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ABSTRACT

To increase Navy Nurse Corps manpower management efficiency, we developed a Markov model of the personnel flow of junior officers (O1-O4). The Nurse Corps manages personnel primarily through the recruitment process, drawing on multiple accession sources. Accession sources were shown to have a statistically significant effect on promotion and retention rates. However, these effects were not found to be practically significant in the Markov model. Only small improvements in rank imbalances are possible given current recruiting guidelines. Allowing greater flexibility in recruiting practices, fewer recruits would generate a 25% reduction in rank imbalances, but result in understaffing. Recruiting different ranks at entry would generate a 65% reduction in rank imbalances without understaffing issues. Policies adjusting promotion and retention rates are more powerful in controlling personnel flows and are the only means for addressing the fundamental sources of rank imbalances in the Navy Nurse Corps arising from current manpower guidelines.

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1. INTRODUCTION

The Navy Nurse Corps (NC) is part of a team of professionals that provides high quality, economical health care to approximately 700,000 active duty Navy and Marine Corps members, as well as 2.6 million retired and family members [1]. Managing its resources more efficiently continues to be a high priority for the Nurse Corps and for the Department of Defense (DOD) in general. In 2002, the Chief of Naval Operations (CNO) released "Sea Power 21", a design to create a leaner, more effective Navy [2]. In response to this and prior directives, the Navy Nurse Corps has been making reductions in its officer configuration. As a result of a recent study to define the most efficient and effective mix of manpower readiness requirements, 115 Nurse Corps billets have been targeted for conversion to GS employees starting in FY06 [3]. Manpower planning is essential to ensuring that the Nurse Corps continues to be able to perform its vital services.

The use of Markov models in manpower planning is well established in the literature in general [4-9] as well as in the military [10-16]. Published models are available for the Marine Corps enlisted and officer forces [17,18] as well as for the US Army Reserves [19]. Recently a prototype model was developed for the NC [20] but was not comprehensive. Other than historical trends, there currently is no formal model upon which gain and loss predictions are based [email from CAPT Buda; received 9/28/04].

The community manager for the Nurse Corps develops an annual accession plan that determines the recruiting goals, based on guidance from the Chief of Naval Personnel. New Nurse Corps Officers may enter through six different accession sources, described in Table 1. Two other long-running accession sources have been discontinued. The Nurse corps considers MECP, ROTC, NCP, and STA-21 "pipeline programs". Two remaining accession sources, recall and direct accessions, are used as 'valves' to ensure targeted manpower levels are met, leveling out yearly inconsistencies from the pipeline programs.

Past research has compared the impact of accession source on an individual's willingness to stay beyond his or her initial obligation [21-24] as well as conducted comparisons of the costs of different accessions sources [25]. It is not clear, however, whether these accession sources can be used in the manpower planning process to mitigate imbalances seen in the officer ranks - both overages (too many in a given rank) and underages (too few in a given rank).

With the challenges of personnel draw-down and conversion of some military positions to civilian positions, it is important to assess personnel planning and end strength systematically within the NC. To this end, we developed a Markov model of the Navy Nurse Corps, identifying probabilities of promotion and retention from historical data, and exploring the impact of the different accession sources available to the NC. Statistical analyses were conducted to determine points in a military career where the accession source was a statistically significant factor in either the promotion or the retention of an officer. Once identified, the the Markov model was adjusted for that accession source, thereby allowing differential progression by accession source.

2. METHODOLOGY

2.1 Datasets

The Bureau of Medicine and Surgery Manpower Information System (BUMIS) is an automated personnel information system maintained by the Navy's Bureau of Medicine and Surgery (BUMED) . Started in 1990, BUMIS is being built gradually with new entries being added every year. As of 2001, 2,236 nurses (of a total end strength of just over 3,000) have been entered into the database. Once entered into the database, a nurse is followed until discharge from the NC. Due to its construction, there are no Captains (O-6s) in the database and only a small number of Commanders (O-5). Therefore, we limit our model to Lieutenant Commanders (O-4) whose career progression is captured within the database. The Defense Manpower Data Center'S (DMDC) officer personnel records containing extensive demographic data [26] and BUMIS were merged to produce a combined data base (CDB) tracking nurse accessions for the years 1990 through 2001.

The civilian unemployment rate from the Bureau of Labor Statistics was added to the combined data set as a proxy for an individual's ability to find a non-nursing job civilian job. A variable identifying a nurse as having one of six subspecialties considered "critical" to the Nurse Corps during times of increased operational commitments (Medical/Surgical Nurse, Psychiatric Nurse, Emergency / Trauma Nurse, Perioperative Nurse, Critical Care Nurse, and

Nurse Anesthetist) [27] was also constructed and , additionally, a “time in rank” variable was created so it could be determined how long an individual remained in a given rank before being promoted or leaving the service. Ranks in the model included: Ensign (ENS) (O-1), Lieutenant Junior Grade (LTJG) (O-2), Lieutenant (LT) (O-3), and Lieutenant Commander (LCDR) (O-4).

2.2 Statistical Analysis

Logistic regression has been used in numerous studies to identify important influences on military retention and promotion. Characteristics examined have included demographic variables such as age, race, gender, and family status, as well as military background and job characteristics such as accession source and occupational specialty, and also external market conditions such as the civilian unemployment rate. While nurse-specific studies have found demographic factors to influence an individual nurse’s likelihood of retention [21,24,25,28,29], accession source has also been found to be significant in determining nurse retention [21,25]. Studies of officer promotion (not nurse-specific) have shown a similar pattern, with accession source consistently identified as a significant influence on promotion [30-32].

This study uses two sets of multivariate logistical regression models to evaluate the role of accession sources in an individual’s leaving the service and in being promoted within a career path. The binary dependent variables used in each set of the logistic regressions were **Leave** and **Promote**, respectively. The set of explanatory variables used for both sets of regressions included: seven accession sources (NROTC as the base case and STA-21 not included, as it is too new), age at entry (Entry Age**)**, race (White), sex (Male), marital status (Married), number of dependents (Dependents), members with active duty spouses (ActiveSP), advanced educational levels of masters and diploma degrees (Master, Diploma,), the national unemployment rate (Unemp), and having a critical specialty (Critical**)**. Accession source is the focus while all other variables are included as control factors because the Nurse Corps can exert direct and immediate control on its recruiting through the accession sources but cannot control many of the other factors that have been found to be significant predictors in prior studies.

Not all rank/time in rank categories contained sufficient observations for statistical analysis. We were only able to perform ten regressions: 3rd year Lieutenant Junior Grades leaving, 1st, 2nd, 3rd, and 4th year Lieutenants leaving, 2nd and 3rd year Ensigns promoting, 2nd and 3rd year Lieutenant Junior Grades, and 6th year Lieutenants promoting.

2.3 Markov Model Construction

Eight different Markov models were created in Microsoft Excel ™, one for each accession source listed in Table 1. Individuals enter the model through the accession sources and progress along their career paths according to the Markov calculations. Existing forces continue along their career paths as well. Each year, a summary overview of the entire nursing force is calculated by combining the summary status data from each individual model.

To calculate yearly transition probabilities, the historical career progressions of all individuals in the CDB were identified. Using this data, the percentage of people staying, promoting, and leaving from each rank/years in rank combination were calculated for the entire force. For accession sources in rank/years in rank combinations found to be significant by the regressions, the probabilities were recalculated using only individuals from the given accession source.

The combined database used in this study is not complete as approximately 1,000 nurses have not yet been entered into the BUMIS dataset. The accession source and the time in rank of these ~1,000 individuals are unknown. Therefore, to include the already existing nursing force in the model, it is necessary to approximate the starting distribution of individuals by accession source and rank/years in rank combination. To assign accession source to individuals of a given rank, the average of the historical data of the last 5 years of the combined database was used (Table 2).

In addition to the average distribution by accession source, a distribution by years in rank is also required. This was computed using the averages from 1997-2001 in the combined dataset and is available from the corresponding author. In order to obtain the distribution of existing nurses in the NC at any given year, these percentages are multiplied by the known total number of individuals in each rank.

New entrants enter the model through the accession sources. Due to its recent inception, STA-21 does not have any individuals in the database. It was assumed that the transition probabilities would most likely mirror those of MCEP, the other enlisted-to-officer training program. Additionally, not all new accessions enter the Nurse Corps as Ensigns. Some NCP, Direct Accessions, and all Recalls enter at a higher rank. The rank distribution of new accessions differs by accession source, as shown in Table 3 [email from CAPT Buda; received 6/03/05].

3. RESULTS

3.1 Descriptive Statistics

The age at entry into the nurse corps has been relatively constant (between 22 and 26 years) throughout the time horizon. The racial composition (> 98% White) has remained unchanged and the percentage of male nurses (30%) has also remained relatively unchanged over the time horizon. The percentage of individuals that are married has remained relatively constant between 50-60% since 1993, as have the number of dependents (between 2-2.5).

3.2 Regression Results

Table 4 summarizes all of the significant explanatory variables for the ten regressions. For each regression, a test of the full model against a constant-only model produced a likelihood ratio chi-square statistic THAT was statistically significant ($p<0.01$), indicating that the explanatory variables, as a set, reliably distinguished between stayers and leavers or between those promoted and those not promoted. The models correctly classified between 56% and 91% of the observations.

Overall, accession source does appear to have a significant impact on the probability of a person leaving as well as on the probability of promotion. At least one accession source was significant in each retention model and the same was true for all promotion models except the 6th Year LT model. While a number of the other explanatory variables were also significant, these exogenous variables are likely to remain relatively constant over the time horizon under consideration and are not influenced by nurse manpower planners.

3.3 Results of Markov Model

Before examining the results of the model, it was necessary to validate model accuracy against historical data.

3.3.1 Model Validation

Model accuracy was assessed using FY01 through FY04 information provided by the Nurse Corps Community Managers office. Starting with FY01 data, the model results were compared against FY02 actual data. Next, FY02 data were input into the model and results were compared to FY03 data. Averaged over the three year period, the model over predicted personnel by 1.4 percent. Table 5 details the results by rank and year.

3.3.2 Baseline Results

BUMED supplied target end strength numbers for 2005 through 2009. Using these numbers we were able to compute the imbalances, the sum of the overages and underages, created between the model estimates and the desired targets for the next four years starting from our base year, 2005. Given the end strength numbers from 2005 and running the model without adding any new recruits, Lieutenants experience an overage for the next 3 years. In 2006, 2007, and 2008, the model predicts that there will be 91, 79, and 41 more LTs than targeted, respectively. Therefore, bringing in new recruits will increase this excess.

Adding in the currently planned accession rate of 250 new recruits per year, underages were observed in the ranks of LTJG and LCDR. LTJG experiences the greatest underages, ranging between 60 and 130 too few individuals given the end strength targets. LCDR experiences underages between 27 to 52 individuals. Overages in the other two ranks (ENS and LT) are very large. ENS has 70 individuals over target in 2006 which increases to 214 individuals over target in 2009. LTs experience declining overages over time, from 105 excess individuals in 2006 declining to 32 excess individuals in 2009. In summary, the system currently is expected to face an imbalance of approximately 1,500 positions. Using the model, we explored whether it was possible to lower this imbalance using different accession sources.

To help run these analyses, Solver, a part of a suite of commands in EXCEL, was implemented. Solver results were not optimal since the model programming was not done to ensure linearity and precision was set to .001 with a 5% tolerance. In addition, the NC community manager does not have unrestricted ability to alter the use of accession sources.

Therefore, constraints were added allowing 10% flexibility in the system and ensuring that MECP must account for at least 13% of the new recruits, ROTC at least 15%, NPC at least 21%, Direct Accession with bonus and without bonus must each account for at least 15%, Sta-21 at least 6%, and Recall at least 5%. These figures are based on historical distributions of new entrants from 1997-2001 [email from CAPT Bellas; received 10/03/04].

3.3.3 Alternative Solutions

A number of alternative solutions were examined in order to determine if it were possible to lessen the total imbalance (both overages and underages) seen in the ranks. Table 6 summarizes the results. Given that the Navy NC is currently planning on bringing in 250 new recruits each year for the next five years, we first looked for improvements constraining the model to exactly 250 new recruits (Option #1, Table 6). By using a slightly different mix of accession sources, the overall imbalance was reduced by 30 positions. At least 8 different possible solutions were identified at this level allowing the community manager a great deal of flexibility in choosing recruitment goals. This flexibility is important as frequently there are unstated objectives, reflecting unstated needs, preferences or political influences.

Examining these results, ENS overages grew steadily, attaining more than 200 excess individuals by 2009. LTs started with an overage of over 100 positions but declined over time, frequently disappearing after 2008. More importantly, LTJG experienced underages as low as 120 too few individuals for a period of two years. LCDR underages remained relatively constant, between approximately 20 to 50 individuals. These trends are exactly the same as those observed in the base case.

Since the underages in LTJG became large, in the next iteration we limited the model to having underages of at most 100 individuals in any rank and allowed the number of recruits to be unconstrained (Option #2, Table 6). The best solutions in this case recruited approximately 330 individuals and caused an imbalance of ~1,860. This handled the underages, but caused overages to increase with ENS having more that 300 excess spots by 2009 and LT overages no longer declining.

In the next set of runs, we removed the constraints on the total number of recruits and underages (Option #3, Table 6). In these runs, approximately 160 recruits were brought in each year and the total imbalance decreased to ~1,120. Again, there were many different combinations that permitted the model to achieve a similar level of overall imbalance. Each of the results however, tended to achieve the better performance by addressing the overages at the expense of increasing the number of underages, allowing LTJG underages to be greater than 200.

Running the model without constraints on the number of recruits, but limiting the amount of underages to at most 150 in any rank (Option #4, Table 6), generated several solutions bringing in approximately 210 recruits and having an imbalance of 1,380. This is an improvement of ~100 individuals over the case of bringing in 250 recruits each year.

Allowing the model to change the number of new recruits each year gave similar results to Option #3. Since the benefits were so small, this option is likely not to be worth the administrative and planning efforts it would require.

Finally, the model was run without constraints on the number of recruits or the number of underages, but allowing the ranks of the recruits brought in by Recall or Direct Accession to be different (Option #5, Table 6). Recall and Direct Accession are the only two accession sources that can bring in more senior nurses into the Nurse corps. Direct Accession can bring in nurses with ranks up to lieutenant and Recall can bring in nurses with ranks up to lieutenant commander. Allowing the percentage that are brought in at each rank to change, the model was able to lower the imbalance to ~515, an approximately 65% decrease from the baseline. In this scenario, the solutions brought in ~ 235 recruits, with approximately 82 LTJG and 13 LCDR. Direct No Bonus was set to bring in only LTJGs. Direct with Bonus brought in between 80% to 100% LTJGs, with the remainder being ENS. Recall brought in approximately 75% LCDR and 25% as LTJG. The overages of the LTs was controlled to a steady point between 70 to 90 excess individuals, the underages for LTJG were lowered dramatically and growing at a very slow rate. LCDR no longer experienced any underages.

4. CONCLUSIONS AND RECOMMENDATIONS

Over the four year period, the difference between the planned imbalance (~1,500) and the best policies when 250 recruits are brought in (~1,470) are relatively small. A 25% reduction in the overall imbalance can be obtained by recruiting only ~160 individuals, but this causes underages in the rank structure that may not be acceptable. Limiting the number of underages causes the number of recruits and the imbalances to increase again. The most effective policy would be to use the Recall and Direct Accession sources to recruit individuals at higher grade levels than is currently the norm. This results in a 65% reduction in total imbalances and ensures that neither overages nor underages are above ~90 spaces at any point in time. Therefore, changes in accession sources and the entry grade ranks of recruits can lead to increased efficiency in manpower management.

The Markov model demonstrated a pre-existing overage of LTs and an underage of LTJGs and LCDRs. The shortage of LTJG can be directly traced to promotion rates of LTJG and ENS and the Nurse Corps end-strength requirements of each. Specifically, by the end of their 2nd year, 99% of ENS have left their grade – of these 97% promote and 3% leave. By the end of their 2nd year, 95% of LTJG have left their grade – of these 75% promote and 25% leave. LTs typically remain in their grade for 5 years before they are promoted, though many leave the service before that point. Since ENS and LTJG are promoted in the same time frame and the rate of exiting ENS is negligible, the only way to avoid either overages in ENS or underages in LTJG is for the personnel requirements of the two grades to be equivalent. Historically, the requirements for LTJG are double that of ENS and out-year projections widen this gap. Therefore, given current promotion policy and end-strength requirements, it will be impossible to balance these needs unless new recruits are brought in at the LTJG level. This is possible if the Recall and Direct Accession sources can be more thoroughly targeted to these higher ranks.

The pre-existing overage in LTs frequently decreases in the short term, as new recruits will take at least 4 years to enter this rank. However, over the longer term, the overage in LTs will either remain constant at approximately 90 spaces (best case) or may even start to increase. Given the long time period for promotion, the exit rates, while frequently 10% to 25% of a given year's cohort, are not sufficient to prevent pressure to build on this grade level. Overages of LTs could potentially be redistributed to LTJG and LCDR by slowing the promotion rate to LT and increasing the promotion rate to LCDR. However, any changes of this type would require an in-depth policy review.

The rank of LCDR seems to be experiencing a chronic low level shortage in the near term. Except for recruiting directly into that rank, the model does not allow much change to this shortage due the long time it takes to progress to this level. If the shortages are indeed present, it would make more sense to promote from the existing surplus of LTs rather than hiring in from the outside. While a change in the promotion rate itself is possible, it may also be possible to simply promote to fill the vacancies. As this is the current official position, we question whether the observed vacancies are real or whether there have been some other decisions made in regards to this rank. Since so few members of this rank are part of the database, there is a potential for data error as well.

This study was limited by sample size, both in term of the multivariate regression and in terms of the Markov models. We were restricted to conducting only 10 regressions. In addition, the Markov model could only include the ranks ENS through LCDR. Even so, there were a number of rank/year in rank combinations that were sparsely populated and for which the promotion and retention rates could fluctuate.

The Markov model uses static promotion rates based on historical trends. Therefore, this model is limited to the extent that these past rates hold in the future. In addition, the model currently precludes changing promotion and retention rates as a force shaping tool. These decisions have wide ranging policy implications beyond the NC itself. Nurse Corps end-strength targets are only projections. Optimal distribution of both accession source and rank are dependant upon the degree of acceptable deviation from these targets. The degree of acceptable deviation is difficult to determine and changes with operational tempo over time.

Finally, recruiting decisions by accession source have been made without regards to their costs. As shown in Table 1, there are different costs for recruiting/training nurse for the Navy Nurse Corps and an option for future studies would be to examine the cost-effectiveness of each of the recruiting options in tandem with their impact on the force structure.

Changes in the mix of accession sources are not sufficient to resolve the underlying issues that cause pressure at certain grades nor the series of both overages and underages observed within all of the ranks. While accession sources do have a statistically significant effect on promotion and retention rates, these differences are not practically significant in a Markov model. Small improvements are possible, but policies adjusting promotion and retention rates (i.e. the transition probabilities) would have a much greater effect and potentially handle some of the underlying issues. Policy changes should only be attempted after it has been ensured that the desired end-strengths of each rank are correct. Modeling to improve manpower management may enable the Navy Nurse Corps to more efficiently fulfill its mandate for high-quality healthcare.

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Table 1: Summary of Accession Sources

Accession Source [6,19]	Background	Service Obligation	Cost of Nurse Corps Officer [6]
Naval Reserve Officer Training Corps (NROTC)	Started FY 1992 NC community manager sets quotas Chief of Naval Education and Training and the Naval School of Health Sciences manage the program	4 years active duty service obligation; total commitment of 8 years military service	$86,000
Medical Enlisted Commissioning Program (MECP)	Started FY 1992 NC community manager sets quotas Naval School of Health Sciences manages the program	4 years active duty service obligation; total commitment of 8 years military service	$74,781
Nurse Candidate Program (NCP)	Started FY 1993 NC community manager sets quotas Naval School of Health Sciences manages the program	If require 1 year to complete BSN then 4 years active duty service obligation; total commitment of 8 years military service If require 2 years to complete BSN then 5 years active duty service obligation; total commitment of 8 years military service	$30,045
Seaman to Admiral (STA)-21	Started FY 2004 NC community manager sets quotas	4 years active duty service obligation; total commitment of 8 years military service	$74,781 plus up to $10,000 per school year
Direct Accessions	Primary supplement to training pipeline NC community manager sets quotas Chief Naval Recruiting Command manages the program	If bonus not selected then 3 years active duty service obligation; total commitment of 8 years military service	$18,145

		If bonus is selected then 4 years active duty service obligation; total commitment of 8 years military service	$13,145
Recalls	Supplement to training pipeline. Eligible candidates for recall drawn from the Naval Reserve Force	Must be able to complete 20 years of service before age 55	$10,275
Full Time Out Service Training (FTOST)	No longer active – last recruit in 1993 Originally a supplement to pipeline	36 months of service required for the first year and 6 months for each additional 6 months in the program	N/A
Baccalaureate Degree Program (BDCP)	No longer active – last recruit in 1992 Originally part of regular accession pathways	4 years active duty service obligation; total commitment of 8 years military service	N/A

Table 2 . Distribution of Accession Sources by Rank (1997-2001)

	ROTC	Direct (No Bonus)	Direct (with Bonus)	MECP	NCP	FTOST	Recall
ENS	35%	6%	13%	22%	23%	0%	0%
LTJG	30%	6%	26%	19%	18%	0%	1%
LT	12%	9%	33%	30%	10%	2%	3%
LCDR	0%	11%	36%	6%	0%	8%	39%

Table 3. Distribution of New Accessions by Rank

	ROTC	**MECP**	**NCP**	**STA-21**	**Direct** (no bonus)	**Direct** (with bonus)	**Recall**
ENS	100%	100%	95%	100%	80%	80%	
LTJG			5%		15%	15%	30%
LT					5%	5%	65%
LCDR							5%

Table 4. Likelihood Estimates for Significant Variables

	Leave [A]					Promote [B]				
Variable	3rd Year LTJG	1st Year LT	2nd Year LT	3rd Year LT	4th Year LT	2nd Year ENS	3rd Year ENS	2nd Year LTJG	3rd Year LTJG	6th Year LT
N	827	1977	1880	1493	1154	2771	549	2623	827	595
Direct, No B			1.41 *	1.24 *		-1.01 **		-0.59 **		
Direct B	-1.51 *	0.98 **	0.73 *			-0.90 **			0.80 *	
BDCP	-2.96 **	1.59 **	2.00 *	1.26 **					-0.89 *	
NCP			1.02 **			-0.76 **		-0.50 **		
FTOST					2.62 *	-1.35 *	2.62 *			
MECP								0.38 *		
Recall	-3.89 **							-0.72 *	1.88 *	
Male			-0.57 *	-0.83 *		-0.22 *		-0.23 *		-0.50 *
White			-1.74 *			0.41 **				0.65 *
Active SP		-1.61 **						0.52 **	1.93 **	
Master										1.03 **
Diploma										-0.87 *
Critical		-0.49 *	-0.43 **					0.43 **	0.74 **	
Unempl	0.74 **	0.35 *	0.51 **	0.42 *	0.67 *	0.12 *	0.67 *	-0.13 *	-0.27 *	-1.24 **
Dependents	-4.53 **	-2.32 **	-3.55 **	-2.70 **	-3.86 **	-0.11 *	-3.86 **	0.15 **	1.01**	0.27 **
Married			-1.12 *		-3.16 **		-3.15 **			
Entry Age						0.05 **				0.03 *
% Correctly Classified	83%	75-80%	60%	86%	91%	56%	79%	56%	79%	65%

A A negative coefficient indicates that individuals are less likely to leave

B A negative coefficient indicates that individuals are less likely to be promoted

* Significant at the 0.05 level, two-tailed test

** Significant at the 0.01 level, two-tailed test

Table 5. Model Validation

Year	Paygrade	Difference
2001	ENS	+ 5
	LTJG	+29
	LT	+12
	LCDR	- 12
	Total	+34
{(2683-2649)/2649}*100 = 1.3 Over predicted 2002 end strength by 1.2%		
2002	ENS	+33
	LTJG	- 14
	LT	- 18
	LCDR	- 8
	Total	- 7
{(2640-2647)/2647}*100 = 0.3 Under predicted 2002 end strength by 0.3%		
2003	ENS	+15
	LTJG	- 3
	LT	+80
	LCDR	- 25
	Total	+67
{(2659-2592)/2592}*100 = 2.6 Over predicted 2002 end strength by 2.6%		

Table 6. Summary of Results

	Model Specifications	Total Imbalance	No. of Recruits
Baseline	Current practice	1500	250
Option #1	250 Recruits	1470	250
Option #2	No constraint on Recruits Underages ≤100	1860	330
Option #3	No constraint on Recruits	1120	160
Option #4	No constraint on Recruits Underages ≤150	1380	211
Option #5	No constraint on Recruits Rank at entry variable	515	235