MULTI-CRITERIA DECISION SUPPORT SYSTEM
FOR MILITARY FORCE MANAGEMENT
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ABSTRACT
This application of SAS/OR software was designed for Air Staff enlisted policy planners as a decision aide in the complex arena of military force management. By coding an innovative goal programming algorithm in SAS software, the domain of Operations Research problems which can be modelled via the SAS/OR software has been greatly expanded.

No longer does the analyst need to limit his formulation of the real world into a model consisting of a set of constraints having one single objective function. By sequentially calling PROC LP and generating various specially designed reports it is possible to optimize numerous conflicting goals and objective functions.

The multi-goal programming procedure outlined in this project is Ching-La Hwang and Abu Syed Masud’s 1988 version of their ISGP-II algorithm. The Interactive Sequential Goal Programming algorithm allows decision makers to incorporate their preferences in reaching a compromise between competing goals by explicitly displaying the trade offs.

FORMOEC, the name given to this military FORce Management DECision tool incorporates both the basic ISGP shell coded in the SAS software as well as the required DOD force management problem specific parameters. A “matrix generator” was manually created to help the user set up the 500 various constraints and input the 800 variables necessary to model a typical military problem.

The objective of this project was to interactively guide a decision maker to a satisfactory solution by using FORMOEC on the MVS/TSO environment via SAS version 5 software.

DOD requirement
Military enlisted force managers are faced with decisions involving many competing goals across multi-year time periods. Optimization of one objective often constrains the optimization of other objectives. For example, current year cost minimization may result in higher costs in future years, or maximization of force experience levels might increase costs in current and future years.

This management process needs to be systematized. After the desired characteristics of the enlisted force are specified, optimal force structures can be projected. Then the decision makers (hereafter referred to as DMs) make trade offs between their conflicting programs and priorities. Given an analytical basis the DMs can steer toward mutually satisfactory solution. This SAS decision support tool will show the DMs the sensitivities of goal attainment as well as the temporal effects of their decisions. Such a system would be especially beneficial when crucial decisions and actions are required on short notice.

ISGP II
The first optimization in the ISGP II procedure involves finding an initial solution such that all goals are achieved to the degree that no goal could be improved without detriment to other goals. The DMs are then given the opportunity to select desired values for each goal. The result of the first iteration shows a set of solutions indicating to the DMs how achievable each goal is and how sensitive goals are to each other. With this information, the DMs revise their goal values. The next step begins by optimizing again under the modified formulation. This process continues until a satisfactory solution is obtained.

Each ISGP iteration for a multi-criteria problem with m goals will present one principal solution and m auxiliary solutions. The principal solution meets or exceeds the desired values for all but one goal. For each auxiliary solution, a particular goal is forced to be achieved by entering it as a constraint in the underlying LP. The mathematical linear programming formulas for ISGP II may be found in the references in the end of this paper.

Linear Enlisted Model
The main structure of FORMOEC tracks the flow of personnel through the enlisted force. Each enlisted member is described in terms of his grade and year of service. FORMOEC models 30 YOS and 7 grade categories (E-1, E-2, and E-3 are combined into one group) and thus defines 80 valid grade/YOS cells. Once the individuals are counted and represented in their appropriate cells, FORMOEC will enlist new troops, promote in and out of each rank, retire, and separate them.

In addition to the inventory flow constraints, FORMOEC structures the enlisted force with ten other types of constraints. These constraints define total end-strength, congressional limits on percentages of E-8s and E-9s, experience in terms of percentage of force with YOS greater than four, selection opportunity and deviation from the planned grade distribution. NPS accession levels are given lower bounds, and prior service accessions are given upper bounds. The cost type constraint defined in FORMOEC consists of the present value of personnel payroll costs over the horizon of the model. The last two types of constraints included are the deviation in NPS accessions from model year to model year, and reenlistment bonus retention.
Since a majority of Air Force personnel analysis data and models are maintained using SASsoftware, FORMDEC was written with SAS/OR software. FORMDEC requires nine different input data sets; initial inventory, continuation rates, percent of people in each YOS to be promoted, prior service accession rates, percentages of people effected by high year of tenure, career job reservations, and bonus payments. The percent of promotion eligibles per cell and the continuation rate of those who remain in grade beyond their high year of tenure are also required as input data.

Once the enlisted force is structured in terms of the above linear constraints, the decision makers choose which constraints are to be respecified as goals to be maximized or minimized. Interacting with FORMDEC the DMs will choose a solution which "best" meets their goals. The decision variables optimized each model year are the following; the promotions to each grade, the NPS accessions, prior service accessions per grade, losses in each grade due to high year of tenure and lack of career job reservations, additional personnel retained in each grade due to payment of reenlistment bonuses, and the ending inventory for each grade/YOS cell. These results are expressed in terms of grade/YOS profiles.

Example. Consider a three goal problem: Minimize total cost, Maximize experience levels in model year one, and Maximize experience levels in model year two. (Experience is defined here as the number of people with YOS greater than four over the minimum level of 52% of the force.) FORCE, the matrix generator program, will access the recent data for the various input rates. With SAS* array processing, FORCE defines the appropriate variable names, assigns values and sets up the input matrix in the format required by SAS PROC LP Operations Research software. The SLCTGOAL program merges the FORCE data set with the goal data set. The chosen identifiers for these goals are DISCOST, EXP_T01, and EXP_T02. This two year problem represents an LP matrix of 197 constraints and 227 variables.

PHASE1 of the ISGP II process calculates the positive/negative ideal solution table so that the DMs will see the absolute best and worst values for each goal considered independently. PHASE1 proceeds to find the Maximum Achievable Goal (MAG) solution by determining the point at which all goals are achieved to the same degree relative to the difference between the positive and negative ideal solutions. The computer printout below shows a Maximum Achievable Rate of 67. This MAR signifies that the solution presented as the MAG reached 66.9% of the least weighted goal and 67% of the other goals.
Suppose the OMs are not satisfied with any of the solutions achieved on the trade off table. They desire stable experience levels from year to year and are willing to spend more money to do so. In order to set both year's experience goals at 25,000, they increased the personnel cost budget from $23.1 billion to $23.2 billion. These PHASE2 results are shown below.

Goals may be continually revised and the PHASE2 process repeated until the OMs agree on an acceptable solution. In this example the OMs see that with a modest cost increase, the first auxiliary solution offers experience levels which are consistently high from year to year.

Once the final solution is chosen, a post processing program will summarize the optimized results for each model year. The displayed force structure decision variables printed in matrix form by grade and YOS are the inventories, promotions, policy losses, and normal losses. Standard SAS OR* linear programming output also can be studied to learn the reduced costs and the dual activities for all variables and constraints in the final problem.

**ISGP II TRADE OFF TABLE**

<table>
<thead>
<tr>
<th>ID</th>
<th>DISCOST</th>
<th>EXP_T01</th>
<th>EXP_T02</th>
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</thead>
<tbody>
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</tr>
<tr>
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<tr>
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<tr>
<td>AS3</td>
<td>23.144M</td>
<td>27500</td>
<td>25000</td>
</tr>
</tbody>
</table>

**Lessons Learned**

The basic and yet the most crucial step in this study involved modeling the enlisted force as a set of linear constraints. The first formulation of the US Air Force Enlisted Force and personnel policies was elegantly designed. This was done to enhance the speed of the LP solution process by working with a minimal number of variables. However after many unsuccessful attempts to find the cause of infeasibility, it became necessary to switch to a simpler description of the enlisted force which allows greater programming ease for debugging and modification purposes.

After a major overhaul of the enlisted linear matrix generator program FORCE, tedious validation began. The parameter names and the assigned values for each variable in each constraint were reviewed. The sample 5 year 2 goal problem corresponded to a 500 by 560 matrix. Additional modifications to the FORCE program corrected small errors which would have been compounded and difficult to trace later in the ISGP process.

The actual ISGP II coding was done both with interactive SAS and with batch jobs sent to the mainframe system. As the number of model years are increased the CPU time dramatically increases. In fact, a ten year problem could take up to 30 minutes CPU time for each phase of the ISGP II process. FORMDEC's output summaries were designed in the same format as the Air Force standard EPOM Enlisted Force Analysis Model so that comparisons may be made between the "optimized" projected force and the current programmed force. The proposed number of promotions to make each year, the expected losses due to certain policies, or the reenlistment rate changes due to a particular combination of optimized goals may provide great insight to enlisted policy analysts. In fact, the discoveries of relationships and sensitivities between enlisted issues and parameters may comprise the most valuable "lessons learned" in this entire effort.

ISGP is an effective tool for decision makers since it provides the opportunity to interactively make trade offs between conflicting goals. The backbone ISGP process is fully programmed in a SAS code and can be applied to general multi-criteria decision scenarios by entering a corresponding linear problem. Once the current prototype model of the enlisted force is fully developed to more realistically represent the enlisted personnel force, then FORMDEC may be critiqued as it is applied to actual decisions and current personnel issues.
Future Efforts
The immediate need is for a more accurate representation of the enlisted force. Inspection of the output summaries show excess losses and subsequent gains generated by the policy variables (re-enlistment bonus, career job reservation and high year of tenure) within the same grade for different YOS.

Another problem is that the model allows more people to leave a cell (losses and promotions out) than there are people existing in the YOS cell. As this is corrected, checks will also be added to ensure that the number of promotees is always less than the number of eligibles.

One approach for modeling a more realistic YOS profile is to remove the constraint which requires the force to follow a fixed input continuation rate. FORMDEC could essentially choose loss and gain variables for each grade and YOS if additional constraints were set up to govern these relationships. It is likely however, that these additional YOS variables and constraints may vastly increase the size of the LP causing the solution time to lengthen by an unacceptable amount.

A novel modification to the ISGP II algorithm has been discovered and may greatly reduce FORMDEC's computational time. By following this new procedure the initial MAR value may be found after one single LP calculation. Due to the large size of the enlisted force matrix, each LP requires considerable time. The full impact of this discovery will be realized once the modification has been implemented into the SAS code.

The prototype FORMDEC has some policy switches built in by the programmer for the DM as he runs the code. More computer programming aids will be added so that new policy parameters and variables can be generated from the inner programming statements of the FORCE code in an easier fashion. A menu driven front end system either in SAS* software or an artificial intelligence language will allow a staff level DM with no programming background to run an updated user-friendly version of FORMDEC himself.

In conclusion, although the prototype FORMDEC is not ready to be used interactively by top level policy decision makers today, the potential is high that once the enlisted force representation is embellished this multi-criteria model may become a primary tool for the enlisted policy analyst of the future.

BIBLIOGRAPHY


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