months) was necessary for the decreased attrition model (−20% attrition). Additionally, overall opportunities rose significantly (average of 4.5% percentage points from the optimum solution in Table 3) for the increased attrition model (+20% attrition). An interesting result of the decreased attrition model was that grade strength was slightly exceeded for FY11 (492). Because this small of a delta is easily fixed in monthly promotions, the projected grade strength overage is not a big issue. However, if a promotion plan with projected grade strength of 490 became a requirement for FY12, not allowing for any deviation from the target (no slack), then there would be a need to decrease the opportunity to 40% at nine months, which is the minimum allowed according to SecNav guidance for promotion opportunity.

Reprioritizing the goal programming also provided interesting results. Specifically, loosening the grade strength overage penalty provided a more consistent promotion plan and we recommended M&RA adopt this model over their original requirements given the ability to fix small overages in execution.

Long-Term Projections and Steady-State Analysis

To assess the long-term consequences of returning to the running mate system, we

Table 3. Optimal promotion plan.

Board	Zone size (months)	Opportunity	Selects	Grade strength as of September 30
FY11	4	40%	41	485
FY12	16	53%	104	483
FY13	13	52%	77	489
FY14	14	51%	97	490
FY15	15	52%	47	-

Table 4. Promotion opportunity and zone range optimal values for various cases.

Weights		Baseline	Linear	ES 1:1	ES 10:1	+20% attrition	−20% attrition
Opportunity	FY12	53%	53%	52%	55%	57%	48%
	FY13	52%	52%	51%	51%	56%	49%
	FY14	51%	51%	51%	51%	56%	49%
	FY15	52%	52%	52%	52%	57%	49%
Zones	FY12	16	16	16	16	16	9
	FY13	13	13	14	13	15	17
	FY14	14	14	14	14	14	16
	FY15	15	15	14	15	13	16
Grade strength	FY10	503	503	503	503	490	516
	FY11	485	485	486	488	468	492
	FY12	483	483	487	490	476	472
	FY13	489	489	490	491	490	490
	FY14	490	490	489	492	487	489
Objective		14.70	13.70	12.42	37.79	45.76	82.01

expanded the five-year model to 10 years, incorporating each of the unrestricted Reserve officer grades depicted in Figure 2. Three interconnected Markov chains consisting of colonels and lieutenant colonels, lieutenant colonels and majors, and majors and captains were chosen to maintain flexibility and computational ease over a single comprehensive model which would have required 532 nodes.

Additionally, the third model, which included the captain feeder population, enabled the evaluation of recent changes to company grade officer programs such as the reinstitution of active component career designation and the implementation of the Officer Candidate Course-Reserve (OCC-R) commissioning program in 2007. The M&RA officer accession planner provided estimated Reserve officer transitions due to career designation and the Reserve Affairs officer program officer provided the OCC-R accessions.

Table 5, monitoring of colonel grade strength from FY15–19 illustrates the successful return of the colonel population to the running mate system with regard to statutory limitations holding future zone size stable at 12 months with steady promotion opportunity of 52%. However, the FY19 grade strength of 446 also generates some concern as to the sustainability of Reserve colonel grade strength at statutory limitations without a future increase in promotion opportunity. We recommended M&RA review officer mobilization requirements and participation rates to determine minimum on-hand manning levels. Upon M&RA's request, Luther (2011) developed a predictive model for participation rates based on grade strength and completed a review of officer mobilization requirements. As a result of this follow-on analysis, M&RA planners have modified the five-year plan using the Excel tool we provided to implement a ''controlled'' reduction in Reserve colonel grade strength below statutory limitations (in consonance with officer mobilization requirements) mindful of future RPA savings to DoD.

Modeling the entire Reserve officer population is also helpful in providing insight into the long-term impacts of recent policy and

Table 5. Five-year monitoring.

Board	Zone	Opportunity	Selects	Grade strength as of September 30
FY15	12	52%	47	470
FY16	12	52%	79	472
FY17	12	52%	70	477
FY18	12	52%	64	471
FY19	12	52%	53	446

programmatic changes. For instance, the officer grade strengths depicted in Table 6 illustrate an 84.4% increase of captains and 38.2% majors during the next 10 years. Left unchecked, these trends could result in future Reserve colonel grade strength overages and the reoccurrence of an SRB.

Thus, we used steady state analysis, ''forcing'' uniform promotion selects across each of the three models, allowing for the approximation of grade strengths over the next 26 years. As such, the estimated steady state impact of OCC-R accessions and active component career designation is a grade strength of 3,288 captains (FY20), 2,644 majors (FY 32), 1,611 lieutenant colonels (FY36), and 700 colonels (FY38). As suspected, the colonel population will not remain within statutory limitations by a simple reduction of promotion opportunity to the minimum level of 40% beginning in FY30. As such, we recommended that the Marine Corps consider also reducing the lieutenant colonel promotion opportunity to 65% beginning in FY24 as one of several potential courses of action. As a result of this analysis and the beforementioned study by Luther, M&RA planners will begin addressing reducing lieutenant colonel promotion opportunity as early as the FY14 promotion plan.

CONCLUSION

The promotion plan proposed in the results section provides a baseline model to maintain unrestricted Reserve colonel grade strength within statutory limits for the proceeding five years taking into account historical lateral movements and attrition data. Based on the analysis, we demonstrated that the proposed promotion plan will allow the Marine Corps to return to the running mate system within five years.

Sensitivity analysis indicates the model is flexible and fairly robust to variations in attrition. Using average attrition rates based on empirical data from 2001–2009 and not accounting for behavioral changes due to the SRB, the results of the paper confirmed that the Marine Corps would be within FY10 grade strength limitations on September 30, 2010. Variation of attrition behavior among the retained SRB population could have resulted in FY10 grade strength exceeding limitations unless FY10 and some FY09 promotions were withheld until October 1, 2010.

The 10-year model provides a mechanism by which to monitor long-term unrestricted Reserve officer grade strengths. Using steady state analysis, potential issues can be identified and manpower populations maintained using common grade shaping actions before more severe manpower corrections are necessary, such as the SRB implemented during FY09 by the Marine Corps.

The recommendations resulting from this analysis, accepted and adopted by M&RA, were to

- Implement a promotion plan such as the baseline presented in Table 4
- Validate attrition, grade strengths, and lateral movements annually and rerun the model in

Table 6. Ten-year projections.

Grade	Colonel		LtCol		Maj		Capt	
Board	Selects	Strength	Selects	Strength	Selects	Strength	Selects	Strength
FY10	-	503	-	1,309	-	1,539	-	1,776
FY11	41	485	162	1,287	334	1,598	60	1,877
FY12	104	483	157	1,211	385	1,655	60	1,999
FY13	77	489	114	1,125	269	1,674	98	2,270
FY14	97	490	135	1,074	309	1,705	98	2,518
FY15	47	470	108	1,059	257	1,715	98	2,826
FY16	79	472	164	1,055	241	1,721	98	3,057
FY17	70	477	192	1,069	427	1,827	98	3,190
FY18	64	471	177	1,069	449	1,978	98	3,245
FY19	53	446	161	1,100	470	2,127	98	3,275

order to detect changes and differences. This will allow fine-tune corrections as necessary to stay within grade strength limitations given any changes in population behavior and/or dynamics or changes in government policy
- Determine the minimum unrestricted Reserve officer inventory necessary to meet mobilization requirements and appropriately modify the promotion plan in FY15–19 to ensure on-hand manning is sufficient across the Ready Reserve
- Continue to monitor 26-year officer population forecasts, detecting and applying appropriate policy and planning guidance well in-advance of potential issues
- Change the priorities of the optimization to determine the impact on optimal promotion zones and opportunities

This paper presents a framework for studying optimal zone and promotion opportunity policy in order to achieve goals such as target grade strength and consistent zone ranges and opportunity rates. A relaxation of modeling assumptions could add additional insights. This paper illustrates how a specific implementation for modeling the MCR colonels in the Marine Corps can influence or inform manpower policy decisions. Improvements to the model would include creating a model for the active officer Corps, and linking the MCR model with the active duty model in order to effectively study returning to the running mate system. Additionally, incorporating a forecasting approach to model officer continuation could prove beneficial and act as an additional layer for the sensitivity analysis.

NOTES

[a] National Defense Authorization Act for Fiscal Year 1995, Public Law 103-337, § 1662, US Statutes at Large 108 (1994), codified at US Code 10 (2009), §§ 12003 and 12005. Note: two percent of 24,500 is 490.

[b] National Defense Authorization Act for Fiscal Year 1995, Public Law 103-337, § 1662, US Statutes at Large 108 (1994), codified at US Code 10 (2009), § 12006.

[c] Secretary of the Navy Action Memo, *Request for Waiver to Reserve Active Status List (RASL) Colonel End Strength*, February 6, 2008.

[d] Manpower & Reserve Affairs, "Precept Convening the FY11 USMCR Colonel Unrestricted Reserve Promotion Selection Board," under "officer promotions," https://www.manpower.usmc.mil/portal/page/portal/M_RA_HOME/MM/PR/MMPR1/MMPR1_PROMOTION_BOARDS/FY11_MMPR1_PROMOTION_BOARDS/RESERVE_FY11_MMPR1_PROMOTION_BOARDS/FY11%20-%20RESERVE%20-%20COL/USMCR_Col_Precept.PDF.

[e] Manpower & Reserve Affairs, "Maradmin 516/08: FY09 Unrestricted Reserve Colonel Selective Retention Board," under "messages," http://www.marines.mil/News/Messages/MessagesDisplay/tabid/13286/Article/113060/fy09-unrestricted-reserve-colonel-selective-retention-board.aspx.

[f] National Defense Authorization Act for Fiscal Year 1995, Public Law 103-337, § 1611, US Statutes at Large 108 (1994), codified at US Code 10 (2009), § 14306.

[g] The Total Force consists of both the active and Reserve components.

[h] National Defense Authorization Act for Fiscal Year 1984, Public Law 98-94, § 925(a)(1), US Statutes at Large 97 (1983), codified at US Code 10 (2009), § 1465(c).

[i] Army and Air Force Vitalization and Retirement Equalization Act of 1948, Public Law 80-810, § 302(a), US Statutes at Large 62 (1948), codified at US Code 10 (2009), § 12731.

[j] National Defense Authorization Act for Fiscal Year 2008, Public Law 110-181, § 647, US Statutes at Large 122 (2008), US Code 10, § 12301(d).

[k] National Defense Authorization Act for Fiscal Year 1995, Public Law 103-337, § 1641, US Statutes at Large 108 (1994), codified at US Code 10 (2009), § 1370(d)(3)(A).

[l] Army and Air Force Vitalization and Retirement Equalization Act of 1948, Public Law 80-810, § 303, US Statutes at Large 62 (1948), codified at US Code 10 (2009), §§ 12733 and 12739(a).

[m] The Total Force Data Warehouse (TFDW) is a restricted system of the Manpower Information Technology Branch of Manpower & Reserve Affairs (M&RA). It is the Marine Corps' official system of record for USC Title 10 end strength reporting. The TFDW houses more than 30 years of historical manpower data from

a variety of USMC and DoD systems including MCTFS, MASS, RCCPDS, MCTIMS and DEERS, in one central location to provide manpower analysts with a comprehensive view of a Marine's career from "street to fleet."

[n] National Defense Authorization Act for Fiscal Year 2004, Public Law 108-136, § 602(c), US Statutes at Large 117 (2003), codified at US Code 37 (2009), § 1009(c)(1).

[o] Uniformed Services Pay Act of 1963, Public Law 88-132, § 5(g), US Statutes at Large 77 (1963), codified at US Code 10 (2009), § 1401a(b)(2). Annual increases are based on increases in the Consumer Price Index above the base index.

[p] Office of Management and Budget, "Circular No. A-94 Revised," http://www.whitehouse.gov/omb/rewrite/circulars/a094/a094.html. (accessed 1 November 2009).

[q] United States Department of Labor, "ECI Current Dollar Historical Listings," under Bureau of Labor and Statistics: ECT Tables, http://www.bls.gov/web/echistrynaics.pdf. Using March 2001–2008 statistics, the base quarter 8-year ECI is 3.37%.

[r] Social Security Online, "Cost-of-Living Adjustments," under Automatic Increases, http://www.ssa.gov/OACT/COLA/colaseries.html. Using 2002–2009 COLA rates, the average increase is 3.1%.

[s] The AR colonel grade strength limitation of 32 (see 10 US Code § 12011 using an end strength of 2,261) is inclusive of the 490 RASL colonel grade strength. However, these two separate competitive categories are managed and promoted independently.

[t] In practice, these months vary slightly. However, clearing the previous year promotion board during the May–June timeframe allows for the greatest flexibility for fixing grade strength overages in execution prior to the September 30 mandate.

[u] Note: the fiscal year 2011 promotion board precept was approved by the Secretary of the Navy prior to completing this analysis. As such, the first year of the five-year promotion plan cannot be changed and is not used to determine consistency of zones and opportunities.

[v] Secretary of the Navy Instruction (SecNavInstr) 1420.1B, para 12(a), guidance for promotion opportunity is 50% ± 10%.

[w] Promotion zones were artificially constrained based on model and processing power limitations. This constraint was relaxed slightly where appropriate for sensitivity analysis.

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