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West Point, New York 10996

A DECISION SUPPORT TOOL
FOR
DETERMINING ARMY ENLISTMENT
INITIATIVES

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14. ABSTRACT

Periodically, representatives from the United States Army Recruiting Command (USAREC), the Office of the Deputy Chief of Staff Personnel (DCSPER) and the Personnel Command (PERSCOM) meet to form the Enlisted Incentive Review Board (EIRB). The task of the EIRB is to determine the enlistment incentives to offer for each MOS to ensure the Army meets recruiting goals while remaining within the recruiting budget. The current method of assigning enlistment incentives does not consider recruit preferences for incentives and thus cannot predict the number of enlistments for a given incentive nor can it evaluate the effects of new incentives. The EIRB requires a quantitative decision support tool that will assist the members in doing the following: predict the number of individuals who will enlist into a given MOS over a certain time of service for a given incentive; determine the optimal mix of incentives to offer for each MOS to meet its recruiting goal; minimize the deviation from the recruiting goals for each MOS to remain within the recruiting budget. This paper describes the methodology used to create such a decision support tool, known as the Enlisted Bonus Distribution Model

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Executive Summary

Periodically, representatives from the United States Army Recruiting Command (USAREC), the Office of the Deputy Chief of Staff Personnel (DCSPER) and the Personnel Command (PERSCOM) meet to form the Enlisted Incentive Review Board (EIRB). The task of the EIRB is to determine the enlistment incentives to offer for each MOS to ensure the Army meets recruiting goals while remaining within the recruiting budget. The current method of assigning enlistment incentives does not consider recruit preferences for incentives and thus cannot predict the number of enlistments for a given incentive nor can it evaluate the effects of new incentives. The EIRB requires a quantitative decision support tool that will assist the members in doing the following: predict the number of individuals who will enlist into a given MOS over a certain time of service for a given incentive; determine the optimal mix of incentives to offer for each MOS to meet its recruiting goal; minimize the deviation from the recruiting goals for each MOS to remain within the recruiting budget. This paper describes the methodology used to create such a decision support tool, known as the Enlisted Bonus Distribution Model.

USAREC contacted the Operations Research Center to develop such a decision support tool and requested that it be flexible, 'user friendly', and accommodate all entry-level MOSs. A binary integer goal program proved to accurately model the enlistment incentive environment and also met USAREC's requirements.

The Enlisted Bonus Distribution Model uses Microsoft Excel® and the Extended Large-Scale Solver® produced by Frontline Systems, Inc. The model can evaluate 194 entry-level MOSs and over 330 incentives, which results in over 64,000 decision

variables. The model uses results from a choice-based conjoint study to predict the number of recruits per MOS, incentive and term of service. These predictions are used, with incentive costs and recruiting budget, to determine the optimal mix of incentives to offer a MOS that minimizes the deviation from its recruiting goal.

The model performs well in the solution space and produces reasonable answers after executing 100 sub-problems. The run times using a 450MHz desktop PC averaged about 60 minutes. Model input data is obtained from existing personnel reports that are copied into the worksheet, making it is easy to update with new information.
The Enlisted Bonus Distribution Model is a flexible, effective tool for determining enlistment incentives. Taking results from the choice-based conjoint study, the model determines enlistment incentives to meet recruiting goals while remaining within the recruiting budget. The model is also an effective tool for recruiting budget planning.

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1. Introduction

1.1. Background

In recent years, the Armed Forces of the United States particularly the Army, Navy and Air Force, have been faced with the increasingly difficult task of attracting and recruiting the required number of enlistees. These factors become more significant when the US economy is strong which may reduce the number of individuals who would possibly enlist. The fact that the United States has had an extremely strong economy in recent years has played a major role in effectively reducing the number of 17 to 22 year-olds who would consider enlisting in the Armed Forces. The 17 to 22 year-olds comprise the prime market segment in the United States for recruitment into entry-level MOSs. The three factors which have caused the Army to have more difficulty recruiting are:

- an extremely low unemployment rate among the prime market segment

- a decrease in the propensity to serve, as tracked by the Youth Attitude Tracking Survey (YATS)

- an increase in the number of young people attending 2 year and 4 year colleges.

Furthermore, the Army has difficulty matching the number of incoming recruits to the appropriate entry-level military occupation specialty (MOS). This is an important consideration to avoid overfilling certain MOSs while at the same time underfilling others. As a result, the Army and the United States Army Recruiting Command (USAREC) are faced with offering enlistment incentives to entice those who would not otherwise serve in the Army to enlist. The problem is which incentives to offer, when, and to which MOSs. These questions are addressed during the Enlisted Incentive Review Board (EIRB). Currently, the EIRB does not have a decision support tool that will

accurately predict the effects of the incentives offered, nor calculate the total cost for offering these incentives.

2. Primitive Needs Analysis

In 1998, the Operations Research Center of Excellence (ORCEN) within the Department of Systems Engineering completed a decision-support model for USAREC. The model was a mixed integer goal program that would determine which incentives should be offered to which MOSs. The following incentives were evaluated:

- Enlistment Bonuses (EB) that are paid to the soldier over a certain period of time

- Army College Fund (ACF) which is paid to the soldier when he or she enters college at the end of the enlistment period or term of service

- Loan Repayment Program (LRP) which is when the Army assumes the soldier's education debt

In order to accommodate the number of decision variables the analyst team used AMPL as the modeling language. One drawback in using AMPL is that it is a rather difficult language and not very "user friendly". In addition, the model could only evaluate 364 decision variables and 1,000 constraints. This meant the 194 entry-level MOSs would have to be grouped into seven categories: combat arms, administrative, medical, electronic systems operator, engineering/chemical operations, and mechanical/aircraft maintenance. The drawback with grouping the MOSs into seven categories is that during the EIRB, enlistment incentives are determined at the individual MOS level and not using categories such as combat arms etc. Therefore, offering incentives packages to entire categories, which may comprise as many as 15 MOSs, would certainly create overages for some MOSs and shortages in others.

Another limitation of the 1998 model was the probability that an individual would select to enlist for a given MOS at a given incentive package was based upon the analysis done by the Urban Studies Group at the University of Louisville in 1996. The Urban Studies Group conducted a choice-based conjoint analysis survey, an appropriate survey method, was only able to include 81 "highly propensed" respondents. In order for the conjoint analysis survey to accurately represent the probability that any 17 to 22 year old would enlist in the Army today the survey would have to be repeated and would have to include more respondents. In addition, the survey would need to be random samples from diverse regions of the United States in order to accurately represent the 17 to 22 year old population nationwide.

3. Effective Needs Analysis

USAREC requires a decision support tool to assist the members of the Enlisted Incentive Review Board in doing the following:

- Predict the number of individuals who will enlist into a given MOS, for a given incentive and time of service

- Determine the optimal mix of incentives to offer and to which MOSs

- Determine the total cost for offering these incentives

- Minimize the deviation from the recruiting goals for each MOS, including both overages and shortages

The decision support tool should use readily available software packages and most preferably should be compatible with Microsoft Excel® and Microsoft Access®. This is important since many agencies, including USAREC Program Analysis and Evaluation (PA&E), presently use these tools for collecting and analyzing demographic and

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historical recruiting data. This will ensure the decision support tool will be able to accept any new data, as it becomes available.

3.1. Problem Scope

3.1.1. Entry Level-MOSs

In order to effectively model the problem it was necessary to bound and scope the problem. This was done to ensure that only relevant information would be considered in the model itself. The first step was to determine which MOSs should be included. Only entry-level MOS would be considered since these MOSs would be eligible for enlistment bonuses. This meant only MOSs that require no prior military experience or special qualifications would be included. This reduced the number of MOSs from the Army's complete number of 305 to194.

3.1.2. Incentives Considered

The probability that an individual will select a specific MOS for a specific length of service for a given incentive was approximated using data from the MarketVision Research® Enlisted Bonus Distribution Conjoint Study completed in June 2000. Only the specific incentives and Army College Funds used in the MarketVision Research® study will be included in the model. It would be inappropriate to approximate the probability an individual will select an MOS given any incentive that was not included in the MarketVision Research® study. The incentives included in the MarketVision Research® study are shown below.

2-Year Enlistment Incentives
No Enlistment Bonus
$1,000
$3,000
$5,000
$7,000
$9,000
$26,500 Army College Fund
$39,000 Army College Fund
$1,000 and $26,500 Army College Fund
$4,000 and $26,500 Army College Fund
$2,000 and $39,000 Army College Fund
$8,000 and $39,000 Army College Fund

Table 1. 2-Year Enlistment Incentives

3-Year Enlistment Incentives
No Enlistment Bonus
$1,000
$2,000
$4,000
$6,000
$8,000
$10,000
$33,000 Army College Fund
$49,000 Army College Fund
$1,000 and $33,000 Army College Fund
$4,000 and $33,000 Army College Fund
$2,000 and $49,000 Army College Fund
$8,000 and $49,000 Army College Fund

Table 2. 3-Year Enlistment Incentives

4 and 5-Year Enlistment Incentives
No Enlistment Bonus
$2,000
$4,000
$8,000
$12,000
$16,000
$20,000
$40,000 Army College Fund
$50,000 Army College Fund
$60,000 Army College Fund
$75,000 Army College Fund
$1,000 and $40,000 Army College Fund
$4,000 and $40,000 Army College Fund
$2,000 and $60,000 Army College Fund
$8,000 and $60,000 Army College Fund
$1,000 and $50,000 Army College Fund
$4,000 and $50,000 Army College Fund
$2,000 and $75,000 Army College Fund
$8,000 and $75,000 Army College Fund

Table 3. 4 and 5-Year Enlistment Incentives

6-Year Enlistment Incentives
No Enlistment Bonus
$2,000
$4,000
$8,000
$12,000
$18,000
$24,000
$40,000 Army College Fund
$50,000 Army College Fund
$60,000 Army College Fund
$75,000 Army College Fund
$2,000 and $40,000 Army College Fund
$2,000 and $50,000 Army College Fund
$8,000 and $40,000 Army College Fund
$8,000 and $50,000 Army College Fund
$4,000 and $60,000 Army College Fund
$4,000 and $75,000 Army College Fund
$12,000 and $60,000 Army College Fund
$12,000 and $75,000 Army College Fund

Table 4. 6-Year Enlistment Incentives

It is appropriate to interpolate between incentive amounts included in the study. For instance, the probability of selecting a 2-year enlistment for a $2,000 enlisted bonus can be calculated from the data obtained from the study. It would not be appropriate to calculate the probability of selecting a 2-year enlistment for $24,000, since it falls outside the bounds of the study.

4. Problem Statement

The ORCEN will develop a flexible, easy-to-use decision support tool which will accomplish the following:

- Predict the number of individuals who will enlist for a given MOS, for a given incentive and time of service

- Determine the optimal mix of incentives to offer each MOS

- Determine the total cost for offering these incentives

- Minimize the deviation from the recruiting goals for each MOS, including both overages and shortages

5. Methodology

5.1. Modeling Alternatives

USAREC provided the ORCEN a statement of work that outlined their requirements and needs. Their main requirement was to determine or approximate the effects of cash signing bonuses or Army College Funds on recruiting and production goals. The first step was to determine a suitable method to measure the benefits gained from enlisting an individual into a certain MOS. The competing methods evaluated were:

- dynamic program using PowerSim®

- linear program using Microsoft Excel®

- integer goal program also using Microsoft Excel®.

A dynamic program is more difficult to use than an Excel® based program since most operations research analysts are more familiar with Excel® than PowerSim®. A linear program would be inappropriate since it would not allow any solutions that exceed any of the constraints. Thus, a solution that exceeds the budget by one dollar but produces 1,000 more recruits and exactly the right number of recruits for every MOS would be

infeasible. Another reason a linear program is not the best alternative is that there is no quantifiable benefit from recruiting an individual into the Army except for coming closer to achieving a recruiting goal. As a result, a linear program, which attempts to minimize costs or maximize enlistments subject to certain constraints, would not spend any funds unless the objective function contained a theoretical profit received from each enlistment. An Excel® based integer goal program model has the characteristics required to solve the problem and would be easier for most operations research analysts to use and manipulate. The model is integer based because the decision is whether or not to offer a certain incentive to a given MOS for a certain term of service. In addition, a goal program will allow the model to find a solution that attempts to set the number of enlistments for every MOS equal to the number of enlistees required while remaining within the recruiting budget. For these reasons a model using a binary integer goal program was selected as the best alternative.

5.2. Binary Integer Goal Program

A binary integer goal program using Excel® proved to be the best alternative and the model reached acceptable solutions in roughly 60 minutes after executing 100 sub-problems. It is possible to continue searching beyond the limit of 100 sub-problems; however, the value of the objective function did not change significantly. In other words, the solution reached after 100 sub-problems was a near optimal solution that balanced the enlistment requirements for all MOSs. The following is a description of the model:
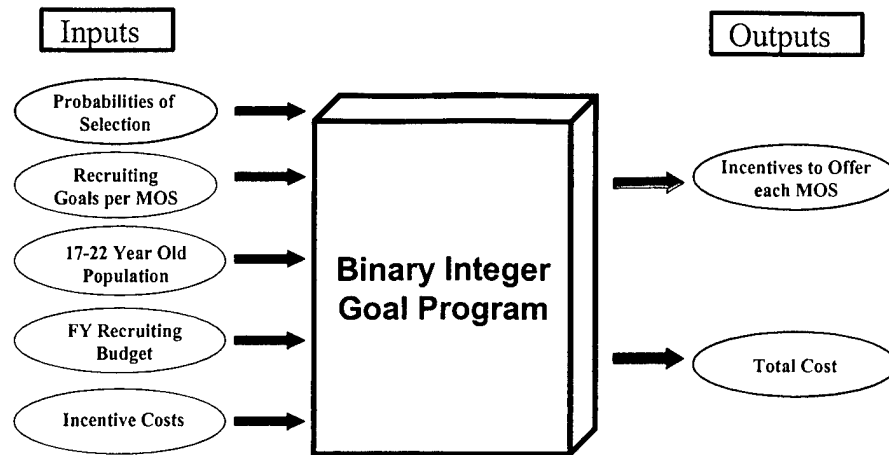
Figure 1. Model Description

The model minimizes the deviations from the recruiting goals for each MOS while remaining within the recruiting budget. As such, the model may reach all the recruiting goals but not at the minimum cost since the budget is a constraint. This is only a problem when the budget has slack and is not a binding constraint. If the budget is a binding constraint then the solution found will also be the minimum cost. A solution in which every recruiting goal has not been met and all the funds available for the budget have been allocated is a case when the budget is a binding constraint. If the budget is not a binding constraint (do not foresee an instance when this would occur), then a second run of the solver must be performed. The second, pre-emptive goal program, would be the same as the first binary integer goal program with the addition of two constraints. The two constraints are:

- Set the number of shortages in the pre-emptive run <= to the number of shortages from the first run

- Set the number of overages in the pre-emptive run <= to the number of overages from the first run

The objective function changes to minimize the total cost. These two new constraints and the new objective function force the second run to search for solutions which are better than, but not worse than the first, and at a minimum cost.

5.3. Upgraded Excel® Solver

The standard solver found on the Excel® can calculate problems that have a maximum of 200 decision variables and 400 constraints. Including all the incentive options outlined in Tables 1 through 4 across all 194 entry-level MOSs results in almost 16,000 decision variables. Solving a problem of this size requires an upgraded solver produced by Frontline Sytems, Inc. Frontline Systems' Extended Large-Scale LP Solver™ has the capability to solve problems with up to 65,000 decision variables and constraints.

5.4. Input Data

5.4.1. MOS Recruiting Goals

The model uses required fiscal year accession seats as the MOS recruiting goal since this represents the true number of I-IIIA recruits that can be accepted in any fiscal year. This data is obtained from USAREC's FY MOS Target Fill Production to Date report. This data is easily pasted onto the accession seat worksheet (see Appendix C), making updating easy.

5.4.2. Incentive Costs

The incentives evaluated in the model are those given in paragraph 3.1.2, Incentives Considered. The costs for these incentives were obtained from Mr. Gerald Giesecke, DMDCEAST. These costs are inputted into the costs worksheet of the model. Costs for both quarterly and annual payment methods are included. The model currently uses the annual payment method costs. See Appendix D for incentive cost values used in the model.

5.4.3. Fiscal Year Recruiting Budget

As of FY 1999, the recruiting budget is no longer separated for the different categories of incentives, but is simply one total budget for which all incentives can compete. The fiscal year recruiting budget is a constraint of the model.

$$\sum EB\ Costs + \sum ACF\ Costs + \sum EB + ACF\ Costs \leq FY\ Recruiting\ Budget$$

The remaining fiscal year budget can also be used when performing periodic planning throughout the year.

5.4.4. Probabilities of Selection

This section highlights the method used to determine the probability that a 17 to 22 year-old will enlist in the Army if offered an incentive. USAREC PA&E contracted MarketVision Research ® to complete a market survey of the Army's target population to assess the effectiveness of different enlistment incentives. MarketVision used choice-based conjoint analysis in its assessment. This technique is one in which the respondent is given a description of the different career fields and then asked to choose which, if any, he or she would choose. To minimize the number of required questions on the survey, MarketVision used career field designations and not each specific MOS. The career fields included in the market survey are shown below.

Military Position
Military Intelligence
Military Police
Psychological Operations
Administration
Aviation Operations
Medical
Transportation
Public Affairs/Journalism
Electronic Warfare/Intercept Systems maintenance
Automatic Data Processing/Computers
Ammunition
Signal Operations
Supply and Services
Visual Information/Signal
Air Defense Artillery
Infantry
Armor
Combat Engineering
Electronic Maintenance and Calibration
Field Artillery
Topographic Engineering
Aircraft Maintenance
Mechanical Maintenance
Electronic Warfare/Cryptologic Operations
General Engineering/Construction
Petroleum and Water

Table 5. Military Positions Surveyed

"Choice based conjoint analysis, also referred to as discrete choice modeling, does not ask people to rate their preference... Rather choice modeling presents multiple concepts to respondents and asks which one they would choose."[1] Conjoint refers to the fact that the respondent must consider the choices, the mix of both career fields and incentives, jointly.

MarketVision set up offices in malls throughout the country to attain random samples, which can be used to represent 17-22 year old preferences nationwide concerning enlisting in the Army. They intercepted 506 respondents in the survey. Using statistical analysis, MarketVision Research calculated utilities that represent respondent's preference for military position, enlistment period and incentive. The utilities calculated from the study are below.

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[1] Pinnell, Jon, *Conjoint Analysis: An Introduction*, 1997

Military Position	Utility
Military Intelligence	1.5446
Military Police	1.0058
Psychological Operations	0.8385
Administration	0.4037
Aviation Operations	0.3262
Medical	0.2913
Transportation	0.2699
Public Affairs/Journalism	0.2505
Electronic Warfare/Intercept Systems maintenance	0.2144
Automatic Data Processing/Computers	0.1446
Ammunition	0.1358
Signal Operations	0.0617
Supply and Services	0.0313
Visual Information/Signal	-0.0535
Air Defense Artillery	-0.1251
Infantry	-0.1379
Armor	-0.1410
Combat Engineering	-0.1996
Electronic Maintenance and Calibration	-0.2006
Field Artillery	-0.2512
Topographic Engineering	-0.5162
Aircraft Maintenance	-0.5431
Mechanical Maintenance	-0.5907
Electronic Warfare/Cryptologic Operations	-0.7675
General Engineering/Construction	-0.7881
Petroleum and Water	-1.2649

Enlistment Period	Utility
2-year	0.4320
3-year	0.3035
4-year	0.0370
5-year	-0.2434
6-year	-0.5291

Incentive	Utility(per $1000)
Enlistment bonus	0.0576
Army College Fund	0.0237

Table 7. Utility Values

The probability that a 17-22 year old will enlist into a certain MOS for a specific term of service given a specific incentive can be calculated from this utility data.

Each military position, term of service and incentive combination is considered a product. The product utility is given by:

$$U_{ijk} = utility\text{military position} + utility\text{term of service} + utility\text{incentive}$$

This product utility represents the odds in favor of a positive response to the product. These odds must then be converted to probabilities of positive response. The probability of a positive response to the product is then given by[2]:

$$p_{ijk} = \frac{e^{U_{ijk}}}{1 - e^{U_{ijk}}}$$

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[2] Joles et al, *An Enlistment Bonus Distribution Model*, 1998

The estimated fraction of the 17-22 year old population who would enlist for a specific military position(i), term of service(j) and incentive(k) is given by[3]:

$$SoP_{ijk} = \frac{P_{ijk}}{\sum_i \sum_j \sum_k P_{ijk}}$$

This gives us the fraction of the population who would enlist into a certain career field given a term of service and incentive.

Incentive policy allows for only one incentive level to be offered to each MOS for a certain term of service. For example, MOS 11X may be offered the following incentives for a 2-year term of service:

$2,000 enlisted bonus
or
$26,500 Army College Fund
or
$1,000 enlisted bonus plus $26,500 Army College Fund

Both a $1,000 and $2,000 enlisted bonus could not be offered to 11X for a 2-year term of service. This affects the fraction of the population calculations above. Because only one incentive type can be offered, we must assume that a higher incentive level will also attract those persons who would enlist for a lower incentive level. For instance, if a $2,000 enlisted bonus is offered to MOS 11X for a 2-year term of service, then we will also attract those who would enlist into MOS 11X for a 2-year term of service given a $1,000 enlisted bonus. Thus, the estimated fraction of the 17-22 year old population that would enlist into MOS m, for term of service j, given incentive k is given below:

$$P_{mjk} = SoP_{ijk} \times [\% \; of \; i] + \sum P_{mjl} \; for \; all \; l < k$$

[3] Joles et al, *An Enlistment Bonus Distribution Model,* 1998

where,

$$\% \text{ of } i = \frac{recruiting\ goal\ for\ MOS, m}{\sum_m recruiting\ goals\ for\ all\ MOSs\ in\ career\ field\ j}$$

These fraction values for all products are calculated on the probabilities worksheet of the model.

The expected number of recruits to enlist into MOS m, for term of service j, given incentive k is given by:

$$R_{mjk} = P_{mjk} * (17\text{-}22\ year\ old\ population)$$

This is calculated on the incentive model worksheet of the model.

The model can easily be updated to reflect current market conditions or demographic changes. The population size is a global variable that can be changed as the 17-22 year old population increases or decreases. The probability an individual will select the incentive can also be changed; however, a new choice based conjoint analysis would be needed to determine these new probabilities.

5.4.5. Decision Variables

The decision variables in this binary integer goal program are which incentives to offer each MOS. The benefits and costs for offering each of the incentives are evaluated and considered globally through out the entire solution space. That is, the effects of each incentive are evaluated with regard to their impact on the model as a whole. If the incentive is offered, the decision variable value is one; if the incentive is not offered, then the variable is a zero.

5.4.6. Constraints

There are six categories of constraints in the model. The first category is the recruiting goal for each MOS. These are goal constraints with the left-hand side as the summation of all the expected recruits from all the offered incentives and the right-hand

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side is the recruiting goal for that individual MOS. An example of the constraint for

MOS 19D follows:

(Expected # of recruits to select 19D without any incentive)+

(Expected # of recruits to select 19D for 2yr TOS[4] given EB) +

(Expected # of recruits to select 19D for 3yr TOS given EB) +

(Expected # of recruits to select 19D for 4yr TOS given EB) +

(Expected # of recruits to select 19D for 5yr TOS given EB) +

(Expected # of recruits to select 19D for 6yr TOS given EB) +

(Expected # of recruits to select 19D for 2yr TOS given ACF) +

(Expected # of recruits to select 19D for 3yr TOS given ACF) +

(Expected # of recruits to select 19D for 4yr TOS given ACF) +

(Expected # of recruits to select 19D for 5yr TOS given ACF) +

(Expected # of recruits to select 19D for 6yr TOS given ACF) +

(Expected # of recruits to select 19D for 2yr TOS given EB and ACF) +

(Expected # of recruits to select 19D for 3yr TOS given EB and ACF) +

(Expected # of recruits to select 19D for 4yr TOS given EB and ACF) +

(Expected # of recruits to select 19D for 5yr TOS given EB and ACF) +

(Expected # of recruits to select 19D for 6yr TOS given EB and ACF) +

U19D - O19D = Annual/quarterly/monthly recruiting goal for 19D.

U19D represents the recruiting shortfall and O19D represents the overage for this

particular MOS.

The second category of constraints is those that limit the decision variables to

being either a 1 or a 0. In Excel® this is accomplished by adding the constraint in the

solver that all the decision variables are "binary". Once these constraints are added, the

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[4] TOS is Term of Service which is the same as length of service

decision is whether to offer the incentive or not; it is not, therefore whether to offer a fraction of the incentive.

The third type of constraint is the budget constraint. Because the budget is for all incentives and for all MOSs there is no budget constraint for each individual MOS. The left-hand side of the budget constraint is the summation of the costs for all the incentives offered multiplied by the number of individuals who select those incentives for all MOSs. The right-hand side is the fiscal year recruiting budget. The budget is represented by one constraint:

$$\sum^{MOSs} \sum^{Incentives} (\# \, who \, select \, the \, incentive) * (incentive \, \cos t) \leq FY \, \mathrm{Re} \, cruiting \, Budget$$

The fourth category of constraint is that only one type of each incentive (EB, ACF, and EB + ACF) can be offered to each MOS for a given term of service. For instance, only one enlisted bonus incentive can be offered to MOS 11X for a 3-year term of service. For each MOS there are fifteen of these constraints (one constraint for each type of incentive and each possible term of service). The constraint for 11X with a 2-year term of service and enlisted bonus incentive looks like this:

$$\sum^{EB \, Incentives} X_{ijk} \leq 1$$

where, X_{ijk} is the decision variable to offer EB incentive k, to MOS i, for term of service j. MOS 11X would also have the above constraint for each possible term of service and constraints for the other two types of incentives (ACF and EB plus ACF).

The final type of constraint is on the minimum term of service required for each MOS. Each MOS is assigned a minimum term of service. No incentives can be offered for terms of service less than the minimum.

5.4.7. Objective Function

The objective function for the goal program attempts to minimize the deviations

from the recruiting goals for each MOS. The objective function follows:

$$\textbf{MINIMIZE} \quad \overset{MOSs}{\sum} \overset{TOS}{\sum} \overset{Incentives}{\sum} (w_U under_{MOS} + w_O over_{MOS})$$

W_U represents the weight assigned for a MOS attracting below/under the recruiting goal

and W_O represents the weight assigned for a MOS attracting above/over. These weights

allow the user to identify critical MOSs. $under_{MOS}$ and $over_{MOS}$ are over and under

variables for each of the MOSs included in the model. This objective function allows

solutions that may include local overages or shortages in order to find a global solution

that minimizes the deviations over all MOSs.

6. Facts

The facts used in the model are based upon the current demographic and economic

situation. These facts will change over time and will need to be adjusted to update the

model. The pertinent facts are the following:

- The current 17-22 year old population is 1,400,000[5] of which 37.1% are

  considered "propensed" for service in the Army. This results in a target

  market of 519,400

- The total population used in the model is 740,000 accounts for the

  projected increase in the size of the target market population

- 50% of the population is male.

- An incentive is either offered or it is not

- There is no budget constraint for any individual MOS

---

[5] *State of the Youth Market*, United States Army Recruiting Command, July 1999

- There is no budget constraint for any individual incentive

- Each MOS will attract a certain number of recruits per year, as determined by the MarkeyVision ® study, without offering any incentives

7. Assumptions

There were times during the development of the model where we needed to make assumptions to bind the problem and to make the problem solvable. The pertinent assumptions are:

- The economy will remain roughly the same during the period the model is used

- There will be no limited or full-scale conflict which has a drastic positive impact on recruiting

- If an incentive is offered, all the individuals who are expected to enlist, based on the MarketVision® study, for this MOS will actually enlist for that MOS.

- All those who are propensed to serve in the Army will be made aware through advertising, of the incentives studied in the MarketVision study

- Soldiers who enlist for the ACF incentive will contribute $1,200 at the beginning of their term of service

8. Output

The model reached an adequate solution after 100 sub-problems in about 60 minutes. Running the model beyond 100 sub-problems improved the solution somewhat but these improvements were insignificant. For example, a solution after 100 sub-problems resulted in an objective function value of 5,609 and a 1,000 sub-problem solution resulted in an objective function value of 5,545. Since the objective function is to minimize the

deviations from the recruiting goals a lower objective function value is better, however, the longer run did not significantly improve the solution. Increasing the number of sub-problems to 1,000, a 1000% increase, improved the objective function by only 1.10%. The run time for 1,000 sub-problems was around 10 hours but again this improved the solution only slightly. Table 8 shows the results from a 100 sub-problem solution for the first ten MOSs:

MOS	TARGET (Acc seats)	# Recruits No Incentives	Offer Incentives		Total Cost
00B1	48	24	Yes		354,744
11X1	8534	4267	Yes		18,234,412
12B1	288	144	Yes		783,080
12C1	80	40	Yes		191,426
13B1	1513	756	Yes		7,015,586
13C1	108	54	Yes		497,587
13D1	162	81	Yes		746,630
13E1	289	144	Yes		1,337,601
13F1	393	196	Yes		1,823,214
13M1	336	168	Yes		1,548,851

Table 8. Model Results

The first column is the MOS. The second column is the recruiting goal for that MOS, accession seats available. The third column is the number of recruits expected to enter the MOS without any incentive. The fourth column is a guide to whether an incentive should be offered to the MOS. If the number of recruits expected to enter the MOS without any incentive is greater than or equal to the recruiting goal, then no incentive is needed. The next column represents the number of recruits expected for the MOS, with the final column showing the total cost for recruiting that number of individuals into the MOS.

For the different iterations the budget remained a binding constraint so a second run, as discussed in 5.2 above, was not needed. Using FY2000 data never resulted in a

run in which this was the case. The following table shows the budget results from a 100 sub-problem run.

Recruiting Budget	$100,000,000
Total Budget Required to Meet Goals	$100,000,000
Total # Recruits Required	39,696
Objective Function	8,988

Table 9. Budget Results

In this case, the model minimized the deviations for all MOSs from the recruiting goals while remaining within the recruiting budget. The use of the budget has been maximized and is binding in this case because there is still a global shortage. This solution produced 30,708 new recruits but the total required was 39,696 that left a shortage of 8,988 for FY2000.

The model is also able to generate an easy to read incentive report. Figure 1 below shows a small portion of a report.

Total Budget Required		$100,000,000					
FY01 Recruiting Budget		$100,000,000					
Total # Recruits		30,708					
MOS	TARGET	Min TOS	Recruit Expected	Total Cost	Incentives to Offer		
13B1	1,513	3	1,513	$7,015,586	3yr10EB	3yr49ACF	3yr4EB33ACF
13C1	108	3	108	$497,587	3yr10EB	3yr49ACF	
13D1	162	3	162	$746,630	3yr10EB	3yr49ACF	
13E1	289	3	289	$1,337,601	3yr10EB	3yr49ACF	3yr4EB33ACF
13F1	393	3	393	$1,823,214	3yr10EB	3yr49ACF	3yr4EB33ACF
13M1	336	3	336	$1,548,851	3yr10EB	3yr49ACF	
13P1	338	3	338	$1,559,387	3yr10EB	3yr49ACF	3yr4EB33ACF
13R1	86	3	86	$395,114	3yr10EB	3yr49ACF	

Figure 2. Incentive Report

The Generate Report macro button on the Incentive Model worksheet creates this report. The shaded portion indicates the incentives to offer each MOS. For instance, MOS 13B1 should be offered a three year, $10,000 enlisted bonus, $49,000 Army College Fund, and $4,000 enlisted bonus plus $33,000 Army College Fund.

8.1. Results

Since the choice-based conjoint study results are the major input into the model, it is important to attempt to verify these results. We chose to verify the results by comparing the model's predicted recruits into a MOS for a specific incentive against FY2000 recruiting data. Figure 1 shows the results for 11X.
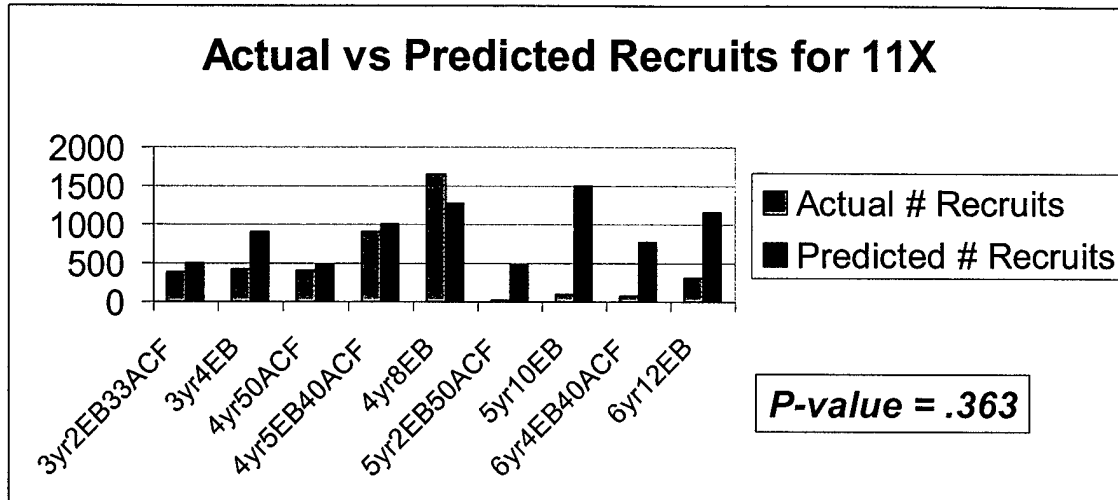
Figure 2. Verification Results

The histogram shows that the model does a very good job of estimating recruits, except for the longer terms of service. Performing a simple analysis of variance for the actual versus predicted recruit data over all MOSs and incentives results in a p-value of .363. This p-value seems to indicate that the data is similar. Reasons for the data not being more similar are discussed in section 10.

9. Future Research

The weakness of this model is that it is valid only as long as the choice-based conjoint analysis results are valid. Previous studies completed by this department concerning recruiting trends have concluded that the two most important factors that affect recruiting trends are the unemployment rate among 17-22 year olds and the 17-22 year olds

propensity to serve in the armed forces[6]. These two factors are readily available on a monthly or annual basis. The Bureau of Labor and Statistics tracks the unemployment rate among 16-19 year olds and USAREC conducts the annual Youth Attitude Tracking Survey that measures propensity to serve in all the branches of the armed forces.

We believe it would be possible to use the goal program in the future by accounting for the effects of unemployment by conducting regression analysis using historical data to determine the relationships. These relationships could then be used to
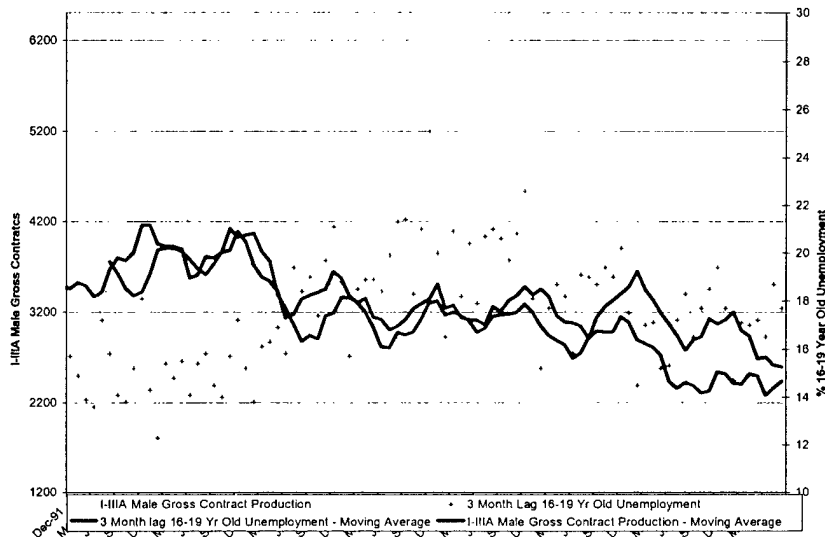
adjust the probabilities of selection. It seems unemployment and recruiting become closely related beginning around September 1996, as seen in the above data provided by DAPE.

These relationships could also be verified by estimating enlistments for the past four years using the current data and then adjusting these estimates using unemployment and propensity to serve for those respective years. The estimates could then be compared with the actual recruiting results for those years.

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[6] Clark, Charles et.al. *The Impact of Desert Shield/Desert Storm and Force Reductions on Army Recruiting and Retention,* Department of Systems Engineering, USMA, May 1991

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10. Conclusions

A binary integer goal program is the appropriate decision support tool for determining the optimal mix of enlistment incentives to offer in order to maximize production while remaining within the budget. The model efficiently predicts the number of recruits per MOS, although it may overestimate the number of recruits at longer terms of service. This may be caused by study subjects being willing to accept longer periods of commitment than if they were actually signing a contract. Recruiting policies may also affect the results. Not every recruit that enters a recruiting station is able to enlist into every MOS. A battery of tests determines his enlistment choices. So not all "products" are available and known by all recruits. This somewhat invalidates the conjoint study assumption that all products are offered to everyone.

The model is very flexible and can be easily updated with new information without changing the basic structure of the model. It is relatively easy to change the any of the input data fields allowing the decision-maker to conduct scenario analysis or contingency planning. The add-in solver using Excel® operates exactly like the default solver found on any Excel® version.

11. References

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Appendix A. Probability Spreadsheet

The probability spreadsheet converts the utility data from the MarketVision Research conjoint analysis study into probabilities that an individual will select each MOS given a certain term of service and incentive.

1. Utility values are included for each CMF, term of service and incentive. These values must be updated as new conjoint analysis studies are completed.

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C140 ▾ = =VLOOKUP(A140,'Accession Seats'!$A$6:$AG$162,33)

	A	B	C	D	E	F	G	H
1	Individual-Level Utilities							
2	Military Position	Utility	CMF					
3	Infantry	-0.1379	11					
4	Combat Engineering	-0.1996	12					
5	Field Artillery	-0.2512	13					
6	Air Defense Artillery	-0.1251	14					
7	Armor	-0.1410	19					
8	Visual Information/Signal	-0.0535	25					
9	Signal Operations	0.0617	31					
10	Electronic Warfare/Intercept Systems ma	0.2144	33					
11	Electronic Maintenance and Calibration	-0.2006	35					
12	Psychological Operations	0.8385	37					
13	Public Affairs/Journalism	0.2505	46					
14	General Engineering/Construction	-0.7881	51					
15	Ammunition	0.1358	55					
16	Mechanical Maintenance	-0.5907	63					
17	Aircraft Maintenance	-0.5431	67					
18	Administration	0.4037	71					
19	Automatic Data Processing/Computers	0.1446	74					
20	Petroleum and Water	-1.2649	77					
21	Topographic Engineering	-0.5162	81					
22	Transportation	0.2699	88					
23	Medical	0.2913	91					

Budget Model \ Probabilities / Costs / Accession Seats / MOS /

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Appendix A. Probability Spreadsheet (cont'd)

2. The utilities from above are then converted to probabilities that an individual will enlist into a certain MOS for a given term of service and incentive. Term of service and incentive are listed together (i.e. 2yr0EB represents a 2-year term of service with $0 enlisted bonus incentive).

MOS and **CMF** data is obtained from MOS spreadsheet (*FY MOS Quality Goals from USAREC/PERSOM Trade-off Analysis*). Copy the new *FY Quality Goals* worksheet onto the MOS spreadsheet ensuring the first MOS is in cell A8.

	A	B	C	D	E	F	G	H	
138	Estimated probability of selecting MOS/Incentive (dividing CMF probability by proportion of MOS requirement to total C								
139	MOS	CMF	TARGET	CMF %	2yr0EB	3yr0EB	4yr0EB	5yr0EB	6yr
140	00B1	51	83	5.7%	0.0000124	0.0000115	0.0000097	0.0000079	0.000
141	11X1	11	13841	100.0%	0.0003055	0.0002886	0.0002531	0.0002164	0.000
142	12B1	12	2693	88.5%	0.0002633	0.0002483	0.0002169	0.0001846	0.000
143	12C1	12	349	11.5%	0.0000341	0.0000322	0.0000281	0.0000239	0.000
144	13B1	13	2345	36.7%	0.0001066	0.0001003	0.0000873	0.0000741	0.000
145	13C1	13	97	1.5%	0.0000044	0.0000041	0.0000036	0.0000031	0.000
146	13D1	13	162	2.5%	0.0000074	0.0000069	0.0000060	0.0000051	0.000
147	13E1	13	572	8.9%	0.0000260	0.0000245	0.0000213	0.0000181	0.000
148	13F1	13	1344	21.0%	0.0000611	0.0000575	0.0000501	0.0000425	0.000
149	13M1	13	1007	15.7%	0.0000458	0.0000431	0.0000375	0.0000318	0.000
150	13P1	13	525	8.2%	0.0000239	0.0000225	0.0000196	0.0000166	0.000
151	13R1	13	114	1.8%	0.0000052	0.0000049	0.0000042	0.0000036	0.000
152	14E1	23	420	7.6%	0.0000232	0.0000219	0.0000192	0.0000164	0.000
153	14J1	14	193	8.5%	0.0000261	0.0000246	0.0000216	0.0000185	0.000
154	14R1	14	315	13.9%	0.0000426	0.0000402	0.0000353	0.0000302	0.000
155	14S1	14	1014	44.6%	0.0001370	0.0001294	0.0001136	0.0000972	0.000
156	14T1	14	752	33.1%	0.0001016	0.0000960	0.0000843	0.0000721	0.000
157	19D1	19	2757	49.9%	0.0001523	0.0001438	0.0001261	0.0001078	0.000
158	19K1	19	2767	50.1%	0.0001528	0.0001444	0.0001266	0.0001082	0.000
159	25M1	25	58	28.9%	0.0000913	0.0000865	0.0000763	0.0000656	0.000
160	25R1	25	55	27.4%	0.0000866	0.0000820	0.0000723	0.0000622	0.000

TARGET data is obtained from Accession Seats spreadsheet (*FY MOS Target Fill Production to Date*). To update, copy new *MOS Target Fill Production to Date* worksheet onto Accession Seats spreadsheet, ensuring *Seats to Go* data is in column AG of the spreadsheet.

CMF% is used in converting probability of CMF selection into probability of specific MOS selection. The probability of selection for each MOS in a CMF is based on that MOS percentage of total CMF target. Ensure CMFs listed in cells B134 to AA134.

Appendix B. MOS Spreadsheet

The MOS spreadsheet provides MOS, CMF and minimum term of service (TOS) data to the probability spreadsheet.

	A	B	AT	AU	AV	AW	AX	AY	AZ	BA	BB
1	FY 01 MOS Quality Goals from PERSCOM/USAREC Trade-Off Analysis							as of 12 July 2000			
2	(FY01 PGM01C3B 000612)										
3											
4											
5					Recommendation						
6			IIIB	IV	I-IIIA	IIIB	IV	I-IIIA	IIIB	IV	MIN
7	MOS	CMF	31%	2%	62.50%	35.50%	2%	#	#	#	TOS
8	00B1	51	0	0	99.20%	0.80%	0.00%		121	1	0	4
9	11X1	11	0	3	54.50%	42.30%	3.30%		6047	4693	365	3
10	12B1	12	0	0	52.10%	44.30%	3.60%		676	574	47	3
11	12C1	12	0	0	51.50%	44.80%	3.60%		85	74	6	3
12	13B1	13	0	0	57.50%	40.10%	2.30%		939	655	38	3
13	13C1	13	0	0	57.30%	40.60%	2.10%		82	58	3	3
14	13D1	13	0	0	69.90%	28.80%	1.30%		109	45	2	3
15	13E1	13	0	0	57.50%	40.30%	2.20%		235	165	9	3
16	13F1	13	0	0	71.40%	27.50%	1.10%		624	240	10	3
17	13M1	13	0	0	69.20%	29.10%	1.80%		388	163	10	3
18	13P1	13	0	0	70.90%	27.70%	1.30%		271	106	5	3
19	13R1	13	0	0	76.20%	21.90%	1.90%		80	23	2	3
20	14E1	23	0	0	82.10%	16.70%	1.20%		206	42	3	4

To update this information, copy the new *FY MOS Quality Goal Trade-off Analysis* onto this worksheet, ensuring the first MOS is located in cell A8. Minimum term of service data was added to the *Trade-off Analysis* sheet in column BB.

Appendix C. Accession Seats Spreadsheet

The Accession Seats spreadsheet provides MOS target data to the probability spreadsheet. The *Seats to Go* values (column AG) are used as the recruiting target for each MOS.

	A	AA	AB	AC	AD	AE	AF	AG
1								
2	FY01 MOS Target Fill Production to Date							
3				FY Future DEP				
4	MOS		Seats to Go	Fill	Target	% Fill		Seats to Go
5	MOS	FYTDTC	FYTDGO	OT	FT	Target	FUTC	Seats to Go
6	00B1	ü	-2	60	110	54.54545455		83
7	11X1		508	2968	10994	26.99654357		13841
8	12B1		22	418	684	61.11111111		2693
9	12C1	ü	-19	40	139	28.77697842		349
10	13B1		143	296	1666	17.76710684		2345
11	13C1		4	16	120	13.33333333		97
12	13D1	ü	0	23	185	12.43243243		162
13	13E1		61	34	262	12.97709924		572
14	13F1	ü	0	279	672	41.51785714		1344
15	13M1	ü	-22	177	535	33.08411215		1007
16	13P1		56	126	408	30.88235294		525
17	13R1	ü	-3	29	118	24.57627119		114
18	14E1		3	66	194	34.02061856		420
19	14J1	ü	-6	23	92	25		193
20	14R1		68	23	358	6.424581006		315
21	14S1	ü	-6	75	140	53.57142857		1014
22	14T1		34	177	574	30.83623693		752
23	19D1		27	506	1408	35.9375		2757

To update, copy new *FY MOS Target Fill Production to Date* worksheet into this spreadsheet, ensuring first MOS is listed in cell A6 and Seats to Go data is in column AG.

Appendix D. Costs Spreadsheet

Costs spreadsheet provides incentive cost data to models. Both quarterly and annual payment costs are included. Model currently uses annual payment costs. If quarterly payment costs are preferred, change cell references in Incentive Model and Budget Model (cells C161..DI161).

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	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Quarterly Payments												
2	Incentive	2yr0EB	3yr0EB	4yr0EB	5yr0EB	6yr0EB	2yr1EB	2yr2EB	2yr3EB	2yr5EB	2yr7EB	2yr9EB	2yr26ACF
3	Cost	0.00	0.00	0.00	0.00	0.00	983.66	1967.32	2950.99	4918.31	6885.63	8773.70	3486.00
4													
5													
6	Annual Payments												
7	Incentive	2yr0EB	3yr0EB	4yr0EB	5yr0EB	6yr0EB	2yr1EB	2yr2EB	2yr3EB	2yr5EB	2yr7EB	2yr9EB	2yr26ACF
8	Cost	0.00	0.00	0.00	0.00	0.00	983.66	1967.32	2950.99	4918.31	6885.63	8801.78	3486.00

Incentive Model / Incentive Report / Budget Model / Probabilities \ Costs /

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Cost data must be updated manually.
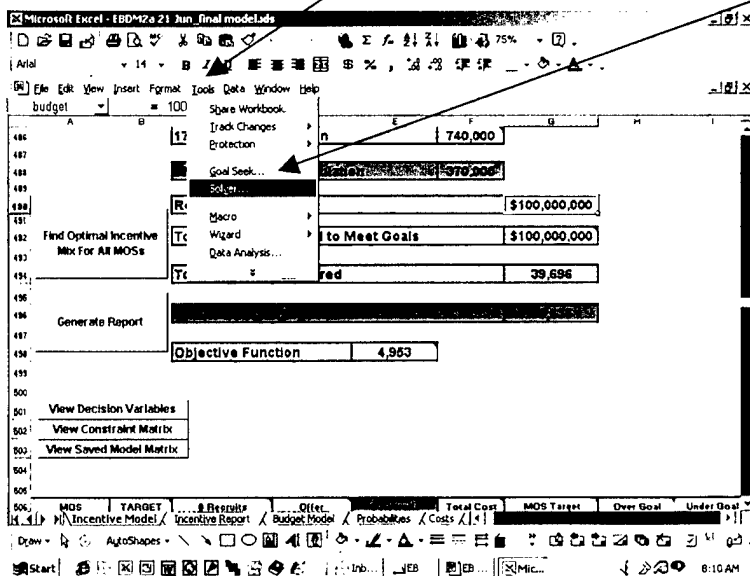
Appendix E. Incentive Model Spreadsheet

Once the model is opened in the "Large-Scale LP Solver" spreadsheet and the pertinent data has been updated as described in previous appendices it is ready for use. The following steps are required to run the model.

1. Update the 17-22 year old population in cell F486.
2. Update the 17-22 year old male population in cell F488. It is currently set at 50% of the total 17-22 year old population.
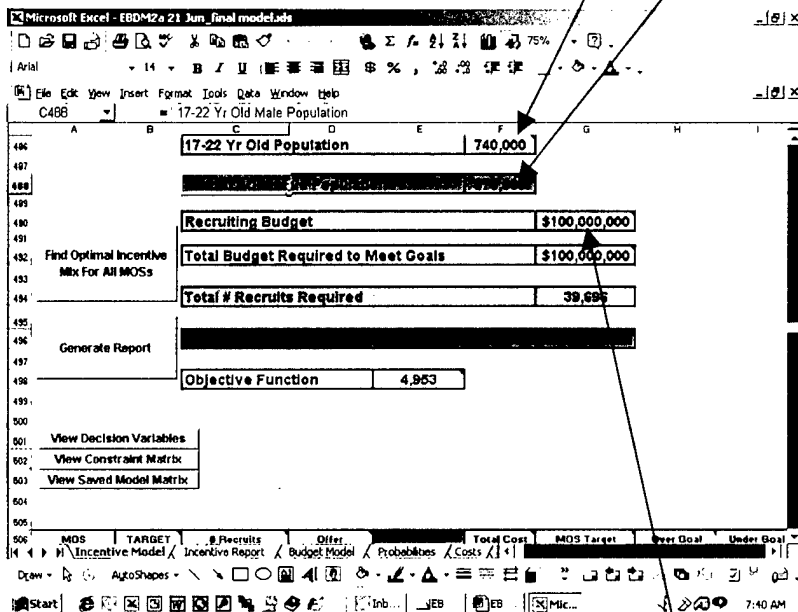

3. Update the fiscal year recruiting budget in cell G490. This can be the total fiscal year budget or the remaining budget.

4. To solve the model, click on the macro button "Find Optimal Incentive Mix For All MOSs". This macro automatically loads the saved solver model and runs the solver. Alternatively, go to the **Tools** drop down menu and select the **Solver**…option.

Appendix E. Incentive Model Spreadsheet (cont'd)

5. The next view is of the Solver parameters. Ensure the Large-Scale LP Solver is selected.
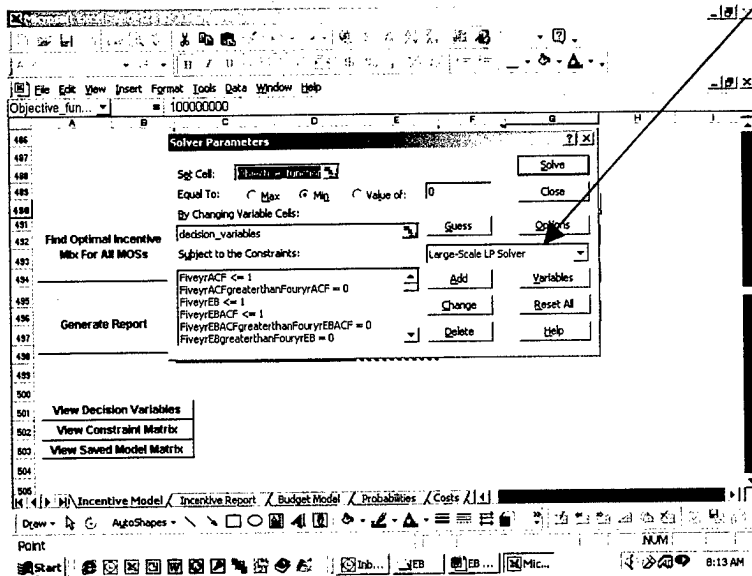
6. Large-Scale LP Solver Options are set as recommended by Frontline Systems, Inc to reduce run time and should not be changed.

- Max Time: 9000 seconds
- Iterations: 7000
- Coeff Tolerance: .000001
- Solution Tolerance: .00001
- Pivot Tolerance: .000001
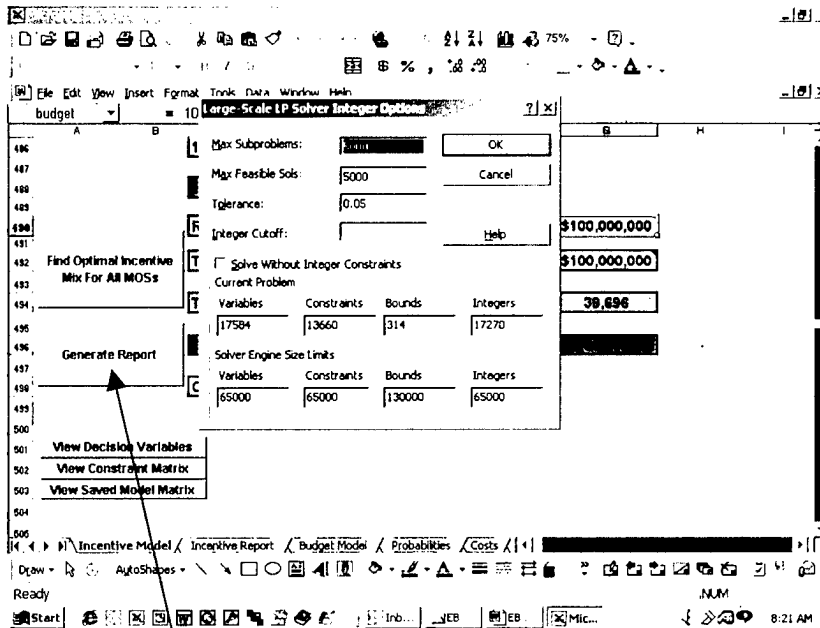- Reduced Tolerance: .000001
- Assume Non-Negative: checked
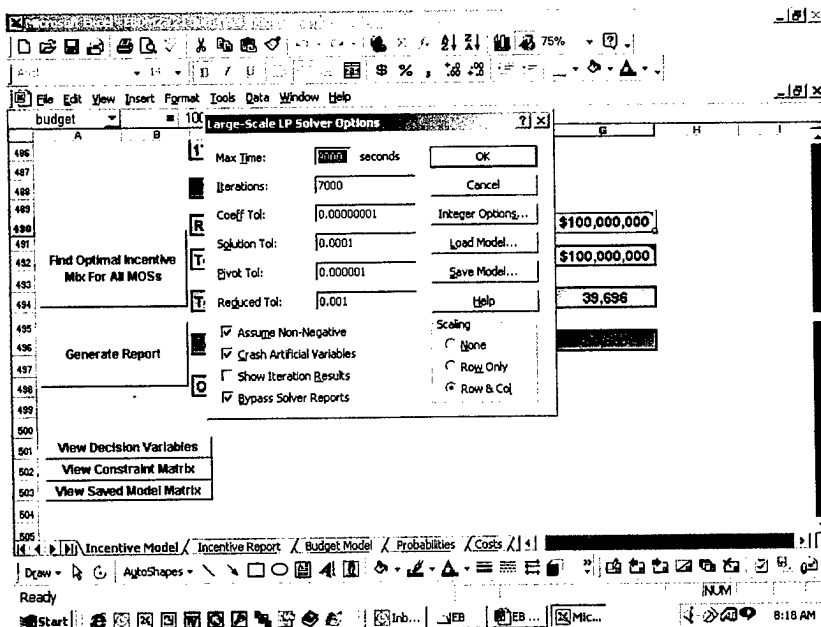
- Bypass Solver Reports: checked
- Scaling: Row & Col checked

7. Large-Scale LP Solver Integer Options are also set to reduce run times and should not be changed.

- Max Subproblems: 5000
- Max Feasible Sols: 5000
- Tolerance: .00001

8. A Generate Report macro was added to the model since Bypass Solver Reports was selected in the Solver Options box. This macro sets up the Incentive Report spreadsheet that is discussed in Appendix F.

9. Macros have also been added to aid navigation through the model.

- View Decision Variables
- View Constraint Matrix
- View Saved Model Matrix

Appendix E. Incentive Model Spreadsheet (cont'd)

10. Cell G492 shows the total budget required to attract the total number of recruits expected in cell G496.

11. Rows 1 to 485 are hidden in the spreadsheet since this data is automatically updated from other spreadsheets. Data from the Probability Spreadsheet and Costs Spreadsheet are used to calculate the expected number of recruits and costs.

Expected Number of Recruits

MOS	TARGET	No EB/ACF	2yr1EB	2yr2EB	2yr3EB	2yr5EB	2yr7EB	2yr3EB
00B1	48	24	17	33	51	69	89	109
11X1	8534	4267	116	235	356	483	614	751
12B1	288	144	89	179	272	369	470	575
12C1	80	40	50	100	151	205	261	319
13B1	1513	756	50	101	154	209	266	325
13C1	108	54	4	8	11	15	19	24
13D1	162	81	6	11	17	23	29	35
13E1	289	144	10	20	30	40	51	63
13F1	393	196	13	27	40	55	69	85
13M1	336	168	12	23	35	47	59	73
13P1	338	169	12	23	35	47	60	73
13R1	86	43	3	6	9	12	16	19
14E1	131	65	12	23	35	48	61	74
14J1	63	31	16	32	48	64	82	100
14R1	403	201	50	100	151	205	261	318
14S1	59	29	8	15	23	30	39	47
14T1	431	215	105	213	323	437	557	680
19D1	923	464	41	82	124	168	214	261
19K1	1742	871	76	153	232	315	400	489
25M1	2	1	80	162	245	332	423	516
25R1	2	1	80	162	245	332	423	516
25V1	2	1	80	162	245	332	423	516
27E1	70	35	25	50	76	103	131	160
27M1	16	8	6	12	18	24	30	37
27T1	50	25	18	36	54	74	94	114
31C1	26	13	3	6	8	11	14	17
31F1	752	376	74	149	225	305	387	472
31L1	164	82	17	33	50	67	85	103
31P1	160	80	16	32	48	65	83	101

Appendix F. Incentive Report Spreadsheet

This spreadsheet is automatically generated from the Incentive Model spreadsheet when the Generate Report macro is run. The report shows the number of recruits expected for each MOS, cost to recruit that number of recruits, and the incentives to offer to attract that number of recruits.

	A	B	C	D	E	F	G	H	I	J
1	Total Budget Required		$100,000,000							
2	FY01 Recruiting Budget		$100,000,000							
3	Total # Recruits		30,635							
4										
5	MOS	TARGET	Min TOS	# Recruits	Total Cost	Incentives to Offer				
6				Expected						
7	00B1	48	4	48	$354,744					
8	11X1	8,534	3	6,004	$16,024,690	3yr10EB	3yr45ACF	3yr4EB33ACF		
9	12B1	288	3	288	$783,080					
10	12C1	80	3	80	$191,426					
11	13B1	1,513	3	1,513	$7,015,586	3yr10EB	3yr45ACF	3yr4EB33ACF		
12	13C1	108	3	108	$436,086	3yr10EB	3yr45ACF			
13	13D1	162	3	162	$747,129	3yr10EB	3yr45ACF			
14	13E1	289	3	144	$0	3yr10EB	3yr45ACF	3yr4EB33ACF		
15	13F1	393	3	393	$1,823,214	3yr10EB	3yr45ACF	3yr4EB33ACF		
16	13M1	336	3	336	$1,549,199	3yr10EB	3yr45ACF			
17	13P1	338	3	338	$1,553,387	3yr10EB	3yr45ACF	3yr4EB33ACF		
18	13R1	86	3	86	$395,941	3yr10EB	3yr45ACF			
19	14E1	131	4	131	$876,299					
20	14J1	63	3	63	$182,651					
21	14R1	403	3	403	$1,484,378	3yr3EB33ACF				
22	14S1	53	3	53	$220,631	3yr3EB33ACF				
23	14T1	431	3	431	$1,234,575					
24	19D1	329	3	329	$4,138,420	3yr3EB33ACF				
25	19K1	1,742	3	1,742	$7,752,126	3yr3EB33ACF				
26	25M1	2	6	1	$0					
27										

Incentive Report / Budget Model / Probabilities / Costs / Accession Seats /

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Appendix G. Budget Model Spreadsheet

This spreadsheet should be used for recruiting budget planning. Functionality is the same as the Incentive Model spreadsheet. Only difference is that the recruiting budget is no longer a constraint of the model.