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A NETWORK FLOW AND GOAL PROGRAMMING APPROACH TO MODELING THE IMPACT OF PRE-ACCESSION TRAINING TO THE TRAINED PERSONNEL REQUIREMENTS PROCESS

THESIS

William J. Beveridge, Captain, USAF

AFIT/GOR/ENS/91M-3

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

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A network modeling and goal programming approach was used. Comparisons between the current training policy and a pre-accession training policy were made. Sensitivity was conducted on the impact of a balk rate on the new policy. The balk rate is the percent of graduates of contract training who do not enter the Air Force.

This study has shown that a policy of pre-accession training could be cost effective. The balk rate and subsistence package impact the savings over the current policy. The number of active duty personnel retraining in skills under this policy could also reduce the savings. Recruiting goals would have to be raised under the new policy. The quality of contract training or "blueness" of training were not factored into this model.

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Preface

The purpose of this study was to develop a model to measure impact of pre-accession training on the Trained Personnel Required (TPR) and training production process. A project of this size could not have been completed without the help of many people. I extend sincerest gratitude and appreciation to my advisor, Dr Yupo Chan. His vast technical expertise, encouragement, and patience kept me on track throughout this project. I am also indebted to Col Tom Schuppe whose comments ensured that all the pertinent information I knew made it into the text.

I would also like to thank Maj Dave Roberts and Capt Mark Emerson, from HQ ATC, for providing data and answering numerous questions. Without their help this research would not have been possible. Thanks also go to my friends and classmates for never letting a day go by without a good laugh. They made the "AFIT experience" a worthwhile one.

Finally, I would like to thank my wife Sandi for her support and patience during the many long nights put into this research. She was the key factor in the successful completion of this project.

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Abstract

HQ ATC was tasked to analyze the impact of pre-accession training to the Trained Personnel Required (TPR) and training production process. Pre-accession training is a policy of providing contracted initial skills training to enlistees prior to entering basic military training. The purpose of this study was to develop a method to model the impact of pre-accession training.

A network modeling and goal programming approach was used. Comparisons between the current training policy and a pre-accession training policy were made. Sensitivity was conducted on the impact of a balk rate on the new policy. The balk rate is the per cent of graduates of contract training who do not enter the Air Force.

This study has shown that a policy of pre-accession training could be cost effective. The balk rate and subsistence package impact the savings over the current policy. The number of active duty personnel retraining in skills under this policy could also reduce the savings. Recruiting goals would have to be raised under the new policy. The quality of contract training or "blueness" of training were not factored into this model.

A NETWORK FLOW AND GOAL PROGRAMMING APPROACH TO MODELING THE IMPACT OF PRE-ACCESSION TRAINING TO THE TRAINED PERSONNEL REQUIREMENTS PROCESS

I. Introduction

Background

The mission of the Air Force is to organize, train, and equip air forces for the conduct of prompt and sustained combat operations in the air. The enlisted force plays a critical role in carrying out that mission. Air Training Command (ATC) is responsible for recruiting and training Air Force enlisted personnel. The Trained Personnel Requirements (TPR) process analyzes Air Force training needs for a three year period. The process looks at the current year, the budget year, and the first planning year. The TPR process, set at the Training Flow Management Conference, is conducted every April and October. HQ USAF/DPPP manages the TPR process. Management control of training production is an ATC concern. The TPR is the total number of trained personnel required in each enlisted Air Force Specialty Code (AFSC). Table 1, on the following page, shows the total TPR for fiscal years 90, 91, and 92.

TABLE 1

TPR TOTALS FOR ALL SKILLS (7)

FY	TOT TPR	TOT TECH	NPS	PS	RET	TOT OTH
90	44700	38863	32758	7	6098	5837
91	38336	34213	29187	0	5026	4123
92	36821	33127	29435	0	3692	3694

The total TPR is made up of the total number of enlisted personnel required to go to technical training (TOT TECH). This includes non-prior service (NPS), prior service (PS), and active duty retrainees (RET). Also included are others not required to go to formal technical training (TOT OTH). This group includes directed duty assignments, OJT retraining, and bypass personnel. This research is concerned with the TOT TECH category only.

ATC has found TPR changes dramatically before and during the fiscal year. Planning for training has become more difficult. The "text book" method is to build a plan based on the projected mission and requirements. A program is built based on the force structure needed for the plan. Dollars are then budgeted based on the program. However, the "school of hardknocks" tells us that dollars are appropriated without regard to the mission or requirements. A program is built to fit the dollars. Then an assessment of impact on the plan is made. The Air Force is now in an era of decreasing TPR. Budget pressures are forcing manning drawdowns and subsequent accession cuts (10). In addition, budget cutbacks are forcing base closures which include ATC operations at Chanute AFB and Mather AFB (7). In response to this, a small think tank called the Northern National Education Foundation designed a new system for training enlisted personnel called Technical Training, Pre-enlistment Opportunities (TECH/PrO). The proposal called for military technical training courses that have generic civilian equivalent courses to be contracted out. This proposal drove the Government Accounting Office (GAO) to study the feasibility of conducting military technical training at civilian institutions. The ATC commander directed a study group to analyze the impact of this proposal to the TPR and training production process (23).

Current System. Currently, an enlistee can spend up to twelve months in the Delayed Enlistment Program (DEP) before reporting to Basic Military Training (BMT). Upon completing the six week BMT course, an enlistee can be sent directly to an operational unit for on-the-job training or to a military technical training center for specialized training. Figure 1, on the following page, illustrates the current training policy.

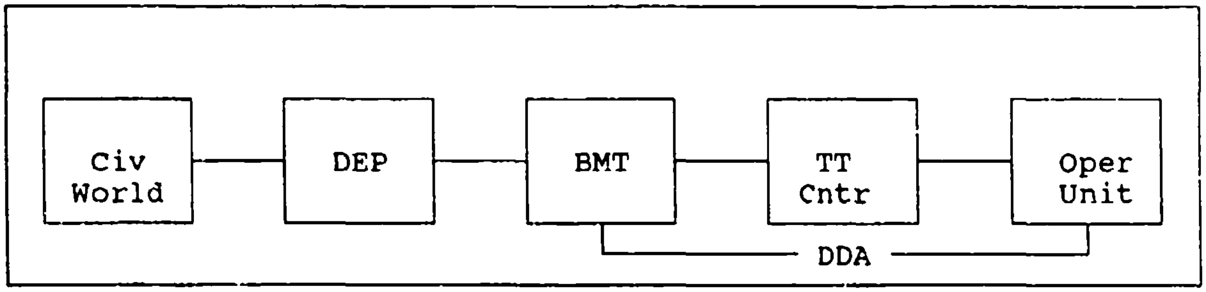


Figure 1. Current Training Policy

Table 2 illustrates the number of personnel processed through the system during the last three fiscal years.

TABLE 2

PERSONNEL PROCESSED THROUGH

CURRENT SYSTEM FY88-FY90 (10)

	FY88	FY89	FY90
DEP			
TOTAL POOL	77601	80175	60398
TOTAL LOSS	8346	7459	6865
%	10.8	9.3	11.4
BMT			
TOTAL ENLISTED	41200	43450	36000
TOTAL DISCHARGED	2620	3185	2642
%	6.4	7.3	7.3
TT			
TOTAL ENTERED	3[illegible]616	36153	**
TOTAL ELIMINATED	1695	1552	
%	4.8	4.3	

** Data not currently available

The cost for an individual to make it through the system is given in Table 3.

TABLE 3

ACQUISITION VARIABLE COST

PER RECRUIT IN FY90 DOLLARS (11)

Recruiting	$ 2,993
Travel	$ 382
Clothing	$ 703
BMT Cost	$ 3,066
Tech Training	$ 8,300
Total	$15,444

The cost of technical training is based on an average course length of 11.86 weeks. A $1,300/month cost is associated with pay and allowances, the approximate cost of tuition alone would be $4,700 per student (11; 21).

Proposed System. Pre-accession training is the initial skills technical training an enlistee would receive prior to BMT. The training would prepare an enlistee to perform a job at an operational unit. While in the DEP, an enlistee would receive specialized training from a contracted source before entering BMT. After BMT, the enlistee would be sent directly to an operational unit. Figure 2, on the following page, illustrates the proposed system.

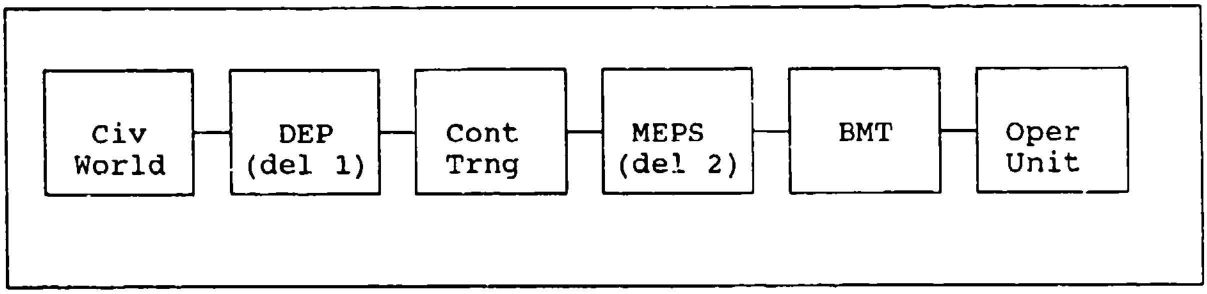


Figure 2. Pre-accession Training Policy

As in the current system, an enlistee can spend up to twelve months in DEP before attending a training course, upon completion of a course, the enlistee could be delayed an additional four weeks before reporting to a Military Entrance Processing Station (MEPS) and proceeding to BMT. ATC expects contract training to be 80% of the tuition cost of military training. In addition, active duty pay does not start until BMT. A student in contract training could be paid a subsistence allowance of up to $700 per month (22). This allowance would include a small stipend plus $300 per month for contract housing. This would be a considerable savings over the $1300 per month for pay and allowances currently associated with military technical training. Attrition rates for initial DEP, BMT, and technical training are expected to be the same as the current system. However, a problem exists during the second delay after completion of contracted technical training. An unknown balk rate exists during the additional delay. The balk rate is the percent of individuals who decide not to go to BMT after successfully completing technical training. The rate could be as low as five percent or even as high as fifty percent (although this is highly unlikely) (21).

Issues. In addition to the unknown balk rate, other concerns are raised about the impact of pre-accession training. The Guaranteed Training Enlistment Program (GTEP) is a program that guarantees an enlistee a specific type of training and AFSC upon entering the Air Force. Errors in production can increase as the lead time from AFSC classification to BMT and first assignment increases. The training demand process is adaptive. Training production can be lowered or raised as TPR is lowered or raised as long as the course start date can be met. The GTEP hinders management control of training production. Currently, few enlistees are in the GTEP. However, pre-accession training would force all enlistees to be in GTEP and could further aggravate the management control problem (10; 21). The impact of a pre-accession training policy to recruiting goals is also unknown. In addition, the quality of training and "blueness" of the training are unknown. The "blueness" factor is the development of military qualities, such as adherence to military standards, self discipline, and physical conditioning a student would receive at a military technical training center (21).

Problem Statement

HQ ATC has been tasked to identify critical factors and minimize costs associated with options for conducting USAF initial skills training. HQ ATC needs an effective model to simulate the uncertainty in the Training Personnel Requirements

(TPR) process. The objective of this research is to model the impact of pre-accession training on the TPR and training production processes. The model should compare the current training policy with a policy that includes pre-accession training. The model should have the flexibility to accommodate policy changes affecting the processes (21).

Sub-objectives. To accomplish the research, the following objectives must be met:

1. Determine specific output requirements needed by HQ ATC;

2. Identify which training courses should be modeled;

3. Determine the number of graduates produced for a fiscal year;

4. Identify surplus/shortage of personnel for a given course;

5. Determine cost of pre-accession training;

6. Determine the impact of rising balk rates on the model.

II. Literature Review

Review of Methodologies Applicable to Modeling Personnel Problems

There are various methodologies available for use in modeling personnel problems. Jameson found in her thesis research applicable methods fall into the following categories:

1. Simulation methods
   a. Entity flow simulations
   b. System dynamics simulations
2. Analytic methods
   a. Probabilistic models
   b. Linear programming models
   c. Network flow programming models (12:9).

Not all methods lend themselves readily to meeting the research goals of this project.

Specific output requirements for the project will be determined during interviews with knowledgeable individuals from HQ ATC/CSY. In addition, which training courses should be used for the model can also be identified during interviews with ATC personnel. Data is available on 32 enlisted specialty codes.

Charpie effectively used entity flow simulations in his study of B-52 radar navigators (6:13). However, entity flow approaches in the past have proved to be ineffective in evaluating the effects of policy changes (12:10-11).

According to two previous thesis efforts, the system dynamics approach has been used to evaluate the effects of policy changes on personnel problems in the past. System dynamics models use feedback loops to simulate real world interactions, thereby effectively testing the impact of policy changes. Jameson and Olson found that Clark and Lawson used a system dynamics simulation to model the impact of policy changes on a segment of Air Force enlisted personnel subject to a high number of overseas rotations (12:11-12; 18:16). The system dynamics approach could be used to determine the impact of policy changes on management control of the TPR process.

Probabilistic models, such as Markov models, alone would be inappropriate for this project. Zanakis and Maret stated that Markov models do not "consider costs, restrictions, and conflicting objectives that exist in a real world situation" (26:55). Markov techniques could be used with linear programming techniques to build a more realistic model.

Linear programming has been used on many occasions to model personnel problems. Goal programming is an extension of linear programming. Traditional linear programming optimizes a single objective. On the other hand, goal programming satisfies multiple objectives. Zanakis and Maret used goal programming to project the number of engineers needed by a chemical company. They also used goal programming to evaluate various management policies (26:61).

Network flow models are closely related to linear programming models. Network flow models can be solved more efficiently. Personnel problems can be solved readily by network flow models.

The combination of goal programming and network flow programming can be used to identify the surplus/shortage of trained personnel, determine the cost of pre-accession training, and determine the average time of an enlistee in the DEP.

The initial search for methodologies to model the impact of pre-accession training on the TPR process revealed numerous options. The following paragraphs will look at literature applicable to this research proposal. A discussion of analytical methods will be addressed. The specific topics of uncertainty, goal programming approaches, and network flow approaches will be covered.

Uncertainty. Uncertainty is a lack of confidence in something. Uncertainty often interferes with decision-making. Battilega and Grange state "virtually every problem related to military analysis carries with it some element of uncertainty and randomness" (2:28). The management of training production under a pre-accession training option is no exception to the rule.

Uncertainty can be dealt with directly or indirectly. Statistical methods are used to directly deal with uncertainty. Random events which occur in a problem are explicitly represented in statistical methods. On the other hand, indirect treatment of uncertainty is handled by probabilistic methods. In probabilistic methods, random events are less explicitly represented. Usually, the mean or average value of a random variable is used to model the problem. Probabilistic methods are generally considered easier to do and understand than statistical methods (2:28-31).

Dixon examined the problem of representing uncertainty in models in his comparative analysis of three models developed for acid-rain assessment. He states that uncertainty "may be due to unpredictable human factors, imprecision of measuring instruments, poor records of past experience, lack of understanding of certain processes, or many other reasons" (9:29). Sometimes uncertainty is small and has little effect on the outcome of analysis of a problem. Other times, uncertainty is so extreme the question of how to model problems of this nature is relevant.

The strengths and weaknesses of the methods of representing uncertainty in the models were addressed by Dixon. The scope of the uncertainty representation, source of model inputs, and techniques for combining probabilities were discussed. Uncertainty about interrelationships and uncertainty about variable values were the two representation types used in the models. Dixon considered the representation of uncertainty about variable values to be a weakness of all three models.

Model inputs were of the subjective view or objective view of probability. The subjective approach allows the analyst to input the probabilities on model variables. The objective approach lets the analyst predetermine the probabilistic representation of inputs. The strength of the subjective approach is the ability to experiment and investigate the consequences of a range of possible inputs. However, the problem of how, and from where, the most reliable inputs might be obtained arises. The objective approach relieves the analyst of this burden but does not allow for experimentation.

The combining of probabilities was done using either Monte Carlo simulation or a decision-tree. Monte Carlo simulation is a method that uses random sampling techniques to get approximate solutions to a problem. A range of values, each with a probability of being the correct solution, is given. A decision-tree is a method of counting each of the possible decisions that can be made and each of the possible outcomes that can occur based on those decisions. The strength of Monte Carlo simulation is the ability to combine numerous probability distributions within realistic time constraints. The complexity of calculations increases linearly with the number of variables in Monte Carlo simulations. The complexity of calculations increases exponentially with the number of variables in decision-tree models. One weakness of Monte Carlo simulation is the occurrence of significant variance between results of successive runs of the model. Another weakness is the "large increase in complexity of calculations required to reflect dependencies between input distributions" (9:35-37).

The following questions about developing models in situations of uncertainty were raised by Dixon:

1. How should the model be structured, what elements of the problem are important enough for inclusion, and how are the interrelationships defined?

2. Is the danger of modeling under uncertainty twofold: that of producing results which, if verifiable, would prove highly inaccurate, and that of undue reliability attributed to misleading results, since the analytic approach inspires confidence?

3. Does model accuracy increase with greater inclusion of detail?

4. Is there an optimal minimizing balance between model unreliability caused by oversimplification and unreliability caused by the inclusion of detail despite uncertainty about its role?

5. Where is uncertainty to be represented explicitly, and how should this be done?

6. Which problem elements are represented as uncertain, what form should the elements be, and how should these uncertainties be combined (9:38)?

Lindley claims that "probability is the only sensible description of uncertainty" (16:1). Kohlas presents a new approach for the representation and analysis of uncertainty. Uncertainty is described by belief functions instead of probability distributions. A belief function is the summation of the probabilities that an unknown variable X takes a value in some arbitrary interval [r,s]. The interval is set by one or more oracles (e.g. an expert, a forecasting procedure, sources of evidence, etc.). The probability that X takes a value in the interval is then assigned. A Monte Carlo method is then applied for the computation of belief (14:378-381).

Kohlas compared two techniques currently used to cope with uncertainty with the belief function approach. In the first technique, a few possible and reasonable values for each uncertain input variable are selected and evaluated. A drawback to this approach is the number of combinations grow very fast. It is practically impossible to evaluate all possible combinations. Therefore, the analyst must choose small numbers of possible value combinations and limit the model evaluation to them. This introduces certain arbitrariness into the analysis. A second technique is modeling uncertain input variables as random variables with some given probability distributions. This technique avoids the problems described in the first technique. However, the problem of how to express the available knowledge about the possible and probable values of these input variables arises. The main problem is modeling this knowledge correctly and consistently. The model must incorporate highly subjective judgements (14:378).

The use of belief functions provides better incorporation of subjective judgments concerning input variables and the relationship between variables. It allows for the combination of evidence from different sources, the modeling of partial knowledge, and the inclusion of contradicting evidence. The new approach "allows a much more realistic and flexible description of knowledge, opinions, judgments and evidence" (14:377).

Goal Programming Techniques. Goal programming (GP) is a linear programming technique for optimizing a problem with multiple objectives. Goal programming techniques have been used to solve numerous manpower problems. Figure 3 illustrates a generic GP formulation.

$$\text{Min } \Sigma_{i=1}^{m} (d_i^- + d_i^+)$$

$$\text{s.t. } Ax + Id^- - Id^+ = b$$

$$Bx \leq h$$

$$x,\ d^-,\ d^+ \geq 0$$

where d_i^- and d_i^+ represent the negative and positive deviations from m goals

b is a column vector for m goals

x represents the number of personnel

$Bx \leq h$ are additional constraints placed on the model

Figure 3. Generic GP Formulation (15:39-41)

Goal programming models have been developed to deal with the multiple objectives driving personnel planning. The objective function used in goal programming models "weights the importance of various constraints and sub-objectives according to priorities expressed by one or several decision-makers" (17:187). Martel and Price have found results of goal programming models to be good, despite the lack of theoretical justification for the way objective function weights are obtained.

Goal programming is appropriate in manpower planning cases where information on manpower supply, budget, demand, etc., is fixed. For manpower planning problems under uncertainty, Martel and Price suggest using a dynamic stochastic programming approach. This approach was used to solve a manpower planning problem for officers of the Canadian Armed Forces (17:193).

Sengupta also addressed goal programming under uncertainty. A typical goal programming model could be:

$$\min \Sigma_{k=1}^{K} (d_k^+ + d_k^-)$$

$$\text{s.t. } \Sigma_{j=1}^{n} c_{kj}\, x_j - (d_k^+ - d_k^-) = g_k;\ k=1,2,\ldots,K$$

$$\Sigma_{j=1}^{n} a_{ij}\, x_j \le b_i,\ i=1,\ldots,m$$

$$d_k^+,\ d_k^-,\ x_j \ge 0,\quad j=1,\ldots,n$$

where g_k represents k TPR goals, and d_k^+ and d_k^- represent positive and negative deviations from the goals.

He found "stochastic goal programming may also be formulated when the deviations can be probabilistically interpreted" (24:50). Let $g_k = \Sigma_{j=1}^{n} c_{jk}x_j + e_k$, where e_k is the error which is known to be normally distributed with mean zero and variance unity for each k (e.g. TPR goals that fluctuate up and down). Then the objective function becomes:

$$\min E[\Sigma_{k=1}^{K} d_k]$$

Zanakis and Maret used another variation by combining Markov processes with goal programming. Markov processes have been used since the early sixties to model manpower planning problems. Markov processes enable the analyst to predict the number of personnel gains and losses in future years based on a given policy for hiring, promotion, dismissal, etc.. However, Markov processes cannot consider costs, restrictions, and conflicting objectives that exist in real world situations. Therefore, Markov processes were combined with goal programming to solve planning problems under various restrictions and conflicting objectives. This approach provides versatility in handling multiple conflicting goals common in real world planning (26:55-56).

Aronson and Thompson applied the forward simplex method to multiperiod personnel planning goal programming models. The forward simplex method is "an adaption of the ordinary simplex method used for solving general multiperiod linear programs" (1:129). The general step in the method is to find the solution to the T period problem by augmenting the solution to the T-1 period problem. Aronson and Thompson applied the method to a goal programming personnel planning model dealing with recruiting requirements for a large naval laboratory. The method proved to be more efficient than conventional LP methods (1:130-132).

Network Flow Programming Techniques. Network flow techniques follow many of the general rules found in goal programming techniques. However, network flow techniques are usually more efficient. A network is a collection of nodes which are connected by arcs. It is easy to visualize a manpower system as a network. The nodes of the network represent the states of the manpower system at some time T. The arcs represent hires, promotions, and staying in the same state (19:1233-1234).

Price used network flow techniques to solve manpower problems that are often modeled using goal programming techniques. He modeled a military manpower system consisting of 28 classifications, four ranks in each classification, and three "general service" ranks. When modeled using goal programming, over 600 constraints and over 1250 variables were needed. The same model using network flow programming had fewer than 400 nodes and fewer than 1200 arcs (19:1239). Solving manpower problems with network flow techniques proved to be more efficient than solving the same problem with goal programming techniques.

Price and Gravel provide a method for solving network problems with side constraints. Side constraints are those constraints that are not inherently modeled within the network. Constraints that might be modeled within the network are upper and lower bounds on arc flow. Standard network constraints such as conservation of flow (e.g. flow into a network equals flow out of a network) would also be modeled within the network. On the other hand, side constraints could include the effects of attrition on the network and/or the impact of budgetary limits on the network (20:198-202).

Charpie used network flow programming in analyzing personnel shortages in the B-52 radar navigator career field. He examined changes occurring in the crew force. This included reductions of B-52 crew force to man the B1-B, reductions in staff positions, changes in the policy of allowing crew members to go to career broadening positions, and decreases in retention rates. A cross-sectional network model was used. The model traces the netflow throughout the network without regard to time spent in a given state. However, this model could not be applied to a system in which the length of time spent in a state affects the outcome. In addition, the model is not an optimization technique (6:13-26).

Summary

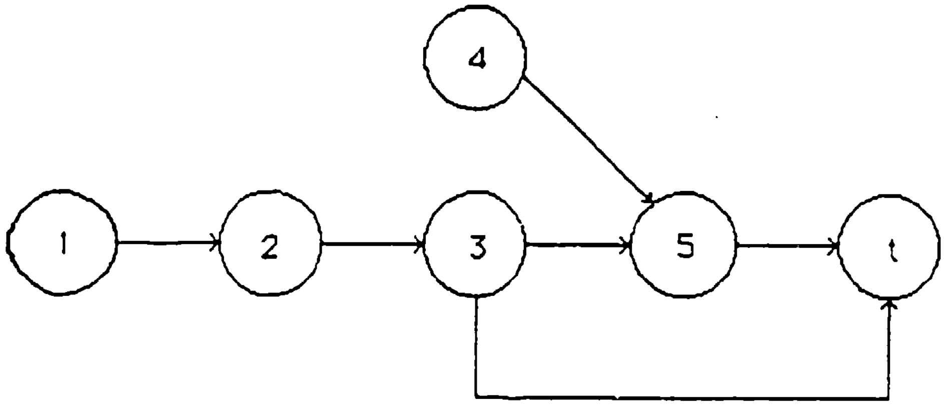
The literature review provided a discussion of topics pertinent to the problem of modeling the impact of pre-accession training on the TPR and training production process. Coping with the effects of uncertainty will be an underlying concern throughout the research effort. Goal programming techniques, when combined with other techniques, can be a successful part of the overall approach to meeting the research objectives. Network flow techniques that incorporate some aspects of goal programming will also be an effective tool in solving the research problem.

III. Methodology

General Approach

The purpose of this chapter is to discuss the methodology selected to model the impact of pre-accession training on the TPR and training production processes. Since TPR goals are established in advance, goal programming (GP) would appear to be an appropriate solution technique. GP adds flexibility and realism to the model. GP can be used to look at deviations in the required number of personnel trained and the actual number trained. However, GP alone cannot deal with the costs associated with the change in training policy.

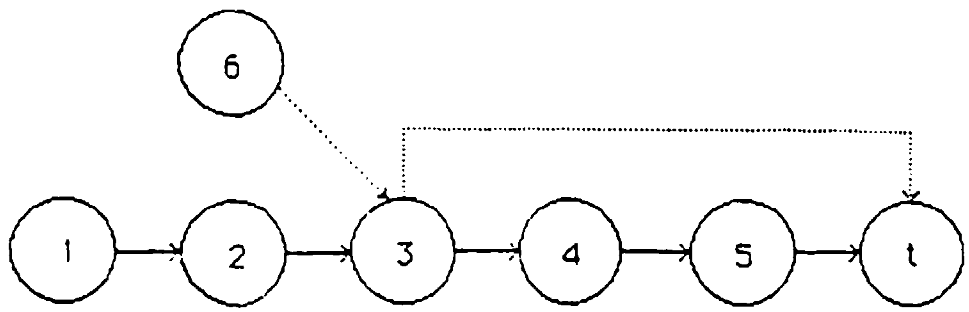
Multicommodity Network Flow. The flow of personnel through the training process can be modeled using network flow programming. A general network model consists of nodes which are connected by arcs. The nodes of the network represent the state of an enlistee at any given point in time. Example states could include: Delayed Enlistment Program (DEP); Basic Military Training (BMT); or Technical Training (TT). Flow along the arcs represents the movement of an enlistee through the network. The flow between the nodes represents an assignment path which connects the nodes. Figure 4, on the following page, illustrates the network representation of the current training policy.



Node	Description
1	NPS Recruit Pool
2	DEP
3	BMT
4	RET Pool
5	Military Technical Training
t	Operational Unit

Figure 4. Network Representation of Current Training Policy

The arc connecting node 3 to node t represents the 2.6% of enlistees that bypass technical training and go directly to an operational unit. Figure 5, on the following page, illustrates a network representation of a pre-accession training policy.



Node	Description
1	NPS Recruit Pool
2	DEP
3	Contract Technical Training
4	MEPS
5	BMT
6	RET Pool
t	Operational Unit

Figure 5. Network Representation of Pre-accession Training Policy

The dotted line connecting node 3 to node t represents the fact that active duty retrainees go directly back to an operational unit after completing contract technical training.

Multicommodity network flow techniques are used when it is necessary to distinguish among the units that flow in the network (3:587). Figure 6, on the following page, illustrates a multicommodity minimal cost flow (MMCF) formulation.

$$\min \Sigma_{k,m} c_m^k x_m^k$$

$$\text{s.t.} \quad \Sigma_{em\epsilon An} x_m^k - \Sigma_{em\epsilon Bn} x_m^k = \begin{cases} S_k, & \text{if } n=s_k \\ -S_k, & \text{if } n=t_k \\ 0, & \text{otherwise} \end{cases}$$

$$\Sigma_k x_m^k \le b_m, \text{ all } m$$

$$0 \le x_m^k \le u_m^k, \text{ all } m,k$$

where k = commodities

m = arcs

c_m^k = the unit cost of commodity k in arc m

x_m^k = the flow of commodity k in arc m

b_m = capacity of arc m

u_m^k = upper bound on commodity k in arc m

$e_m \epsilon A_n$ represents arcs originating at node n

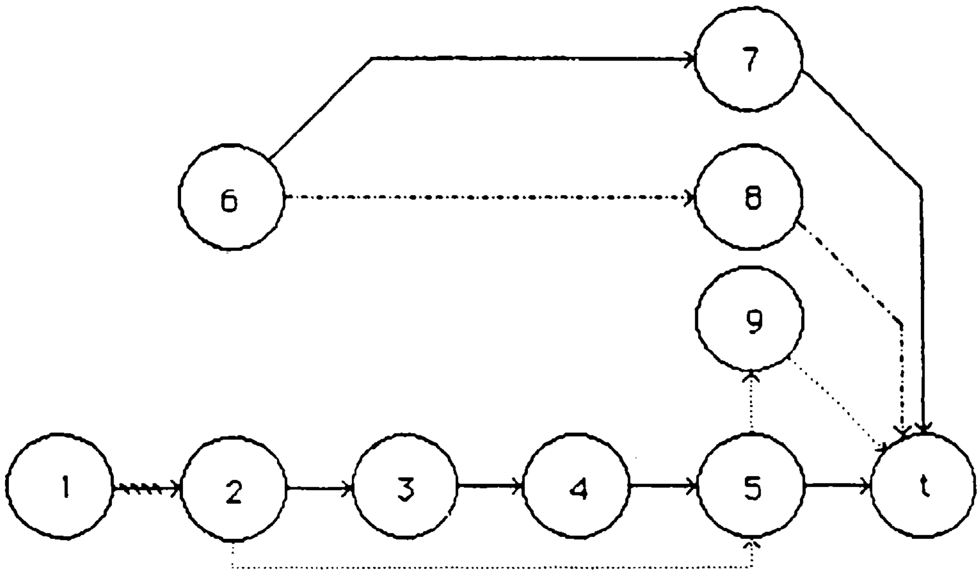
$e_m \epsilon B_n$ represents arcs terminating at node n

s_k = source

t_k = sink

Figure 6. Multicommodity Minimal Cost Flow (13:209-210)

An MMCF network, combined with GP techniques was used to solve the problem in this thesis. Figure 7, on the following page, illustrates the network modeled for this research.



Node	Description
1	NPS Recruit Pool
2	DEP
3	Contract Technical Training (NPS)
4	MEPS
5	BMT
6	RET Pool
7	Contract Technical Training (RET)
8	Military Technical Training (RET)
9	Military Technical Training (NPS)
t	Operational Unit

Path Key

______	Pre-accession Training Policy
....	Current Training Policy (NPS)
_._._._	Current Training Policy (RET)
—\\—\\—\\—	Common to both Policies

Figure 7. Network Representation of Combined Training Policy

Model Structure

The approach used to formulate the model included the following:

1. Identify the decision variables;

2. Identify the constraint set;

3. Identify the data necessary to quantify the constraints;

4. Formulate the constraint set;

5. Formulate the objective functions.

Decision Variable Identification. Identification of the decision variables for this problem is straight forward. Thirty-two courses representing thirty-two Air Force Specialty Codes (AFSCs) were available for use in this study. The number of trainees in each of these AFSCs represent the decision variables. Appendix A is a list of the AFSCs and corresponding fiscal year 1991 TPR goals.

Constraint Set Identification. Constraints pertaining to the problem of conducting training were placed in several categories. Constraints that influence how many enlistees will be trained in each AFSC for each fiscal year fall under the categories of TPR goal constraints, attrition constraints, and accession constraints. The TPR for each AFSC, attrition rates, and course length can influence the cost of production. In addition, zero-one switch constraints were used in the model.

Data Identification. The following input data has been provided by ATC:

1. Course identification numbers by AFSC;

2. Course length;

3. Variable costs of each course;

4. Course attrition rates;

5. DEP attrition rates;

6. BMT attrition rates;

7. TPR values.

Constraint Set Formulation. Decision variables will be represented generically by

$$x_{ij}$$

where: i = originating node

j = terminating node

x = number of personnel in the network

$$x_{ij} \geq 0.$$

Table 4, on the following page, is presented to provide references for indices, technological coefficients, and constants used.

TABLE 4

INDICES, TECHNOLOGICAL COEFFICIENTS,

AND CONSTANTS SYMBOLOGY

INDEX	DEFINITION
s	source
t	sink
i	originating node
j	terminating node
k	commodity
m	arc
TECHNOLOGICAL COEFFICIENTS	
c	training cost
s	pay and allowances/subsistence
cl	class size
a_{ij}	attrition rates
br	balk rate
CONSTANTS	
TPR_k	trained personnel required for $AFSC_k$
ACC_k	accessions per $AFSC_k$

TPR Goal Constraints. The TPR goal constraints represent the total formal technical training production requirements for non-prior service (NPS) enlistees and active duty retrainees (RET). The following generic formulations represent the constraint:

$$\Sigma_i x^k_{it} = TPR_k$$

$$\Sigma_i x^k_{it} + d^-_k - d^+_k = TPR_k$$

$$\Sigma_i x^k_{it} \leq TPR_k(NPS)$$

$$\Sigma_i x^k_{it} \leq TPR_k(RET)$$

where, d^-_k = the negative deviation from TPR_k

d^+_k = the positive deviation from TPR_k

Attrition Constraints. Attrition constraints include DEP losses, BMT discharges, and technical training (TT) eliminations. Also included is the balk rate associated with the second delay in the pre-accession training policy. A generic formulation of an attrition constraint would be:

$$\Sigma_i x^k_{ij} - \Sigma_i (1-a_{ij}) x^k_{i-1\ i} = 0$$

Several assumptions were used in the attrition constraints. DEP, BMT, and TT attrition rates for a policy of pre-accession training are comparable to the current system. Balk rates were to be tested, at five percent increments, from ten to fifty percent.

Accession Constraints. Accession constraints represent the restriction on the number of NPS enlistees entering BMT. The generic formulation would be:

$$\Sigma_i x^k_{ij} \leq ACC_k$$

Switch Constraints. Zero-one variables were used as switches to select the most efficient path to take through the network. The variable y_{ij} was set to zero if the arc between two nodes was not taken or set to one if the arc was chosen. A detailed explanation of the use of switches is given in the next chapter.

Objective Function Formulation. The following objective function was formulated for the network model:

$$\min \Sigma\ c^k_m x^k_m$$

where c^k_m = training cost of traveling along arc m

x^k_m = the flow of personnel in arc m for the GP model the following formulation was used:

$$\min \Sigma (d^-_k + d^+_k)$$

where d^-_k = the negative deviation of training $AFSC_k$

d^+_k = the positive deviation of training $AFSC_k$

Output Requirements. A set of comparisons between pre-accession training and the status quo will be made. Comparisons between the network model and the GP model will be made. The number of trained personnel and surplus/shortages will be identified. The costs associated with training under varying balk rates and subsistence options will be provided.

Summary

This chapter presented a general model for representing the impact of pre-accession training on the TPR and training production processes. A brief discussion of input and output requirements was given. The next chapter presents a illustrative example and analysis of the problem.

IV. Illustrative Example and Analysis

Illustrative Example

This chapter presents the results of an illustrative example of the network model and goal programming model discussed in the previous chapter. The objective is to determine how increasing balk rates affect the cost of training and the ability to meet TPR goals under a policy of pre-accession training. The examples were processed on the linear optimization package QSB (5). As stated in the last chapter, the approach used to formulate the example was: 1) identify decision variables; 2) identify the constraint set; 3) identify the data necessary to quantify the constraints; 4) formulate the constraint set; and 5) formulate the objective functions.

Decision Variable Identification. The following AFSCs are represented: 1) 23131, Graphics Specialist; 2) 45234A, Apprentice Tactical Aircraft Maintenance Specialist; 3) 45430A, Apprentice Aerospace Maintenance Specialist; 4) 45730A, Apprentice Strategic Aircraft Maintenance Specialist; 5) 49131, Apprentice Communications-Computer System Specialist; 6) 54531, Apprentice Liquid Fuels System Specialist; 7) 67231, Financial Management Specialist; 8) 90430, Cardiopulmonary Lab Specialist; 9) 91330, Apprentice Physical Therapist; and 10) 98130, Dental Assistant Specialist.

Constraint Set Identification. The following set of constraints will be used: 1) TPR goal constraints; 2) attrition constraints; 3) accession constraints; and 4) switch constraints.

Data Identification. Table 5 contains the AFSC TPR goal and course attrition data used for the example.

TABLE 5

TPR AND ATTRITION DATA FOR ILLUSTRATIVE EXAMPLE

AFSC	Attrition Rate (%)	FY91 TPR GOALS NPS	RET	TOT
23131	3.4	8	0	8
45234A	3.8	554	0	554
45430A	1.4	750	0	750
45730A	10.0	75	0	75
49131	1.9	434	125	559
54531	1.1	40	0	40
67231	0.8	82	7	89
90430	9.4	41	20	61
91330	6.7	22	30	52
98130	3.8	239	90	329

Cost data for each AFSC was based on a tuition rate of $4,700 per month plus $1,300 pay and allowances per month for the current training policy. For a policy of pre-accession training, tuition was 80% of the current tuition, a cost of $3,750 per month. In addition, a stipend and housing allowance can be provided. The example was run using a $300 per month housing allowance with a $150 per month stipend and also with a $300 per month stipend. Retrainees would continue to receive $1,300 per month pay and allowances under a pre-accession policy. Table 6, on the following page, presents cost data for military training (MT), contract training for non-prior service (CT(NPS)), and contract training for retrainees (CT(RET)) used in the example. All costs include pay/stipend/housing allowances.

TABLE 6

COST DATA FOR ILLUSTRATIVE EXAMPLE

AFSC	Course Length (wks)	MT	$150 Stipend CT(NPS)	$300 Stipend CT(NPS)	CT(RET)
23131	11.4	8150	4950	5340	7200
45234	8.0	7120	4585	4865	6170
45430	9.6	7600	4750	5090	6650
45730	8.0	7120	4580	4865	6170
49131	7.6	7000	4550	4810	6050
54531	7.6	7000	4550	4810	6050
67231	9.8	7650	4775	4775	6700
90430	11.4	8150	4950	5340	7200
91330	9.6	7600	4750	5090	6650
98130	9.6	7600	4750	5090	6650

Additional data for recruiting, travel, and BMT costs identified in Chapter I were also used.

Constraint Formulations. Decision variables for constraint formulation will be represented by

$$x^k_{ij},$$

where i = originating node
j = terminating node
$x_{ij} \geq 0$

k: a = 23131
b = 45234A
c = 45430A
d = 45730A
e = 49131
f = 54531
g = 67231
h = 90430
i = 91330
j = 98130

and

$$y_{ij},$$

where i = originating node

j = terminating node
$y_{ij} = 0,1$

<u>TPR Goal Constraints</u>. The following TPR goal constraint equations were used in the network models.

$$
\begin{aligned}
x^{a}_{5t} + x^{a}_{7t} + x^{a}_{8t} + x^{a}_{9t} &= 8 \\
x^{b}_{5t} + x^{b}_{7t} + x^{b}_{8t} + x^{b}_{9t} &= 554 \\
x^{c}_{5t} + x^{c}_{7t} + x^{c}_{8t} + x^{c}_{9t} &= 750 \\
x^{d}_{5t} + x^{d}_{7t} + x^{d}_{8t} + x^{d}_{9t} &= 75 \\
x^{e}_{5t} + x^{e}_{7t} + x^{e}_{8t} + x^{e}_{9t} &= 559 \\
x^{f}_{5t} + x^{f}_{7t} + x^{f}_{8t} + x^{f}_{9t} &= 40 \\
x^{g}_{5t} + x^{g}_{7t} + x^{g}_{8t} + x^{g}_{9t} &= 89 \\
x^{h}_{5t} + x^{h}_{7t} + x^{h}_{8t} + x^{h}_{9t} &= 61 \\
x^{i}_{5t} + x^{i}_{7t} + x^{i}_{8t} + x^{i}_{9t} &= 52 \\
x^{j}_{5t} + x^{j}_{7t} + x^{j}_{8t} + x^{j}_{9t} &= 329
\end{aligned}
$$

In addition, TPR upper bounds for the network model were required.

$x^{a}_{5t} - 8y_{5t} \leq 0$	(NPS upperbound, CT)
$x^{a}_{9t} - 8y_{9t} \leq 0$	(NPS upperbound, MT)
$x^{a}_{7t} \leq 0$	(RET upperbound, CT)
$x^{a}_{8t} \leq 0$	(RET upperbound, MT)
$x^{b}_{5t} - 554y_{5t} \leq 0$	(NPS upperbound, CT)
$x^{b}_{9t} - 554y_{9t} \leq 0$	(NPS upperbound, MT)
$x^{b}_{7t} \leq 0$	(RET upperbound, CT)
$x^{b}_{8t} \leq 0$	(RET upperbound, MT)
$x^{c}_{5t} - 750y_{5t} \leq 0$	(NPS upperbound, CT)
$x^{c}_{9t} - 750y_{9t} \leq 0$	(NPS upperbound, MT)
$x^{c}_{7t} \leq 0$	(RET upperbound, CT)
$x^{c}_{8t} \leq 0$	(RET upperbound, MT)
$x^{d}_{5t} - 75y_{5t} \leq 0$	(NPS upperbound, CT)
$x^{d}_{9t} - 75y_{9t} \leq 0$	(NPS upperbound, MT)
$x^{d}_{7t} \leq 0$	(RET upperbound, CT)
$x^{d}_{8t} \leq 0$	(RET upperbound, MT)
$x^{e}_{5t} - 434y_{5t} \leq 0$	(NPS upperbound, CT)
$x^{e}_{9t} - 434y_{9t} \leq 0$	(NPS upperbound, MT)
$x^{e}_{7t} - 125y_{9t} \leq 0$	(RET upperbound, CT)
$x^{e}_{8t} - 125y_{7t} \leq 0$	(RET upperbound, MT)
$x^{f}_{5t} - 40y_{5t} \leq 0$	(NPS upperbound, CT)
$x^{f}_{9t} - 40y_{9t} \leq 0$	(NPS upperbound, MT)
$x^{f}_{7t} \leq 0$	(RET upperbound, CT)
$x^{f}_{8t} \leq 0$	(RET upperbound, MT)

$$x^{g}_{5t} - 82y_{5t} \le 0 \quad \text{(NPS upperbound, CT)}$$
$$x^{g}_{9t} - 82y_{9t} \le 0 \quad \text{(NPS upperbound, MT)}$$
$$x^{g}_{7t} - 7y_{9t} \le 0 \quad \text{(RET upperbound, CT)}$$
$$x^{g}_{8t} - 7y_{7t} \le 0 \quad \text{(RET upperbound, MT)}$$

$$x^{h}_{5t} - 41y_{5t} \le 0 \quad \text{(NPS upperbound, CT)}$$
$$x^{h}_{9t} - 41y_{9t} \le 0 \quad \text{(NPS upperbound, MT)}$$
$$x^{h}_{7t} - 20y_{9t} \le 0 \quad \text{(RET upperbound, CT)}$$
$$x^{h}_{8t} - 20y_{7t} \le 0 \quad \text{(RET upperbound, MT)}$$

$$x^{i}_{5t} - 22y_{5t} \le 0 \quad \text{(NPS upperbound, CT)}$$
$$x^{i}_{9t} - 22y_{9t} \le 0 \quad \text{(NPS upperbound, MT)}$$
$$x^{i}_{7t} - 30y_{9t} \le 0 \quad \text{(RET upperbound, CT)}$$
$$x^{i}_{8t} - 30y_{7t} \le 0 \quad \text{(RET upperbound, MT)}$$

$$x^{j}_{5t} - 239y_{5t} \le 0 \quad \text{(NPS upperbound, CT)}$$
$$x^{j}_{9t} - 239y_{9t} \le 0 \quad \text{(NPS upperbound, MT)}$$
$$x^{j}_{7t} - 90y_{9t} \le 0 \quad \text{(RET upperbound, CT)}$$
$$x^{j}_{8t} - 90y_{7t} \le 0 \quad \text{(RET upperbound, MT)}$$

These constraints also helped drive the zero-one integer variables.

The TPR goal constraints for the G.P. model appear as follows:

$$x^{a}_{5t} + x^{a}_{7t} + x^{a}_{8t} + x^{a}_{9t} + d^{-}_{1} - d^{+}_{1} = 8$$
$$x^{b}_{5t} + x^{b}_{7t} + x^{b}_{8t} + x^{b}_{9t} + d^{-}_{2} - d^{+}_{2} = 554$$
$$x^{c}_{5t} + x^{c}_{7t} + x^{c}_{8t} + x^{c}_{9t} + d^{-}_{3} - d^{+}_{3} = 750$$
$$x^{d}_{5t} + x^{d}_{7t} + x^{d}_{8t} + x^{d}_{9t} + d^{-}_{4} - d^{+}_{4} = 75$$
$$x^{e}_{5t} + x^{e}_{7t} + x^{e}_{8t} + x^{e}_{9t} + d^{-}_{5} - d^{+}_{5} = 559$$
$$x^{f}_{5t} + x^{f}_{7t} + x^{f}_{8t} + x^{f}_{9t} + d^{-}_{6} - d^{+}_{6} = 40$$
$$x^{g}_{5t} + x^{g}_{7t} + x^{g}_{8t} + x^{g}_{9t} + d^{-}_{7} - d^{+}_{7} = 89$$
$$x^{h}_{5t} + x^{h}_{7t} + x^{h}_{8t} + x^{h}_{9t} + d^{-}_{8} - d^{+}_{8} = 61$$
$$x^{i}_{5t} + x^{i}_{7t} + x^{i}_{8t} + x^{i}_{9t} + d^{-}_{9} - d^{+}_{9} = 52$$
$$x^{j}_{5t} + x^{j}_{7t} + x^{j}_{8t} + x^{j}_{9t} + d^{-}_{10} - d^{+}_{10} = 329$$

Upper bound constraints for the goal pr[illegible]amming model are:

$$x^{a}_{5t} \le 8$$
$$x^{a}_{9t} \le 8$$
$$x^{a}_{7t} \le 0$$
$$x^{a}_{8t} \le 0$$

$$x^{b}_{5t} \le 554$$
$$x^{b}_{9t} \le 554$$
$$x^{b}_{7t} \le 0$$
$$x^{b}_{8t} \le 0$$

$$x^c_{5t} \leq 750$$
$$x^c_{9t} \leq 750$$
$$x^c_{7t} \leq 0$$
$$x^c_{8t} \leq 0$$

$$x^d_{5t} \leq 75$$
$$x^d_{9t} \leq 75$$
$$x^d_{7t} \leq 0$$
$$x^d_{8t} \leq 0$$

$$x^e_{5t} \leq 434$$
$$x^e_{9t} \leq 434$$
$$x^e_{7t} \leq 125$$
$$x^e_{8t} \leq 125$$

$$x^f_{5t} \leq 40$$
$$x^f_{9t} \leq 40$$
$$x^f_{7t} \leq 0$$
$$x^f_{8t} \leq 0$$

$$x^g_{5t} \leq 82$$
$$x^g_{9t} \leq 82$$
$$x^g_{7t} \leq 7$$
$$x^g_{8t} \leq 7$$

$$x^h_{5t} \leq 41$$
$$x^h_{9t} \leq 41$$
$$x^h_{7t} \leq 20$$
$$x^h_{8t} \leq 20$$

$$x^i_{5t} \leq 22$$
$$x^i_{9t} \leq 22$$
$$x^i_{7t} \leq 30$$
$$x^i_{8t} \leq 30$$

$$x^j_{5t} \leq 239$$
$$x^j_{9t} \leq 239$$
$$x^j_{7t} \leq 90$$
$$x^j_{8t} \leq 90$$

Attrition Constraints. Constraints dealing with attrition rates include DEP attrition, BMT attrition, course attrition, and the balk rate. The following set of constraints apply:

DEP Attrition:

$$-.9x_{12} + x^a_{23} + x^a_{25} + x^b_{23} + x^b_{25} + \ldots = 0 \text{ (network model)}$$
$$-.9x_{12} + x^a_{23} + x^b_{23} + \ldots + x^j_{23} + \ldots = 0 \text{ (GP model)}$$

BMT Attrition (applies to both models):

$-.93x^{a}_{45} + x^{a}_{5t} = 0$
$-.93x^{b}_{45} + x^{b}_{5t} = 0$

.
.
.

$-.93x^{j}_{45} + x^{j}_{5t} = 0$

Course Attrition (both models):

$-.966x^{a}_{23} + x^{a}_{34} = 0$ (NPS contract training)
$-.966x^{a}_{67} + x^{a}_{7t} = 0$ (RET contract training)
$-.966x^{a}_{59} + x^{a}_{9t} = 0$ (NPS military training)
$-.966x^{a}_{68} + x^{a}_{8t} = 0$ (RET military training)

$-.962x^{b}_{23} + x^{b}_{34} = 0$ (NPS contract training)
$-.962x^{b}_{67} + x^{b}_{7t} = 0$ (RET contract training)
$-.962x^{b}_{59} + x^{b}_{9t} = 0$ (NPS military training)
$-.962x^{b}_{68} + x^{b}_{8t} = 0$ (RET military training)

$-.986x^{c}_{23} + x^{c}_{34} = 0$ (NPS contract training)
$-.986x^{c}_{67} + x^{c}_{7t} = 0$ (RET contract training)
$-.986x^{c}_{59} + x^{c}_{9t} = 0$ (NPS military training)
$-.986x^{c}_{68} + x^{c}_{8t} = 0$ (RET military training)

$-.9 \quad x^{d}_{23} + x^{d}_{34} = 0$ (NPS contract training)
$-.9 \quad x^{d}_{67} + x^{d}_{7t} = 0$ (RET contract training)
$-.9 \quad x^{d}_{59} + x^{d}_{9t} = 0$ (NPS military training)
$-.9 \quad x^{d}_{68} + x^{d}_{8t} = 0$ (RET military training)

$-.981x^{e}_{23} + x^{e}_{34} = 0$ (NPS contract training)
$-.981x^{e}_{67} + x^{e}_{7t} = 0$ (RET contract training)
$-.981x^{e}_{59} + x^{e}_{9t} = 0$ (NPS military training)
$-.981x^{e}_{68} + x^{e}_{8t} = 0$ (RET military training)

$-.989x^{f}_{23} + x^{f}_{34} = 0$ (NPS contract training)
$-.989x^{f}_{67} + x^{f}_{7t} = 0$ (RET contract training)
$-.989x^{f}_{59} + x^{f}_{9t} = 0$ (NPS military training)
$-.989x^{f}_{68} + x^{f}_{8t} = 0$ (RET military training)

$-.992x^{g}_{23} + x^{g}_{34} = 0$ (NPS contract training)
$-.992x^{g}_{67} + x^{g}_{7t} = 0$ (RET contract training)
$-.992x^{g}_{59} + x^{g}_{9t} = 0$ (NPS military training)
$-.992x^{g}_{68} + x^{g}_{8t} = 0$ (RET military training)

$-.906x^{h}_{23} + x^{h}_{34} = 0$ (NPS contract training)
$-.906x^{h}_{67} + x^{h}_{7t} = 0$ (RET contract training)
$-.906x^{h}_{59} + x^{h}_{9t} = 0$ (NPS military training)
$-.906x^{h}_{68} + x^{h}_{8t} = 0$ (RET military training)

$$-.933x^{i}_{23} + x^{i}_{34} = 0 \quad \text{(NPS contract training)}$$
$$-.933x^{i}_{67} + x^{i}_{7t} = 0 \quad \text{(RET contract training)}$$
$$-.933x^{i}_{59} + x^{i}_{9t} = 0 \quad \text{(NPS military training)}$$
$$-.933x^{i}_{68} + x^{i}_{8t} = 0 \quad \text{(RET military training)}$$

$$-.962x^{j}_{23} + x^{j}_{34} = 0 \quad \text{(NPS contract training)}$$
$$-.962x^{j}_{67} + x^{j}_{7t} = 0 \quad \text{(RET contract training)}$$
$$-.962x^{j}_{59} + x^{j}_{9t} = 0 \quad \text{(NPS military training)}$$
$$-.962x^{j}_{68} + x^{j}_{8t} = 0 \quad \text{(RET military training)}$$

Balk Rate:

$$-br\ x^{a}_{34} + x^{a}_{45} = 0$$
$$-br\ x^{b}_{34} + x^{b}_{45} = 0$$
$$\vdots$$
$$-br\ x^{j}_{34} + x^{j}_{45} = 0$$

where br = .9
= .85
= .80
= .75
= .70
= .65
= .60
= .55
= .50

Accession Constraints. The total number of NPS accessions for FY91 is 36,000. The accession limit for the illustrative example was calculated by the percent of the total NPS TPR represented by the example (approximately 7.7%) and finding the appropriate proportion of the total accessions for the example. The following constraint represents the limit on accessions for the network model:

$$x^{a}_{45} + x^{b}_{45} + \ldots + x^{j}_{45} - 2774\ y_{45} \le 0$$

The following constraint was used for the goal programming model:

$$x^{a}_{45} + x^{b}_{45} + \ldots + x^{j}_{45} \le 0$$

Switch Constraints. Switch constraints were used in the network model to select the most cost effective path for a commodity to travel. Several rules for setting switches applied:

1) A commodity could follow the path of pre-accession

training or the current policy, but not both. The following constraints represent this rule:

$$y_{23} + y_{25} = 1$$
$$y_{67} + y_{68} = 1$$

2) If the "a" switch was set for a particular training policy, all subsequent switches along the chosen path must be set. The following constraints apply:

$$y_{23} - y_{34} = 0$$
$$y_{34} - y_{45} = 0$$
$$y_{45} - y_{5t} = 0$$
$$y_{25} - y_{59} = 0$$
$$y_{59} - y_{9t} = 0$$
$$y_{67} - y_{7t} = 0$$
$$y_{68} - y_{8t} = 0$$

3) Both NPS and RET entities of the same commodity must be trained under the same policy. The following constraint sets this rule:

$$y_{25} - y_{68} = 0$$

In addition to the above switches, a set of constraints drives the remaining zero-one integer variables. The following constraints were used:

$$x_{23} - 1.0e^{12}\, y_{23} \leq 0$$
$$x_{34} - 1.0e^{12}\, y_{34} \leq 0$$
$$x_{59} - 1.0e^{12}\, y_{59} \leq 0$$
$$x_{67} - 1.0e^{12}\, y_{67} \leq 0$$
$$x_{68} - 1.0e^{12}\, y_{68} \leq 0$$

<u>Objective Function</u>. Two objective functions were formulated following the formulation given in the previous chapter. To find the minimum cost, the following objective function was used in the network model:

$$\begin{aligned} \text{Min} \quad & 2993x_{12} + 382x^{a}_{23} + \ldots + 382x^{j}_{23} + c^{1}x^{a}_{34} + \ldots + c^{1}x^{j}_{34} + \\ & 3769x^{a}_{5t} + \ldots + 3769x^{j}_{5t} + 382x^{a}_{67} + \ldots + 382x^{j}_{67} + \\ & c^{2}x^{a}_{7t} + \ldots + c^{2}x^{j}_{7t} + 382x^{a}_{25} + \ldots + 382x^{j}_{25} + 3769x^{a}_{59} + \\ & \ldots + 3769x^{j}_{59} + c^{3}x^{a}_{9t} + \ldots + c^{3}x^{j}_{9t} + 382x^{a}_{68} + \ldots + \\ & 382x^{j}_{68} + c^{3}x^{a}_{8t} + \ldots + c^{3}x^{j}_{8t} \end{aligned}$$

where, c1 - appropriate cost coefficient from Table 6, column CT(NPS)

c2 - appropriate cost coefficient from Table 6, column CT(RET)

c3 - appropriate cost coefficient from Table 6, column MT

The following objective function was used for the goal programming model:

$$\begin{aligned} \text{Min} \quad & d^{-}_{1} + d^{+}_{1} + d^{-}_{2} + d^{+}_{2} + d^{-}_{3} + d^{+}_{3} + d^{-}_{4} + d^{+}_{4} + d^{-}_{5} + d^{+}_{5} \\ & + d^{-}_{6} + d^{+}_{6} + d^{-}_{7} + d^{+}_{7} + d^{-}_{8} + d^{+}_{8} + d^{-}_{9} + d^{+}_{9} + d^{-}_{10} + d^{+}_{10} \end{aligned}$$

QSB Processing

The QSB software package used for the example is a user friendly optimization package that can solve linear programs with up to 500 constraints and 500 decision variables. The ILP Decision Support System in QSB was used to solve the network. This system solves mixed integer problems using the branch-and-bound method (5). This technique enumerates all feasible solutions, then converges on the optimal solution. Appendix B presents an example QSB input file. The output from the example is presented in Appendix C. The goal programming model was solved with QSB's LP Decision Support System. This system solves LP's using the well known simplex method. Appendix D presents the QSB input file for the goal programming model. An example of the output is presented in Appendix E.

Results and Analysis

Two models were run for the illustrative example. Initially, the minimum cost network model was run to measure the impact of increasing balk rates to the TPR and training production process. A stipend of $150 per month and housing allowance of $300 per month for contract training NPS students was used for the first set of runs. Active duty retrainees continued to receive $1,300 per month salary if attending contract training. An accession ceiling of 536 NPS enlistees can enter BMT. A summary of results for AFSC 49131 is presented in Table 7, on the following page. The remaining AFSC results are given in Appendix F.

TABLE 7

SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT $450/MONTH SUBSISTENCE ALLOWANCE

AFSC	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd NPS	Per RET	Cost (mil)
49131									
10% Balk	588	529	128	519	125	467	434	125	6.8
15% Balk	622	560	128	549	125	467	434	125	7.0
20% Balk	661	595	128	584	125	467	434	125	7.3
*25% Balk	529	443	128	434	125	467	434	125	7.4

* Denotes switch to current training policy from pre-accession

The first column, recruiting requirement, identifies the number of NPS students to be recruited, at the different balk rates, to still achieve the TPR goal. The next two columns show the number of NPS and RET students entering technical training. The accessions column represents the number of NPS enlistees sent to BMT. The next two columns show the number of trained NPS and RET personnel. The final column represents the total cost to meet the TPR goal. The balk rate does not impact the number of prior service retrainees. Accession rates for the current policy are higher than those for the pre-accession policy, but are under the maximum number of accessions allowed. Enlistees in the current policy hit fewer "attrition gates" prior to going to BMT. This information applies to all runs of the network example.

The cost advantage of a pre-accession training policy over the current policy was diminished as the balk rate increased. At a balk rate of 25%, the model selected the current policy over the pre-accession policy. At a 10% balk rate, an 8.6% savings over the cost of the current policy was realized. A 15% balk rate lowered the savings to 5.1%. A savings of only 1.3% was made at a balk rate of 20%.

In addition, recruiting requirements were impacted by the pre-accession training policy and rising balk rates. An 11.2% increase over recruiting NPS under the current policy was needed under pre-accession policy at a 10% balk rate. When the balk rate was raised to 15%, recruiting requirements rose to 17.6% over current policy needs. At a 20% balk rate, recruiting requirements were 25% higher than current policy requirements.

Table 8 represents the results of the model when the student stipend is raised by $150 per month to $300 per month. The remaining AFSC results are presented in Appendix G.

TABLE 8

SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT $600/MONTH SUBSISTENCE ALLOWANCE

AFSC	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd Per NPS	Trnd Per RET	Cost (mil)
49131									
10% Balk	588	529	128	519	125	467	434	125	6.9
15% Balk	622	560	128	549	125	467	434	125	7.2
*20% Balk	529	443	128	434	125	467	434	125	7.4

* Denotes switch to current training policy from pre-accession

When the stipend was increased by $150 per month the model selected the current policy over the pre-accession policy when the balk rate was at 20%. A 6.7% savings over the current policy was realized when the balk rate was 10%. At a balk rate of 15%, the savings was only 3.2% better. Recruiting requirements remained the same as the previous example.

Table 9 represents all ten AFSCs used in the illustrative example. A $450 per month subsistence allowance and an accession ceiling of 2775 were used.

TABLE 9

SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT $450/MONTH SUBSISTENCE ALLOWANCE

Balk	Rec	TT Enters		TT Grads			Trnd	Per	Cost
Rate	Req	NPS	RET	NPS	RET	Acc	NPS	RET	(mil)
10%	3121	2809	285	2683	272	2414	2245	272	33.4
15%	3305	2974	285	2840	272	2414	2245	272	34.8
20%	3511	3160	285	3018	272	2414	2245	272	36.3
*25%	2809	2351	285	2245	272	2528	2245	272	37.2

* Denotes switch to current training policy from pre-accession

The overall cost savings for the pre-accession training policy is 10.2% better than the current policy when the balk rate was 10%. However, recruiting requirements were 11.1% higher for the pre-accession policy. At a balk rate of 15%, the cost savings dropped to 6.5% while recruiting requirements rose to 17.7%. The savings was only 2.4% at a 20% balk rate while recruiting went up to 25% higher.

Table 10, on the following page, represents the same model run at a $600 per month subsistence.

TABLE 10

SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT $600/MONTH SUBSISTENCE ALLOWANCE

Balk Rate	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd Per NPS	Trnd Per RET	Cost (mil)
10%	3121	2809	285	2683	272	2414	2245	272	34.3
15%	3305	2974	285	2840	272	2414	2245	272	35.7
*20%	2809	2351	285	2245	272	2528	2245	272	37.2

* Denotes switch to current training policy from pre-accession

The cost savings for this run was 7.9% greater than the current policy at a 10% balk rate. At a 15% balk rate, the savings dropped to 4.1%. The current policy was chosen when the balk rate was at 20%. Recruiting requirements remained the same as the previous model.

The goal programming model was run to identify any deviations in meeting TPR goals under a policy of pre-accession training due to increasing balk rates. Table 11, on the following page, represents a summary of results for AFSC 49131. The remaining AFSCs are presented in Appendix H.

TABLE 11

SUMMARY OF RESULTS FOR EXAMPLE GP MODEL

AFSC	TPR GOAL NPS	TPR GOAL RET	TECH TRN ENTRIES NPS	TECH TRN ENTRIES RET	TECH TRN GRADS NPS	TECH TRN GRADS RET	ACCESS	TRAINED PERSONNEL NPS	TRAINED PERSONNEL RET
49313	434	125							
BALK RATE									
10%			529	128	519	125	467	434	125
15%			560	128	549	125	467	434	125
20%			595	128	584	125	467	434	125
25%			635	128	623	125	467	434	125
30%			680	128	667	125	467	434	125
35%			732	128	718	125	467	434	125
40%			793	128	778	125	467	434	125
45%			865	128	849	125	467	434	125
50%			952	128	934	125	467	434	125

TPR goals were met at each balk rate. Since the balk rate does not affect RET students, no change in the number of entries and graduates were recorded. While the number of NPS entries to technical training and graduates increased, the rising balk rate before entering BMT prevented the accessions ceiling of 536 NPS enlistees from being exceeded. The only known restrictions on the system are TPR goals for a fiscal year and the number of accessions per fiscal year. Unless restrictions are placed on the number of students recruited and/or allowed to enter technical training in a given fiscal year, the TPR goal would always be met. However, unlimited recruiting to meet TPR goals as the balk rate increased would not be cost effective. The previous network model found the current training policy to be more cost effective if the balk rate became excessively high.

V. Conclusions

This final chapter presents observations about the results of this study. The purpose of this research was to develop a model to aid decision makers in choosing an initial skills training policy. The key results, issues and concerns, and policy implications for management will be discussed.

Key Results

The most important result was that implementing a policy of pre-accession training would be more cost effective than the current policy under certain conditions. The balk rate and subsistence allowance are key factors impacting the savings realized for pre-accession training. Table 12 shows the savings for the ten AFSC's modeled in the previous chapter.

TABLE 12

SUMMARY OF SAVINGS FOR PRE-ACCESSION TRAINING

Balk Rate	Subsistence Allowance	Savings	% Difference
10%	$450	3.8 million	10.2
15%	$450	2.4 million	6.5
20%	$450	.9 million	2.4
10%	$600	2.9 million	7.9
15%	$600	1.5 million	4.1

While recruiting levels were found to be higher for the pre-accession policy, as much as 25% higher than the current policy, accession levels were 4.5% lower. Under the pre-accession policy, enlistees pass through more levels of attrition (DEP, technical training, balk rate) prior to entering BMT than they would for the current policy (DEP only). The pre-accession policy would be more flexible at meeting TPR goals during periods of decreasing accessions.

The network model proved to be a much more realistic approach than the goal programming model in determining the impact of pre-accession training on the TPR process. Both models provided information on recruiting requirements, technical training school entry requirements and the number of graduates, the number of accessions, and the results of meeting TPR goal requirements. In addition, the network model provided data on the total cost of going through the training pipeline. The goal programming model provided information on the number of deviations from TPR goals. However, due to the limited known restrictions placed on the goal programming model, there was never a case where a deviation from a TPR goal existed. The only known restrictions on the model are TPR goals and accession levels. The ceiling on accession levels was high enough to ensure TPR goals were met. Training budget restrictions, recruiting restrictions, or restrictions on the number of students entering technical training could have made the model more meaningful. Without these restrictions, recruiting levels could be raised to counter a rising balk rate and still meet TPR goals.

A potential bottleneck could exist in the model. A bottleneck could be created if restrictions were placed on the number of classes conducted per fiscal year. In addition, if the number of accessions were reduced too much, TPR goals may not be met. The number of retrainees could be raised to counter this problem. Additionally, increasing the number of retrainees could be effective in countering prohibitive costs associated with rising balk rates or higher recruiting goals.

Issues and Concerns

Several issues and concerns are left unanswered. An optimization approach was used to model the impact of pre-accession training on the TPR process. Issues such as quality of training and "blueness" of training cannot be addressed in such a model. The impact of greater requirements to the recruiting mission cannot be measured with the model (short of the actual cost per additional recruit). An actual test of the policy would be required to accurately measure these issues. Surveys could be conducted to determine the quality of graduates trained by contract against those trained by the military. This method could address the "blueness" questions and quality of training issues. The impact of higher recruiting goals could also be measured.

Policy Implications for Management

The implementation of a pre-accession training policy could hinder management control of the training production process. A flexible contract would have to be established to allow managers to respond to fluctuations in the TPR. Classes would have to be added or dropped during the fiscal year to reduce under or over production of any AFSC. Management must also be able to respond to rising costs in training. Competitive bidding on training contracts could counter rising costs. Balk rates must also be controlled to keep the new policy cost effective.

The model developed for this thesis could be used to calculate recruiting goals, establish the required number of classes to meet TPR goals, and estimate a training budget. The model can be adjusted to calculate annual or quarterly figures. It is flexible enough to incorporate changes in TPR goals, accessions, or acquisition costs.

Appendix A: Sample AFSCs and FY91 TPR Goals (7;10)

AFSC	SPEC DESC	COURSE ATTRITION	TOT TPR (TECH)	NPS	RET
23131	Graphics	0.034	8	8	0
25130	Weather	0.096	324	269	55
27630C	Appr Aero C&W	0.011	250	225	25
30430	Appr WB Comm Equip	0.058	172	172	0
30534Q	Elec Comp & SW	0.000	104	104	0
36231	Appr Tele Switch	0.033	132	51	81
36233	Missile Cont Comm	0.000	12	12	0
45233A	Appr F/FB-111 Avion	0.000	19	19	0
45234A	Appr Tact Acft Maint	0.038	554	554	0
45234B	Appr Tact Acft Maint	0.043	330	330	0
45235	Appr Tact Elec-Envir	0.030	192	192	0
45430A	Appr Aero Prop	0.014	750	750	0
45730A	Appr Strat Acft Maint	0.100	75	75	0
45730B	Appr Strat Acft Maint	0.021	117	117	0
45730D	Appr Strat Acft Maint	0.023	38	38	0
45831	Appr Non Dest Insp	0.017	54	54	0
46230F	Acft Arm Sys	0.006	660	660	0
47232	Appr Gen Purp Ven	0.000	198	198	0
49131	Appr Comm-Comp Sys Opr	0.019	559	434	125
49330	Appr Comm-Comp Sys Cost	0.027	296	248	48
54531	Appr Liq Fuels Sys Maint	0.011	40	40	0
55230	Appr Struc Spec	0.013	130	130	0
56630	Appr Pest Mngt	0.000	24	24	0
57130	Fire Protect	0.004	760	760	0
62330	Appr Serv Spec	0.006	367	365	2
67231	Fin Mngt	0.008	89	82	7
75330	Combat Arms	0.034	25	20	5
90330	Radiologic	0.112	175	139	36
90430	Cardiopulm Lab	0.094	61	41	20
90630	Med Admin	0.005	364	294	70
91330	Appr Phys Therap	0.067	52	22	30
98130	Dental Asst	0.038	329	239	90

Appendix B: Example OSB Input File (AFSC 49131)

Input Data Describing Your Problem 49131.10%BR Page 1

Min	+2993.00X12	+382.000X23	+4550.00X34	__________X45	+3769.00X5t
	+382.000X67	+6050.00X7t	+382.000X25	+3769.00X59	+7000.00X9t
	+382.000X68	+7000.00X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t		
Subject to					
(1)	__________X12	__________X23	__________X34	__________X45	+1.00000X5t
	__________X67	+1.00000X7t	__________X25	__________X59	+1.00000X9t
	__________X68	+1.00000X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= +559.000	
(2)	-.900000X12	+1.00000X23	__________X34	__________X45	__________X5t
	__________X67	__________X7t	+1.00000X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	
(3)	__________X12	__________X23	__________X34	-.930000X45	+1.00000X5t
	__________X67	__________X7t	__________X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	
(4)	__________X12	__________X23	__________X34	__________X45	__________X5t

Input Data Describing Your Problem 49131.10%BR Page 2

(4)	__________X67	__________X7t	-.930000X25	+1.00000X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	
(5)	__________X12	-.981000X23	+1.00000X34	__________X45	__________X5t
	__________X67	__________X7t	__________X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	
(6)	__________X12	__________X23	__________X34	__________X45	__________X5t
	-.981000X67	+1.00000X7t	__________X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	
(7)	__________X12	__________X23	__________X34	__________X45	__________X5t
	__________X67	__________X7t	__________X25	-.981000X59	+1.00000X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	
(8)	__________X12	__________X23	__________X34	__________X45	__________X5t
	__________X67	__________X7t	__________X25	__________X59	__________X9t
	-.981000X68	+1.00000X8t	__________Y23	__________Y25	__________Y34

Input Data Describing Your Problem 49131.10%BR Page 3

(8)	______Y45	______Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	______	
(9)	______X12	______X23	-.900000X34	+1.00000X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	______Y23	______Y25	______Y34
	______Y45	______Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	______	
(10)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	+1.00000Y23	+1.00000Y25	______Y34
	______Y45	______Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	+1.00000	
(11)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	+1.00000Y23	______Y25	-1.00000Y34
	______Y45	______Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	______	
(12)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	______Y23	______Y25	+1.00000Y34
	-1.00000Y45	______Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	______	

Input Data Describing Your Problem 49131.10%BR Page 4

(13)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	______Y23	______Y25	______Y34
	+1.00000Y45	______Y59	-1.00000Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	______	
(14)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	______Y23	+1.00000Y25	______Y34
	______Y45	-1.00000Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	______Y9t =	______	
(15)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	______Y23	______Y25	______Y34
	______Y45	+1.00000Y59	______Y5t	______Y67	______Y68
	______Y7t	______Y8t	-1.00000Y9t =	______	
(16)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t
	______X68	______X8t	______Y23	______Y25	______Y34
	______Y45	______Y59	______Y5t	+1.00000Y67	+1.00000Y68
	______Y7t	______Y8t	______Y9t =	+1.00000	
(17)	______X12	______X23	______X34	______X45	______X5t
	______X67	______X7t	______X25	______X59	______X9t

Input Data Describing Your Problem 49131.10%BR Page 5

```
(17) __________X68 __________X8t __________Y23 __________Y25 __________Y34
     __________Y45 __________Y59 __________Y5t +1.00000Y67 __________Y68
     -1.00000Y7t   __________Y8t __________Y9t =  __________
(18) __________X12 __________X23 __________X34 __________X45 __________X5t
     __________X67 __________X7t __________X25 __________X59 __________X9t
     __________X68 __________X8t __________Y23 __________Y25 __________Y34
     __________Y45 __________Y59 __________Y5t __________Y67 +1.00000Y68
     __________Y7t -1.00000Y8t   __________Y9t =  __________
(19) __________X12 __________X23 __________X34 +1.00000X45 __________X5t
     __________X67 __________X7t __________X25 __________X59 __________X9t
     __________X68 __________X8t __________Y23 __________Y25 __________Y34
     -536.000Y45   __________Y59 __________Y5t __________Y67 __________Y68
     __________Y7t __________Y8t __________Y9t ≤  __________
(20) __________X12 __________X23 __________X34 __________X45 __________X5t
     __________X67 __________X7t +1.00000X25 __________X59 __________X9t
     __________X68 __________X8t __________Y23 -536.000Y25 __________Y34
     __________Y45 __________Y59 __________Y5t __________Y67 __________Y68
     __________Y7t __________Y8t __________Y9t ≤  __________
(21) __________X12 __________X23 __________X34 __________X45 +1.00000X5t
     __________X67 __________X7t __________X25 __________X59 __________X9t
     __________X68 __________X8t __________Y23 __________Y25 __________Y34
     __________Y45 __________Y59 -434.000Y5t   __________Y67 __________Y68
```

Input Data Describing Your Problem 49131.10%BR Page 6

```
(21) __________Y7t __________Y8t __________Y9t ≤  __________
(22) __________X12 __________X23 __________X34 __________X45 __________X5t
     __________X67 __________X7t __________X25 __________X59 +1.00000X9t
     __________X68 __________X8t __________Y23 __________Y25 __________Y34
     __________Y45 __________Y59 __________Y5t __________Y67 __________Y68
     __________Y7t __________Y8t -434.000Y9t ≤  __________
(23) __________X12 __________X23 __________X34 __________X45 __________X5t
     __________X67 +1.00000X7t   __________X25 __________X59 __________X9t
     __________X68 __________X8t __________Y23 __________Y25 __________Y34
     __________Y45 __________Y59 __________Y5t __________Y67 __________Y68
     -125.000Y7t   __________Y8t __________Y9t ≤  __________
(24) __________X12 __________X23 __________X34 __________X45 __________X5t
     __________X67 __________X7t __________X25 __________X59 __________X9t
     __________X68 +1.00000X8t   __________Y23 __________Y25 __________Y34
     __________Y45 __________Y59 __________Y5t __________Y67 __________Y68
     __________Y7t -125.000Y8t   __________Y9t ≤  __________
(25) __________X12 +1.00000X23   __________X34 __________X45 __________X5t
     __________X67 __________X7t __________X25 __________X59 __________X9t
     __________X68 __________X8t -1.0E+12Y23   __________Y25 __________Y34
     __________Y45 __________Y59 __________Y5t __________Y67 __________Y68
     __________Y7t __________Y8t __________Y9t ≤  __________
(26) __________X12 __________X23 +1.00000X34   __________X45 __________X5t
```

(26)	__________X67	__________X7t	__________X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	-1.0E+12Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	≤ __________	
(27)	__________X12	__________X23	__________X34	__________X45	__________X5t
	__________X67	__________X7t	__________X25	+1.00000X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	-1.0E+12Y59	__________Y5t	__________Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	≤ __________	
(28)	__________X12	__________X23	__________X34	__________X45	__________X5t
	+1.00000X67	__________X7t	__________X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	-1.0E+12Y67	__________Y68
	__________Y7t	__________Y8t	__________Y9t	≤ __________	
(29)	__________X12	__________X23	__________X34	__________X45	__________X5t
	__________X67	__________X7t	__________X25	__________X59	__________X9t
	+1.00000X68	__________X8t	__________Y23	__________Y25	__________Y34
	__________Y45	__________Y59	__________Y5t	__________Y67	-1.0E+12Y68
	__________Y7t	__________Y8t	__________Y9t	≤ __________	
(30)	__________X12	__________X23	__________X34	__________X45	__________X5t
	__________X67	__________X7t	__________X25	__________X59	__________X9t
	__________X68	__________X8t	__________Y23	+1.00000Y25	__________Y34

(30)	__________Y45	__________Y59	__________Y5t	__________Y67	-1.00000Y68
	__________Y7t	__________Y8t	__________Y9t	= __________	

Input Data Describing Your Problem 49131.10%BR PG 1
(Default values are continuous with lower bound 0 and no upper bound)

Var. no.	Var.	Integrality (I/C)	Lower bound	Upper bound
1	X12	<C>	<0 >	<32000 >
2	X23	<C>	<0 >	<32000 >
3	X34	<C>	<0 >	<32000 >
4	X45	<C>	<0 >	<32000 >
5	X5t	<C>	<0 >	<32000 >
6	X67	<C>	<0 >	<32000 >
7	X7t	<C>	<0 >	<32000 >
8	X25	<C>	<0 >	<32000 >
9	X59	<C>	<0 >	<32000 >
10	X9t	<C>	<0 >	<32000 >
11	X68	<C>	<0 >	<32000 >
12	X8t	<C>	<0 >	<32000 >
13	Y23	<I>	<0 >	<1 >
14	Y25	<I>	<0 >	<1 >
15	Y34	<I>	<0 >	<1 >
16	Y45	<I>	<0 >	<1 >
17	Y59	<I>	<0 >	<1 >
18	Y5t	<I>	<0 >	<1 >
19	Y67	<I>	<0 >	<1 >
20	Y68	<I>	<0 >	<1 >

Input Data Describing Your Problem 49131.10%BR PG 2
(Default values are continuous with lower bound 0 and no upper bound)

Var. no.	Var.	Integrality (I/C)	Lower bound	Upper bound
21	Y7t	<I>	<0 >	<1 >
22	Y8t	<I>	<0 >	<1 >
23	Y9t	<I>	<0 >	<1 >

Appendix C: Example QSB Output File (AFSC 49131)

Summary of Results for 49131.10%BR								Page : 1
Variables No.	**Names**	**Solution**	**Obj. Fnctn. Coefficient**	**Variables No.**	**Names**	**Solution**	**Obj. Fnctn. Coefficient**	
1	X12	+587.29022	+2993.0002	13	Y23	+1.0000000	0	
2	X23	+528.56116	+382.00000	14	Y25	0	0	
3	X34	+518.51849	+4550.0000	15	Y34	+1.0000000	0	
4	X45	+466.66666	0	16	Y45	+1.0000000	0	
5	X5t	+434.00000	+3769.0000	17	Y59	0	0	
6	X67	+127.42099	+382.00000	18	Y5t	+1.0000000	0	
7	X7t	+125.00000	+6050.0000	19	Y67	+1.0000000	0	
8	X25	0	+382.00000	20	Y68	0	0	
9	X59	0	+3769.0000	21	Y7t	+1.0000000	0	
10	X9t	+1.137E-14	+7000.0000	22	Y8t	0	0	
11	X68	0	+382.00000	23	Y9t	0	0	
12	X8t	+2.842E-15	+7000.0000					
Minimum value of the OBJ = 6759600				Total iterations = 1				

Summary of Results for 49131.15%BR								Page : 1
Variables No.	**Names**	**Solution**	**Obj. Fnctn. Coefficient**	**Variables No.**	**Names**	**Solution**	**Obj. Fnctn. Coefficient**	
1	X12	+621.83667	+2993.0002	13	Y23	+1.0000000	0	
2	X23	+559.65295	+382.00000	14	Y25	0	0	
3	X34	+549.01959	+4550.0000	15	Y34	+1.0000000	0	
4	X45	+466.66666	0	16	Y45	+1.0000000	0	
5	X5t	+434.00000	+3769.0000	17	Y59	0	0	
6	X67	+127.42099	+382.00000	18	Y5t	+1.0000000	0	
7	X7t	+125.00000	+6050.0000	19	Y67	+1.0000000	0	
8	X25	0	+382.00000	20	Y68	0	0	
9	X59	0	+3769.0000	21	Y7t	+1.0000000	0	
10	X9t	0	+7000.0000	22	Y8t	0	0	
11	X68	0	+382.00000	23	Y9t	0	0	
12	X8t	0	+7000.0000					
Minimum value of the OBJ = 7013655				Total iterations = 1				

Summary of Results for 49131.25%BR   Page : 1

Variables No.	Names	Solution	Obj. Fnctn. Coefficient	Variables No.	Names	Solution	Obj. Fnctn. Coefficient
1	X12	+528.56116	+2993.0002	13	Y23	0	0
2	X23	+3.469E-15	+382.00000	14	Y25	+1.0000000	0
3	X34	+2.776E-15	+4550.0000	15	Y34	0	0
4	X45	0	0	16	Y45	0	0
5	X5t	0	+3769.0000	17	Y59	+1.0000000	0
6	X67	0	+382.00000	18	Y5t	0	0
7	X7t	0	+6050.0000	19	Y67	0	0
8	X25	+475.70505	+382.00000	20	Y68	+1.0000000	0
9	X59	+442.40570	+3769.0000	21	Y7t	0	0
10	X9t	+434.00000	+7000.0000	22	Y8t	+1.0000000	0
11	X68	+127.42099	+382.00000	23	Y9t	+1.0000000	0
12	X8t	+125.00000	+7000.0000				

Minimum value of the OBJ = 7392805   Total iterations = 1

Summary of Results for 49131.20%BR   Page : 1

Variables No.	Names	Solution	Obj. Fnctn. Coefficient	Variables No.	Names	Solution	Obj. Fnctn. Coefficient
1	X12	+660.70142	+2993.0002	13	Y23	+1.0000000	0
2	X23	+594.63123	+382.00000	14	Y25	0	0
3	X34	+583.33325	+4550.0000	15	Y34	+1.0000000	0
4	X45	+466.66666	0	16	Y45	+1.0000000	0
5	X5t	+434.00000	+3769.0000	17	Y59	-5.551E-17	0
6	X67	+127.42099	+382.00000	18	Y5t	+1.0000000	0
7	X7t	+125.00000	+6050.0000	19	Y67	+1.0000000	0
8	X25	-2.842E-14	+382.00000	20	Y68	0	0
9	X59	-1.137E-14	+3769.0000	21	Y7t	+1.0000000	0
10	X9t	0	+7000.0000	22	Y8t	0	0
11	X68	0	+382.00000	23	Y9t	-5.551E-17	0
12	X8t	+2.842E-15	+7000.0000				

Minimum value of the OBJ = 7299466   Total iterations = 1

<u>Appendix D: Example OSB Input File For TPR Goal Program (AFSC 49131)</u>

```
                    Input Data Describing Your Problem 49131.10%BR  .  Page  1

Min    __________X12 __________X23 __________X34 __________X45 __________X5t
       __________X67 __________X7t +1.00000D1M +1.00000D1P
Subject to
(1)    __________X12 __________X23 __________X34 __________X45 +1.00000X5t
       __________X67 +1.00000X7t +1.00000D1M -1.00000D1P = +553.000
(2)    -.900000X12 +1.00000X23 __________X34 __________X45 __________X5t
       __________X67 __________X7t __________D1M __________D1P = __________
(3)    __________X12 __________X23 __________X34 -.930000X45 +1.00000X5t
       __________X67 __________X7t __________D1M __________D1P = __________
(4)    __________X12 -.981000X23 +1.00000X34 __________X45 __________X5t
       __________X67 __________X7t __________D1M __________D1P = __________
(5)    __________X12 __________X23 __________X34 __________X45 __________X5t
       -.981000X67 +1.00000X7t __________D1M __________D1P = __________
(6)    __________X12 __________X23 -.900000X34 +1.00000X45 __________X5t
       __________X67 __________X7t __________D1M __________D1P = __________
(7)    __________X12 __________X23 __________X34 +1.00000X45 __________X5t
       __________X67 __________X7t __________D1M __________D1P ≤ +536.000
(8)    __________X12 __________X23 __________X34 __________X45 +1.00000X5t
       __________X67 __________X7t __________D1M __________D1P ≤ +434.000
(9)    __________X12 __________X23 __________X34 __________X45 __________X5t
       __________X67 +1.00000X7t __________D1M __________D1P ≤ +125.000
```

Appendix E: Example QSB Output File For TPR Goal Program (10% Balk Rate)

Summarized Results for TPRGP.10%BR							Page : 1
Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
1	X12	+2992.0149	0	16	X34e	+518.51855	0
2	X23a	+9.8943529	0	17	X34f	+47.789726	0
3	X23b	+628.03296	0	18	X34g	+97.968941	0
4	X23c	+908.73027	0	19	X34h	+48.984394	0
5	X23d	+31.403046	0	20	X34i	+26.284349	0
6	X23e	+528.56122	0	21	X34j	+285.54361	0
7	X23f	+48.321259	0	22	X45a	+8.6021509	0
8	X23g	+98.759010	0	23	X45b	+595.69891	0
9	X23h	+54.066658	0	24	X45c	+806.45160	0
10	X23i	+28.171864	0	25	X45d	+25.436466	0
11	X23j	+296.82288	0	26	X45e	+466.66669	0
12	X34a	+9.5579453	0	27	X45f	+43.010754	0
13	X34b	+661.88770	0	28	X45g	+88.172043	0
14	X34c	+896.05737	0	29	X45h	+44.085953	0
15	X34d	+28.262741	0	30	X45i	+23.655914	0
Minimum value of the OBJ = 0 (multiple sols.)							Iters. = 62

Summarized Results for TPRGP.10%BR							Page : 2
Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
31	X45j	+256.98923	0	46	X67e	+127.42099	0
32	X5ta	+8.0000000	0	47	X67f	0	0
33	X5tb	+554.00000	0	48	X67g	+7.0564513	0
34	X5tc	+750.00000	0	49	X67h	+22.075054	0
35	X5td	+75.000000	0	50	X67i	+32.154343	0
36	X5te	+434.00000	0	51	X67j	+93.555092	0
37	X5tf	+40.000000	0	52	X7ta	0	0
38	X5tg	+82.000000	0	53	X7tb	0	0
39	X5th	+40.999935	0	54	X7tc	0	0
40	X5ti	+22.000000	0	55	X7td	0	0
41	X5tj	+239.00000	0	56	X7te	+125.00000	0
42	X67a	0	0	57	X7tf	0	0
43	X67b	0	0	58	X7tg	+7.0000000	0
44	X67c	0	0	59	X7th	+20.000000	0
45	X67d	0	0	60	X7ti	+30.000000	0
Minimum value of the OBJ = 0 (multiple sols.)							Iters. = 62

Summarized Results for TPRGP.10%BR Page : 3

Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
61	X7tj	+90.000000	0	76	D8M	0	+1.0000000
62	D1M	0	+1.0000000	77	D8F	0	+1.0000000
63	D1P	0	+1.0000000	78	D9M	0	+1.0000000
64	D2M	0	+1.0000000	79	D9P	0	+1.0000000
65	D2P	0	+1.0000000	80	D10M	0	+1.0000000
66	D3M	0	+1.0000000	81	D10F	0	+1.0000000
67	D3F	0	+1.0000000	82	A1	0	0
68	D4M	0	+1.0000000	83	A2	0	0
69	D4F	0	+1.0000000	84	A3	0	0
70	D5M	0	+1.0000000	85	A4	0	0
71	D5F	0	+1.0000000	86	A5	0	0
72	D6M	0	+1.0000000	87	A6	0	0
73	D6P	0	+1.0000000	88	A7	0	0
74	D7M	0	+1.0000000	89	A8	0	0
75	D7F	0	+1.0000000	90	A9	0	0

Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62

Summarized Results for TPRGP.10%BR Page : 4

Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
91	A10	0	0	106	A25	0	0
92	A11	0	0	107	A26	0	0
93	A12	0	0	108	A27	0	0
94	A13	0	0	109	A28	0	0
95	A14	0	0	110	A29	0	0
96	A15	0	0	111	A30	0	0
97	A16	0	0	112	A31	0	0
98	A17	0	0	113	A32	0	0
99	A18	0	0	114	A33	0	0
100	A19	0	0	115	A34	0	0
101	A20	0	0	116	A35	0	0
102	A21	0	0	117	A36	0	0
103	A22	0	0	118	A37	0	0
104	A23	0	0	119	A38	0	0
105	A24	0	0	120	A39	0	0

Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62

Summarized Results for TPRGP.10%BR					Page : 5
Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost
121 A40	0	0	133 S52	0	0
122 A41	0	0	134 S53	0	0
123 A42	0	0	135 S54	0	0
124 S43	+415.23019	0	136 S55	0	0
125 S44	0	0	137 S56	0	0
126 S45	0	0	138 S57	0	0
127 S46	0	0	139 S58	0	0
128 S47	0	0	140 S59	0	0
129 S48	0	0	141 S60	0	0
130 S49	0	0	142 S61	0	0
131 S50	0	0	143 S62	0	0
132 S51	+.00006340	0	144 S63	0	0
Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62					

Appendix F: Results of Network Model at $450/Month Subsistence

AFSC	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd NPS	Per RET	Cost
23131									
Balk Rate									
10%	11	10	0	10	0	9	8	0	114,148
15%	12	11	0	11	0	9	8	0	119,089
20%	13	12	0	11	0	9	8	0	124,647
*25%	10	9	0	8	0	9	8	0	129,429
45234A									
Balk Rate									
10%	765	688	0	662	0	596	554	0	7,673,702
15%	810	729	0	701	0	596	554	0	8,002,271
20%	860	774	0	745	0	596	554	0	8,371,911
*25%	688	576	0	554	0	620	554	0	8,410,813
45430A									
Balk Rate									
10%	1010	909	0	896	0	807	750	0	10,452,380
15%	1070	963	0	949	0	807	750	0	10,900,940
20%	1136	1023	0	1008	0	807	750	0	11,405,580
*25%	910	761	0	750	0	818	750	0	11,599,300
45730A									
Balk Rate									
10%	111	100	0	90	0	81	75	0	1,062,649
15%	118	106	0	95	0	81	75	0	1,108,529
20%	125	112	0	101	0	81	75	0	1,160,145
*25%	100	84	0	75	0	90	75	0	1,180,302
54531									
Balk Rate									
10%	54	49	0	48	0	43	40	0	547,357
15%	57	52	0	51	0	43	40	0	570,686
*20%	49	41	0	40	0	44	40	0	593,675
67231									
Balk Rate									
10%	110	99	7	98	7	89	82	7	1,192,619
15%	117	105	7	104	7	89	82	7	1,241,666
20%	124	112	7	111	7	89	82	7	1,296,854
*25%	99	83	7	82	7	89	82	7	1,324,635

AFSC	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd Per NPS	Trnd Per RET	Cost
90430									
Balk Rate									
10%	60	54	22	49	20	44	41	20	749,890
15%	64	58	22	52	20	44	41	20	775,945
20%	68	61	22	56	20	44	41	20	805,256
25%	72	65	22	59	20	44	41	20	838,476
*30%	54	46	22	41	20	49	41	20	856,554
91330									
Balk Rate									
10%	32	29	33	27	30	24	22	30	524,000
15%	34	30	33	28	30	24	22	30	537,489
20%	36	32	33	30	30	24	22	30	552,663
25%	38	34	33	32	30	24	22	30	569,860
30%	41	37	33	34	30	24	22	30	589,515
*35%	29	24	33	22	30	26	22	30	590,359
98130									
Balk Rate									
10%	330	297	94	286	90	257	239	90	3,991,849
15%	350	315	94	303	90	257	239	90	4,136,367
20%	371	334	94	322	90	257	239	90	4,298,951
*25%	297	249	94	239	90	268	239	90	4,462,950

* Denotes switch to current policy

Appendix G: Results of Network Model at $600/Month Subsistence

AFSC	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd NPS	Per RET	Cost
23131									
Balk Rate									
10%	11	10	0	10	0	9	8	0	117,875
15%	12	11	0	11	0	9	8	0	123,036
20%	13	12	0	11	0	9	8	0	128,841
*25%	10	9	0	8	0	9	8	0	129,429
45234A									
Balk Rate									
10%	765	688	0	662	0	596	554	0	7,859,030
15%	810	729	0	701	0	596	554	0	8,198,501
*20%	688	576	0	554	0	620	554	0	8,410,813
45430A									
Balk Rate									
10%	1010	909	0	896	0	807	750	0	10,757,040
15%	1070	963	0	949	0	807	750	0	11,223,520
*20%	910	761	0	750	0	818	750	0	11,599,300
45730A									
Balk Rate									
10%	111	100	0	90	0	81	75	0	1,087,738
15%	118	106	0	95	0	81	75	0	1,135,095
*20%	100	84	0	75	0	90	75	0	1,180,302
54531									
Balk Rate									
10%	54	49	0	48	0	43	40	0	547,357
15%	57	52	0	51	0	43	40	0	570,686
*20%	49	41	0	40	0	44	40	0	593,675
67231									
Balk Rate									
10%	110	99	7	98	7	89	82	7	1,225,929
15%	117	105	7	104	7	89	82	7	1,276,935
*20%	99	83	7	82	7	89	82	7	1,324,635
90430									
Balk Rate									
10%	60	54	22	49	20	44	41	20	768,994
15%	64	58	22	52	20	44	41	20	796,173
20%	68	61	22	56	20	44	41	20	826,748
*25%	54	46	22	41	20	49	41	20	856,554

AFSC	Rec Req	TT Entrs NPS	TT Entrs RET	TT Grads NPS	TT Grads RET	Acc	Trnd Per NPS	Trnd Per RET	Cost
91330									
Balk Rate									
10%	32	29	33	27	30	24	22	30	532,937
15%	34	30	33	28	30	24	22	30	546,951
20%	36	32	33	30	30	24	22	30	562,717
25%	38	34	33	32	30	24	22	30	580,584
*30%	29	24	33	22	30	26	22	30	590,359
98130									
Balk Rate									
10%	330	297	94	286	90	257	239	90	4,088,933
15%	350	315	94	303	90	257	239	90	4,239,163
20%	371	334	94	322	90	257	239	90	4,408,171
*25%	297	249	94	239	90	268	239	90	4,462,950

* Denotes switch to current policy

Appendix H: Results of Goal Programming Model

AFSC	TPR Goal NPS	TPR Goal RET	TT Entries NPS	TT Entries RET	TT Grads NPS	TT Grads RET	Acc	Trnd Pers NPS	Trnd Pers RET
23131	8	0							
Balk %									
10			10	0	10	0	9	8	0
15			11	0	11	0	9	8	0
20			12	0	11	0	9	8	0
25			12	0	12	0	9	8	0
30			13	0	13	0	9	8	0
35			14	0	14	0	9	8	0
40			15	0	15	0	9	8	0
45			17	0	16	0	9	8	0
50			18	0	18	0	9	8	0
45234A	554	0							
Balk %									
10			688	0	662	0	596	554	0
15			729	0	701	0	596	554	0
20			774	0	745	0	596	554	0
25			826	0	795	0	596	554	0
30			885	0	851	0	596	554	0
35			953	0	917	0	596	554	0
40			1032	0	993	0	596	554	0
45			1126	0	1083	0	596	554	0
50			1239	0	1192	0	596	554	0
45430A	750	0							
Balk %									
10			909	0	896	0	807	750	0
15			963	0	949	0	807	750	0
20			1023	0	1008	0	807	750	0
25			1096	0	1076	0	807	750	0
30			1169	0	1152	0	807	750	0
35			1259	0	1241	0	807	750	0
40			1364	0	1344	0	807	750	0
45			1487	0	1467	0	807	750	0
50			1636	0	1613	0	807	750	0

45730A	75	0						
Balk %								
10			100	0	90	0	81	75	0
15			106	0	95	0	81	75	0
20			112	0	101	0	81	75	0
25			120	0	108	0	81	75	0
30			128	0	116	0	81	75	0
35			138	0	124	0	81	75	0
40			150	0	135	0	81	75	0
45			163	0	147	0	81	75	0
50			180	0	162	0	81	75	0
54531	40	0							
Balk %									
10			49	0	48	0	43	40	0
15			52	0	51	0	43	40	0
20			55	0	54	0	43	40	0
25			58	0	58	0	43	40	0
30			63	0	62	0	43	40	0
35			67	0	67	0	43	40	0
40			73	0	72	0	43	40	0
45			79	0	79	0	43	40	0
50			87	0	86	0	43	40	0
67231	82	7							
Balk %									
10			99	7	98	7	89	82	7
15			105	7	104	7	89	82	7
20			112	7	111	7	89	82	7
25			119	7	118	7	89	82	7
30			127	7	126	7	89	82	7
35			137	7	136	7	89	82	7
40			149	7	147	7	89	82	7
45			162	7	161	7	89	82	7
50			178	7	177	7	89	82	7
90430	41	20							
Balk %									
10			54	22	49	20	44	41	20
15			58	22	52	20	44	41	20
20			61	22	56	20	44	41	20
25			65	22	59	20	44	41	20
30			70	22	63	20	44	41	20
35			75	22	68	20	44	41	20
40			81	22	74	20	44	41	20
45			89	22	81	20	44	41	20
50			98	22	89	20	44	41	20

91330	22	30							
Balk %									
10			29	33	27	30	24	22	30
15			30	33	28	30	24	22	30
20			32	33	30	30	24	22	30
25			34	33	32	30	24	22	30
30			37	33	34	30	24	22	30
35			39	33	37	30	24	22	30
40			43	33	40	30	24	22	30
45			46	33	43	30	24	22	30
50			51	33	48	30	24	22	30

98130	239	90							
Balk %									
10			297	94	286	90	257	239	90
15			315	94	303	90	257	239	90
20			334	94	322	90	257	239	90
25			357	94	343	90	257	239	90
30			382	94	368	90	257	239	90
35			411	94	396	90	257	239	90
40			446	94	429	90	257	239	90
45			486	94	468	90	257	239	90
50			535	94	514	90	257	239	90

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Vita

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