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TOUR III: TOUR OPTIMIZATION FOR UNIFORM READINESS MODEL.(U)

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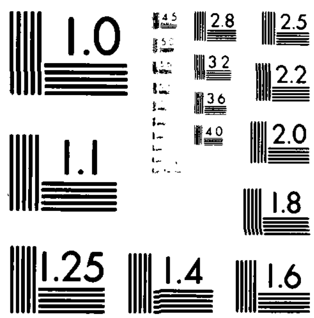

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TOUR II

TOUR OPTIMIZATION FOR UNIFORM READINESS MODEL

FINAL TECHNICAL REPORT
ONR Task NR 047-129
Contract Number N00014-78-C-0400
Deliverable item A005
JULY 1981

DECISION SYSTEMS
DSA
ASSOCIATES, INC.

Decision Systems Associates, Inc.
350 Fortune Terrace
Rockville, Maryland 20854

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TOUR OPTIMIZATION FOR UNIFORM READINESS MODEL

~~(TOUR II) MODEL~~

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20. Abstract

This report describes the Tour Optimization for Uniform Readiness (TOUR) concept and the TOUR II Model.

The TOUR concept entails three major principles:

- Implementing uniform staffing among like Fleet Marine Force (FMF) units,
- Implementing a tour length policy for unit deployment assignments, and
- Advance planning of tour sequences for all first-term Marines.

The operational TOUR II Model developed in this project will soon be implemented as part of the Marine Corps' Precise Personnel Assignment System (PRE-PAS). Once implemented, TOUR II will provide the following capabilities:

- Determine an optimal set of "assignment sequences" (tracks) covering three or four-year enlistment terms;
- Generate an optimal set of flows of recruits, by MOS, into assignment sequences so as to maximize billet fill and even-flow objectives;
- Accomplish manning of deployment units in such a way as to eliminate "mix-mastering" of personnel among units and preclude the necessity of on-board replacements for deployed units; and
- Assign new tracks to Marines whose actual assignments are inconsistent with their tracks.

The TOUR II Model provides (1) the solution to the problem of uneven combat readiness, (2) the only mechanish by which the Marine Corps can effectively respond to DOD Directives reducing PCS costs, and (3) the most important single model driving the overall TOUR process in the TOUR-relevant series of models (PRE-PAS).

Contents

1.0 INTRODUCTION

This report describes the TOUR Optimization for Uniform Readiness (TOUR II) model. TOUR II was developed by Decision Systems Associates, Inc. (DSAI), for the United States Marine Corps' Manpower Plans and Policy Division, Manpower Management Information Systems Branch, under contract N00014-78-C-0400. This report is the final report required by that contract.

TOUR II will form the cornerstone of the Marine Corps' Precise Personnel Assignment System (PRE-PAS). PRE-PAS is a soon-to-be-implemented complex of mathematical models for planning personnel accession, training, and utilization; for implementing those plans; and for monitoring the implementation. TOUR II is that part of PRE-PAS which will generate multiple forward assignments for individuals and monitor their implementation.

TOUR II is designed to be run monthly to plan the future, chargeable utilization of prospective recruit training graduates throughout their first enlistment terms. At the same time, it will compare the actual utilization of Marines with the plans developed for them in previous months, modifying those plans whenever necessary to accommodate actual utilization.

An individual plan will be developed for each prospective recruit training graduate. These plans will be developed by an iterative algorithm which derives an optimum solution to a quadratic programming problem.* The objective of the quadratic programming problem will be to provide the most proportionate fill of Marine Corps' monthly staffing goals that is possible. The extent to which these staffing goals can be proportionately filled will be constrained by the following: (1) the numbers of prospective recruit training graduates who are to be trained for the various military occupational specialties (MOSs); (2) the utilization plans developed by TOUR II in previous months; (3) the Marine Corps' success in implementing those plans; (4) the expected utilization of planned, future recruit training graduates; and (5) Marine Corps' assignment policies.

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* The algorithm employs an approximation technique which is terminated when an optimum solution is achieved, or when the change in the objective function between iterations is less than an arbitrarily selected small number.

The remainder of this report describes TOUR II in greater detail. Section 2 discusses the development of the TOUR concept and the prototype TOUR I model. Section 3 summarizes TOUR II's capabilities, its relationship to PRE-PAS, and its design. Section 4 describes the track assignment methodology.

2.0 BACKGROUND

In early 1975, Marine Corps manpower managers were faced with an imperative need for new efficiencies in manpower management. During the course of that year four elements coalesced to create a unique set of constraints and requirements:

- An unacceptably high level of "personnel turbulence," defined by the Department of Defense (DOD) as "that degree of personnel movement which is over and above the minimum dictated by terms of service and reasonable tours of duty."

- The Brehm Directives, since codified as DOD Directive 1315.7, which placed new constraints on permanent change of station (PCS) moves.

- The Commandant's decision to adopt a "unit deployment" concept to meet FMF Western Pacific (WestPAC) requirements.

- The Commandant's concurrent decision to establish and maintain uniform levels of combat readiness among similar organizational units.

In response to these needs, two efforts were immediately undertaken. First, the Manpower Department at Headquarters Marine Corps formed a "Turbulence Committee" to explore means of reducing personnel turbulence and to assay means to respond to the movement restrictions posed by the Brehm Directives.

Second, a Unit Rotation Analysis Group (URAG) was activated to examine the problem of overseas unaccompanied (without dependents) tours.

While the Personnel Turbulence Committee and URAG were exploring means of achieving greater efficiencies in manpower management, DSAI conceived the TOUR approach to solving the problem of uneven combat readiness among deploying FMF units and as a means of responding to the Brehm Directives. The Personnel Turbulence Committee and URAG quickly recognized that the proposed TOUR concept could be effectively integrated into the evolving Precise Personnel Assignment System (PRE-PAS).

PRE-PAS was designed to integrate a family of computer models to give a total system approach to the training and assignment functions. Three main goals were fundamental to the PRE-PAS concept:

- Reduce personnel turbulence to meet DOD requirements,

- Ensure the highest level of uniform combat readiness throughout the Marine Corps, and

- Support unit rotation.

PRE-PAS evolved from a study of the assignment system used in 1976. This assignment system is still in use today and will be replaced when PRE-PAS becomes operational. This assignment system functions with a six-month horizon: anticipating billet vacancies, identifying the Marines available to fill those vacancies, and selecting Marines from those available to fill the vacancies. In addition, new graduates from recruit training were distributed monthly to entry-level training (ELT), anticipating their use in units following skill training. That system was incapable of assessing the effects of its assignments upon the overall fill of billets beyond the six-month assignment horizon. Paradoxically, although the ultimate effect of a given set of assignments on the distribution one or two years hence was unknown, a two-year ELT plan was developed. A key element in developing that plan was the ability to compare the inventory against the billet fill requirement.

As a result of this study, three concepts evolved that were essential to meeting the PRE-PAS goals:

- Centralized assignments to the battalion and squadron levels,
- Modification of both FMF and non-FMF tour length policies, and
- Implementation of a multiple future tour assignment planning and execution process.

Each of these concepts is described below.

Centralized assignment to the battalion/squadron level

The absence of centralized control has been a chief factor inhibiting the Services' ability to markedly reduce personnel turbulence. The PRE-PAS system will require that Headquarters Marine Corps assign individual Marines to battalions and squadrons. Currently, assignments to battalions and squadrons are made by unit commanders. Thus, PRE-PAS will shift the unit commander's traditional assignment authority to Headquarters Marine Corps. Concurrently, an obligation will be placed on Headquarters to generate and execute a plan that will markedly reduce the turbulence problems that have traditionally plagued local commanders.

Modification of FMF and non-FMF tour length policies

Tour length policies can significantly affect turbulence within the assignment cycle. A twelve-month mandatory tour length, for example, creates more movement within the overall system than a twenty-four-month tour length for the same location and population. The PRE-PAS concept was formulated with the understanding that more balanced tour length policies would reduce turbulence. The principal modifications to existing tour length policies will be to provide:

- Fixed tour lengths with variable staffing levels in the FMF, and
- Variable tour lengths with fixed staffing levels for non-FMF units.

A number of factors underscore the importance of these tour-length modifications:

(1) A command's ability to carry out its mission is affected by the number of personnel assigned to the command, and the ability of those personnel to work together as a unit. A command which has fewer personnel assigned than it is authorized will, in general, not carry out its mission as effectively as a command which has all of its authorized strength. However, even if a command has more personnel than are authorized, it will not be able to carry out its mission unless those personnel can work together effectively. In particular, if a large percentage of the personnel at a command have been there a short time, then they will not perform as effectively as would personnel who have worked together for a long time.

(2) It is seldom possible to supply each Marine Corps command with its authorized strength. The numbers of personnel in the Marine Corps are nearly always different from the numbers authorized. In addition, even when the total number of personnel is near the total number authorized, the numbers in some skills will be far short of their authorized numbers, and the numbers in some other skills will be in excess of their authorizations. The Marine Corps typically has assigned the authorized numbers of personnel to the non-FMF commands and spread the remainder of its personnel among the FMF commands. Thus, when there is a shortage of personnel, the FMF commands will be understaffed, and, when there is an excess of personnel, the FMF commands will be overstaffed.

(3) Maximum effectiveness of a command can most easily be achieved if personnel are assigned to the command for a fixed tour length (i.e., all personnel assigned remain there for the same length of time). Fixed tour lengths make the rate of turnover predictable: personnel who enter a command in different months will be replaced in different months, and personnel who enter in the same month will be replaced in the same month. Thus, so long as the current rate of turnover is kept at acceptable levels, the future rate of turnover also will be at acceptable levels. On the other hand, with variable tour lengths, personnel who enter a command in different months may have to be replaced in the same month. Consequently, a currently acceptable rate of turnover can lead to an unacceptably large turnover in some future months.

Due to differences in enlistment terms and differences in training times, it is not possible to maintain fixed tour lengths at all commands and to utilize all of each Marine's obligated service time. Therefore, to achieve maximum utilization of personnel, the FMF commands have operated with variable-length tours and the non-FMF commands have operated with fixed tour lengths.

(4) The use of variable-length tours at FMF commands has reduced the effectiveness of those commands. Personnel have been assigned to FMF commands who had less time remaining in the Marine Corps than would be required to prepare for and to complete a deployment. Such personnel must be assigned to a unit which will neither train for deployment nor deploy while they remain with the command. They are, therefore, less useful to the command than personnel who may deploy. In addition, if there are vacancies in units which will be deploying, it may be necessary to move a Marine from another unit to the deploying unit and to replace the Marine who is moved with the newly-assigned Marine. The result is that the effectiveness of the unit from which the Marine was moved will be reduced because a trained individual will be replaced by an untrained individual. If large numbers of Marines must be moved to accommodate the remaining times in service of newly assigned Marines, then the effectiveness of some units may drop below acceptable levels.

(5) To improve the overall effectiveness of deploying units, it was decided to adopt fixed length tours which are equal to the deployment cycle of those units. For example, each of three units in an eighteen-month deployment cycle will spend six months in a deployed status. By employing an eighteen-month tour length for those units, it can be ensured that: any new assignees will be able to complete a deployment; it will not be necessary to move other Marines between units to make use of a new assignee; and the overall rate of replacement for all units is acceptable.

(6) To accommodate the change to fixed tour lengths at FMF commands and to continue to achieve maximum utilization of personnel, it was necessary to switch to variable tour lengths at the non-FMF commands. This could be done without degrading the effectiveness of non-FMF commands so long as they continued to receive staffing fixed at their authorized strengths. Thus, what has evolved is an approach to the staffing problem which, in theory, is both simple and feasible: by varying opposite parameters (tour lengths and staffing levels) between the FMF and non-FMF commands, it is possible to establish complementary assignment policies and personnel flows that accommodate staffing priorities, deployment cycles, personnel availability, and turbulence goals. It is a balance of opposites: Marines completing deployment tours of fixed lengths with the FMF become eligible for assignment to the non-FMF, while those in the non-FMF on variable length tours, in turn, provide a ready pool of assets to support the FMF.

Forward (multiple) tour sequence planning

The current assignment system assigns Marines who are available for reassignment to command vacancies that are projected to appear six months in the future. It does not consider vacancies, nor the availability of personnel to fill vacancies, beyond the six-month horizon. As a result, the current system can make assignments which are desirable in the short run, but which are undesirable in the long run. Since there are minimum tour lengths at each command, the system cannot readily correct itself as the consequences of its decisions become apparent.

Marines are not assigned to a command unless they can complete a minimum length tour at that command. However, no consideration is currently given to those Marines' utility to the Marine Corps after they have completed their tours of duty at their new commands. As a result, some Marines may have time left to serve after they have completed their new tours, but may not have enough time left to complete a minimum tour at any command. Even if they could complete a minimum tour at some commands, other factors may prohibit them from being assigned to those commands.

PRE-PAS was therefore based on the commitment to shift from a "single future assignment" to a "multiple future assignment" process in which each Marine's assignments in the total period of enlistment are planned in advance. Such planning has the further advantage that the individual's training can be specifically tailored to need, achieving greater efficiencies in the training line. With extended planning, and with USMC Headquarters controlling both training and the assignment to individual battalions and squadrons, significant economies become possible. These economies result chiefly from more controlled scheduling and efficient movement of manpower throughout the system.

The TOUR concept

The PRE-PAS concept and TOUR solution approaches are congruent in three major respects:

- A greater level of detail in the assignment process, with assignments to the smaller battalion and squadron-size units rather than to the major command level.
- Modification of tour length policies to facilitate more uniform levels of readiness in the FMF, as well as a more effective overall utilization of personnel.
- An expansion of the management system's planning horizon from "single future" assignment to "multiple future tours."

In order to explore the feasibility of the TOUR concept with respect to the PRE-PAS system, a contract (N00014-76-C-0869) was awarded to DSAI in June 1976. That contract required development of a "computer-based policy gaming model (TOUR I) capable of generating optimal tour-relevant assignment strategies aimed at maximizing uniform readiness of FMF combat units." The thrust of this initial effort was to determine the feasibility of a major departure from traditional methods of managing first-term manpower.

As a result of studies made with the TOUR I model*, it was decided that an operational TOUR model (TOUR II) should become the central planning module of the PRE-PAS system. A contract for the development of TOUR II (N00014-78-C-0400) was awarded to DSAI in April 1978. TOUR II has been programmed, and the testing of the model was completed in December 1980. TOUR II, as is the entire PRE-PAS system, is scheduled to become operational in the fall of 1981.

* TOUR I: Final Technical Report. ONR Task NR-047-129, contract N00014-76-C-0869, April 1980.

3.0 SUMMARY OF TOUR II

3.1 Capabilities

TOUR II is a computer-based system designed to plan and monitor the chargeable utilization of a portion of the Marine Corps' enlisted force. That portion of the enlisted force which TOUR II will monitor is referred to as the TOUR-controlled force. In general, the TOUR-controlled force will consist of those enlisted Marines who are in their first enlistment terms. However, the TOUR-controlled force may contain some Marines who have extended their first enlistment terms, or who have reenlisted. Also, some first-term Marines may not be part of the TOUR-controlled force. Therefore, the term "TOUR-controlled" is preferred to the term "first-term" for describing the TOUR-controlled force.

TOUR II will develop chargeable utilization plans for Marines as they complete recruit training. TOUR II will be run monthly following execution of the Recruit Distribution Model (RDM). RDM will (and currently does) assign each Marine scheduled to complete recruit training in the coming month to an entry-level training (ELT) or to an on-the-job training (OJT) program. TOUR II will then develop utilization plans for those Marines which are consistent with their assigned ELT and OJT training programs.

The utilization plan that will be developed for an individual RDM-assignee is called a track. A track consists of the following information:

- the military occupational specialty (MOS) which the Marine should receive upon completing the RDM-assigned ELT or OJT program;
- the first tour category begin date (the year and month in which the Marine should begin chargeable duty);
- the first tour category (a tour category is a user-defined collection of commands and/or units with identical TOUR-relevant assignment characteristics. The first tour category is that tour category to which the Marine should be assigned as of the first tour category begin date.);
- the first tour category end date (the year and month in which the Marine should complete a tour at the first tour category);
- the second tour category (the tour category, if any, to which the Marine should be reassigned after completing a tour at the first tour category);
- the second tour category end date;
- the third tour category (the tour category, if any, to which the Marine should be reassigned after completing a tour at the second tour category); and
- the third tour category end date.

The track developed for an RDM-assignee will specify planned, chargeable utilization of that Marine during his first enlistment term. It will be consistent with the Marine's assigned training program, the time required to complete that program, the length of the Marine's current contract, and with Marine Corps' policy constraints (e.g., minimum and maximum permitted time on station at a tour category). In addition, TOUR II will structure the track, if possible, to meet non-mandatory Marine Corps' policy objectives (e.g., minimum and maximum desired time on station at a tour category).

Tracks will be assigned so as to minimize the deviation between planned staffing and long-range staffing objectives (called staffing goals). Long-range staffing goals will be produced by the Long-range Enlisted Staffing Goals Model (LRESGM). LRESGM will be run annually (or more frequently) to produce staffing goals for the next five years. These staffing goals will be based upon projected authorizations and projected accessions for the five-year period, and upon projected utilization of the TOUR-controlled force on-board at the time of the LRESGM run. The staffing goals will represent the "best" staffing of the authorizations given the projected accessions and the projected use of the on-board population. However, because the actual accessions and the actual use of the on-board force will never exactly equal the projections, it will not be possible to exactly meet these staffing goals. It will be TOUR II's task, given the actual accessions for a particular month and the planned utilization of accessions from previous months, to develop tracks which come as close as possible to meeting the long-range staffing goals.

Tracks will be used by enlisted assignment monitors and by the Enlisted Assignment Model (EAM) to make assignments to overseas and to CONUS MCCs. Generally, a TOUR-controlled Marine will be given orders to move from his current assignment as of the current tour completion date in his track, and to move to a command or unit which is a member of the next tour category in that track. However, circumstances which were unforeseen by TOUR II may require that a TOUR-controlled Marine be moved off-schedule or to a command or unit in another tour category. Such an assignment is said to break the track. A track-breaking assignment is generally undesirable since it will result in greater deviation from the long-range staffing goals than if the Marine were assigned on-track.

TOUR II will monitor the assignments of TOUR-controlled Marines to determine if their tracks have been broken. Whenever it finds a Marine with a broken track, it will assign a new track to that Marine which is consistent with the Marine's actual assignment. The procedure for assigning the new track is similar to that used to assign tracks to RDM-assignees.

A Marine's track will also be broken if that Marine is trained in an MOS other than the track's MOS, or if the Marine completes training at a different time than planned in the track. Therefore, TOUR II will monitor the MOSs of trained Marines to determine if their tracks have been broken. It will also monitor the projected MOSs and projected training completion dates of trainees to determine if their tracks have been broken. New tracks will be assigned to those Marines whose tracks have been broken.

3.2 TOUR II's Role within PRE-PAS

TOUR II is a member of the Precise Personnel Assignment System (PRE-PAS). PRE-PAS is a soon-to-be-implemented collection of automated and manual procedures for planning the utilization of the enlisted force and for making individual assignments which implement those utilization plans. The principal objectives of PRE-PAS are:

— to maximize the Marine Corps' readiness to perform its mission;

— to minimize associated personnel costs;

— to monitor how well the PRE-PAS utilization plans are implemented; and

— to provide Marine Corps' headquarters with the capability to rapidly modify the plans to accommodate changes in mission, policy, force size, and/or force skill structure (or to predict the effects of possible changes).

Once implemented, PRE-PAS will maximize readiness by developing plans for recruiting, training and utilizing the trained force, and by striving to meet those plans as closely as possible. Long-term as well as short-term objectives will be considered in developing and executing the plans. In this way, PRE-PAS will ensure that decisions taken to improve short-term readiness will not (needlessly) degrade future readiness.

TOUR II will play an important role in maximizing readiness. Assuming that individual assignments for the TOUR-controlled force are consistent with the tracks assigned by TOUR II, TOUR II will serve to maximize readiness in four ways. First, in assigning tracks, TOUR II will attempt to proportionately fill the long-range staffing goals. To the maximum extent possible, personnel shortages and excesses will be shared fairly among the tour categories (in general, due to tour length constraints and objectives, and due to tour sequence restrictions, shortages and excesses cannot be exactly fair-shared). Fair-sharing will be accomplished over the entire period that the Marines being tracked are projected to remain in the TOUR-controlled force. Thus, if assignments are made which are consistent with those tracks, then the overall readiness of the MCCs in each tour category will be approximately the same. Additionally, track-consistent assignments will not (needlessly) degrade future readiness.

The second way in which TOUR II will serve to maximize readiness is by minimizing the amount of time lost to stub tours. A stub tour is not a tour at all. Rather, it is the time period between a Marine's last chargeable tour and the date that the Marine leaves the Marine Corps. A stub tour results when a Marine does not have sufficient time remaining after a tour of duty to complete a minimum tour of duty at another location. By minimizing the amount of time spent in stub tours, TOUR II will help to maximize the chargeable utilization of the TOUR-controlled force (in general, due to tour length and tour sequencing policies, stub tours cannot be eliminated if all tour categories are to be staffed).

The third way in which TOUR II will serve to maximize readiness is by helping to minimize the amount of time spent moving between duty stations. In assigning tracks, TOUR II will consider the staffing consequences of those assignments over the entire period that the tracked Marines are projected to remain in the TOUR-controlled force. Therefore, if MCC assignments are consistent with the tracks, the probability will be reduced that unplanned reassignments must be made. This also will help to maximize the chargeable utilization of the TOUR-controlled force.

The fourth way in which TOUR II will serve to maximize readiness is by ensuring the deployability of Marines assigned to deployment MCCs. Readiness at a deployment MCC is maximized if the Marines assigned to it are eligible to participate in that MCC's next deployment. To be eligible to participate in that deployment, a Marine must have completed skill training, that Marine's prior tour history must be acceptable, and that Marine must have sufficient time left in the Marine Corps to complete the deployment. Using user-specified track-construction constraints and objectives, TOUR II will accommodate these three aspects of deployability.

TOUR II will work to reduce personnel costs in the following two ways: by minimizing time lost to stub tours and by helping to minimize the time spent moving between duty stations. As a result, chargeable utilization will be maximized, permitting the Marine Corps to operate with a smaller total force than it could operate with if chargeable utilization were not maximized. In addition, by minimizing the time spent moving between duty stations, TOUR II will help to minimize PCS movement costs.

TOUR II will monitor the implementation of two sets of PRE-PAS utilization plans: those developed by LRESGM and those developed by TOUR II. TOUR II produces three reports which monitor the implementation of LRESGM's long-range staffing goals. These reports compare the long-range staffing goals with expected staffing over a four-year period. The expected staffing will be determined from the tracks of on-board Marines and the tracks projected by LRESGM for future accessions. TOUR II will monitor its own plans (i.e., the tracks) to determine if they have been broken, retracking any Marines with broken tracks, and outputting those new tracks for inclusion in the DBMS.

TOUR II will promote rapid modification of the PRE-PAS plans in the following ways:

— TOUR II will automatically retrack Marines who have received track-breaking assignments;

— TOUR II will automatically retrack Marines who are trained for MOSs other than their track MOSs, or who complete training in other than the nominal training time for their MOSs;

— TOUR II will automatically accommodate variations from the recruiting plans by tracking RDM-assignees so as to achieve proportionate fill of the staffing goals (thus minimizing the effects of these variations upon readiness); and

— TOUR II can be instructed to retrack Marines with particular MOSs, permitting rapid accommodation of changes in policy, the long-range staffing goals, or unacceptably large deviations from the long-range staffing goals caused by track-breaking assignments.

3.3 Operations and Data Flows

Figure 3-1 summarizes the operations and data flows within TOUR II. As indicated in that figure, the following five major operations are performed within TOUR II:

(1) Control cards are validated and transformed into internal model formats for use in the other operations.

(2) Tracking information is extracted from the RDM-recommended assignments and from an extract of the Manpower Management System/Data Base Management System (MMS/DBMS). The tracking information includes sufficient information to track the RDM assignees, to track the Marines who are to be retracked, to project the future chargeable contributions of those Marines who are not to be retracked, and to allocate chargeable assignments to those trainees who are projected statistically to wash out of (i.e., to fail) their current training programs. As part of this operation, TOUR II determines A-MOSs* for those recruits whose RDM assignments specify basic MOSs rather than A-MOSs. Additionally, in extracting the tracking information, RDM assignees who are not tobe tracked, or who cannot be tracked, are identified, and their RDM assignments are preserved for later merging with the tracked RDM assignees.

(3) The relevant plans are extracted from the long-range enlisted staffing goals and from the planned tracks. The long-range enlisted staffing goals and the planned tracks will be produced by LRESGM, one of the TOUR Relevant Inventory Projection (TRIP) models. The extracted tracks include those planned by LRESGM for the graduation month of the RDM assignees and those planned for subsequent months. The current graduation month's planned tracks are used to track the retrackees. The future months' planned tracks are used to track both the retrackees and the RDM assignees.

(4) Tracks are assigned to the retrackees and to the RDM assignees so as to provide the most proportionate possible fill of the long-range enlisted staffing goals. As part of this operation, TOUR II projects the chargeable contributions from all other sources during a 48-month period. This projection is made from the tracks of those on-board Marines who are not retracked, from the planned tracks, and from an allocation of the statistically projected training wash-outs to chargeable assignments.

(5) The track assignments are reported. The records of the RDM assignees who were tracked (including any A-MOSs which were determined by TOUR II) are merged with the records of those who were not, and the resulting file is forwarded to the recruiting depots. The tracks assigned to the RDM assignees and to the retrackees are output to a file which is used to enter the tracks into the MMS/DBMS. Three summary reports are produced. These summary reports compare the long-range enlisted staffing goals with the staffing which will result if the newly-assigned tracks, the tracks of the on-board population which was not retracked, and the planned tracks are honored.

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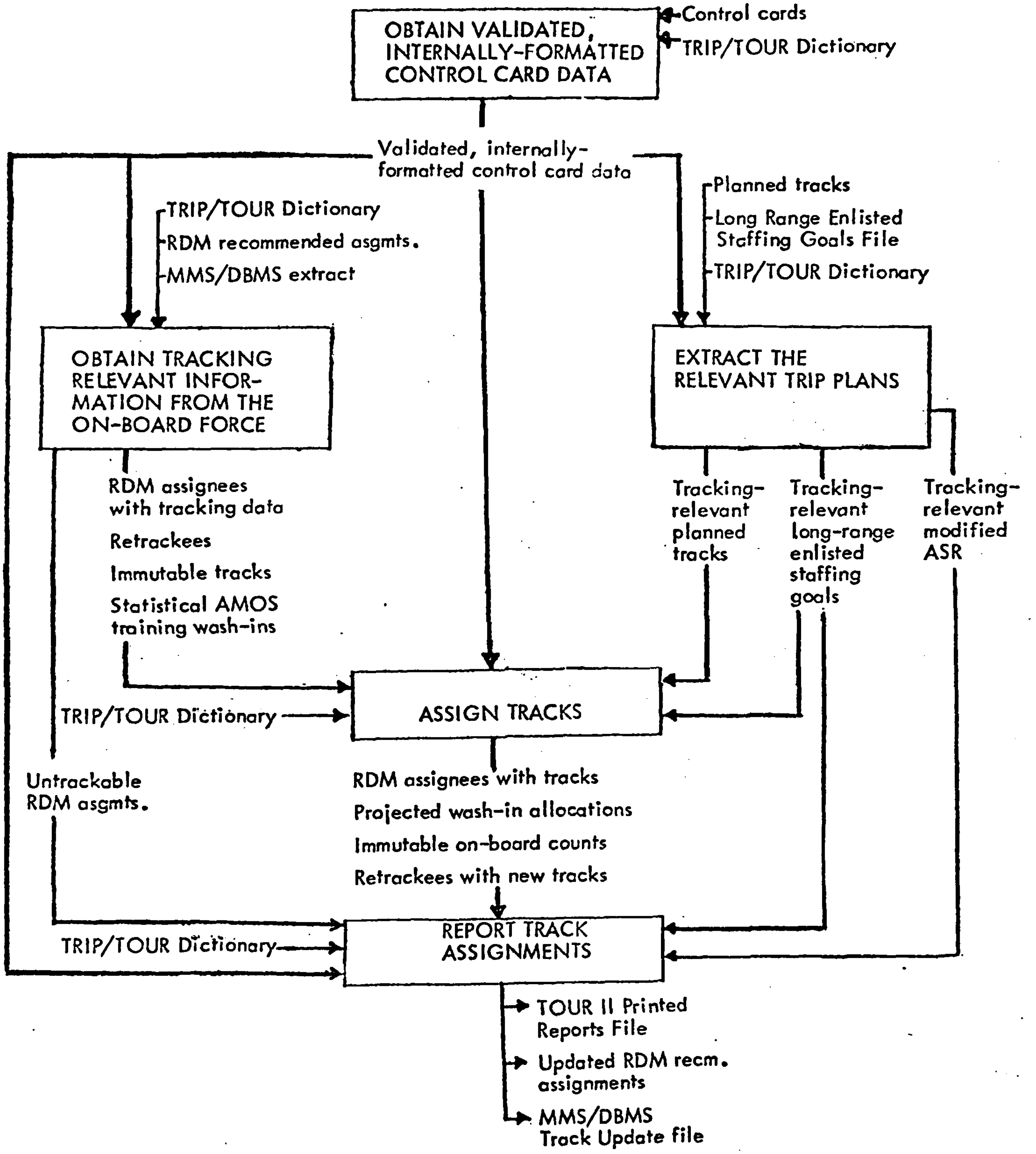
* Untrained Marines carry MOSs which are different from those carried by trained Marines. To differentiate between these types of MOSs, the MOSs of untrained Marines are called basic MOSs, and the MOSs of trained Marines are called A-MOSs.

Figure 3-1: SUMMARY OF TOUR II PROCEDURES AND DATA FLOWS



4.0 TRACK ASSIGNMENT METHODOLOGY

The heart of TOUR II is an iterative algorithm which obtains an optimal solution to a quadratic objective function while maintaining linear constraints. This algorithm employs an approximation technique which is terminated when an optimum solution is achieved or when the change in the objective function between iterations is less than an arbitrarily selected small number. The objective function can be expressed as:

$$z = \sum_{m=1}^{M} \sum_{t=1}^{T} \sum_{p=1}^{P} \sum_{g=1}^{G} \frac{\left[d\,(m,\ t,\ p,\ g) \right]^2}{s\,(m,\ t,\ p,\ g)}$$

where:

M = the number of MOSs;

T = the number of tour categories;

P = the number of time periods (i.e., the number of months);

G = the number of grade groups*;

$d\,(m,t,p,g)$ = the difference between the staffing goal for and the projected staffing of MOS m at tour category t in time period p and grade group g; and

$s\,(m,t,p,g)$ = the staffing goal for MOS m at tour category t in time period p and grade group g.

The difference between the staffing goal and the projected staffing can be expressed as:

$$d\,(m,t,p,g) = s\,(m,t,p,g) - c\,(m,t,p,g) - \sum_{r=1}^{R} \delta(m,t,p,g,r)\, x_r$$

where:

$c\,(m,t,p,g)$ = the projected chargeable contribution of MOS m at tour category t in time period p and grade group g from the on-boards who will not be retracked and from the planned tracks;

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* There are two grade groups. The grade group of a particular Marine is a function of that Marine's MOS and time in service.

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R = the number of tracks*;

$\delta(m,t,p,g,r)$ = 1 or 0 as track r does or does not flow through tour category t in time period p with MOS m assignees who will be in grade group g in time period p*; and

x_r = the number of Marines assigned to track r.

The linear constraints which are maintained by the iterative, optimal algorithm are of two types: (1) absolute constraints which indicate which Marines may be assigned to which tracks, and (2) objective constraints which bound the staffing at and/or the flow into some tour categories by some MOSs. The absolute constraints can be expressed as:

$$b(m,a,e,h) = \sum_{r=1}^{R} x_r \, g(m,a,e,h)$$

where:

$b(m,a,e,h)$ = the number of Marines to be tracked in MOS m whose active duty began in month a, whose TOUR-controlled service will end in month e, and who have tour history h; and

$g(m,a,e,h)$ = 1 or 0 as track r is or is not a track for MOS m Marines whose active duty began in month a, whose TOUR-controlled service will end in month e, and who have tour history h.

There is one such constraint for each different MOS/active duty begin month/end of TOUR-controlled service month/tour history combination which is found amongst the retrackees and the RDM assignees. A Marine's tour history includes the Marine's current chargeable tour category (if any), the month that the current chargeable tour began, any previous chargeable tour categories, and, if the Marine is on orders to a chargeable assignment, the tour category to which the Marine has been ordered and the date that that tour will begin.

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* All Marines assigned to a particular track must have the same grade group in each month. This is possible only if they all joined the service in the same month. Therefore, TOUR II differentiates between the tracks of Marines with the same MOS who joined the service in different months, even if those tracks contain the same tour sequence and transfer dates.

The objective constraints consist of upper and lower bounds which can be expressed in the following forms:

$$c(m,t,p,g) + \sum_{r=1}^{R} \delta(m,t,p,g,r)\, x_r \geq l_s(m,t)\, s(m,t,p,g);$$

$$c(m,t,p,g) + \sum_{r=1}^{R} \delta(m,t,p,g,r)\, x_r \leq L_s(m,t)\, s(m,t,p,g);$$

$$f(m,t,p,g) + \sum_{r=1}^{R} \varphi(m,t,p,g,r)\, x_r > l_f(m,t)\, s(m,t,p,g);$$

$$f(m,t,p,g) + \sum_{r=1}^{R} \varphi(m,t,p,g,r)\, x_r \leq L_f(m,t)\, s(m,t,p,g)$$

where:

$l_s(m,t)$ = the lower bound ratio for staffing at tour category t by MOS m $(0 \leq l_s(m,t) \leq 1)$;

$L_s(m,t)$ = the upper bound ratio for staffing at tour category t by MOS m $(1 \leq L_s(m,t))$;

$f(m,t,p,g)$ = the number of arrivals projected in MOS m at tour category t in time period p and grade group g from the on-boards who will not be retracked and from the planned tracks;

$\varphi(m,t,p,g,r)$ = 1 or 0 as track r does or does not begin a tour at tour category t in time period p with MOS m assignees who will be in grade group g in time period p;

$l_f(m,t)$ = the lower bound ratio for flow into tour category t by MOS m $(0 \leq l_f(m,t) \leq 1)$; and

$L_f(m,t)$ = the upper bound ratio for staffing at tour category t by MOS m $(l_f(m,t) \leq L_f(m,t))$.

These bounds cannot necessarily be met. When they cannot be met, TOUR II minimizes the sum of the squared deviations from the bounds. The resulting bounds are then used in place of the original bounds.

The quadratic programming problem which results from the objective function and the constraints is solved via an algorithm which employs a classical approximation technique. This is an in-core algorithm which has been programmed in an extended version of FORTRAN V for a CDC CYBER 175 computer. The algorithm has been programmed to take advantage of bit-packing and unpacking instructions which are available in CDC FORTRAN, thereby permitting the algorithm to solve larger problems than would otherwise be possible.

The number of computer words required to solve a particular problem is:

$$S = N + (7 + N) R + 4 TP + R (N+C)$$

where:

S = the number of computer words required;

N = the number of distinct combinations of MOS/active duty begin month/end of TOUR-controlled service month/tour history;

R = number of tracks;

T = number of tour categories;

P = number of time periods; and

C = the number of objective constraints.

In general, the following approximations hold:

$N = MH$;

$R \geq 100N = 100MH$;

$T = 20$; and

$P = 40$.

where:

M = the number of MOSs; and

H = the average number of active duty begin month/end of TOUR-controlled service month/tour history combinations per MOS.

Thus, the number of computer words required to solve a particular problem is approximately:

$$S = MH + (7 + MH)\ 100MH + 3200 + 100MH\ (MH + C)$$

$$= (701 + 100C)\ MH + 200M^2H^2 + 3200 \geq 701M + 200M^2 + 3200.$$

Since the number of MOSs is approximately 300, the number of computer words required to solve a particular problem is in excess of 18,143,400. This number is far greater than the number of words which are available within the core of the CDC CYBER 175 computer.

It is not necessary to solve the entire problem at once. The quadratic programming problem can be broken into independent problems, one problem per MOS. If each of these is solved optimally, then the entire problem has been solved optimally. A single MOS requires approximately the following number of computer words:

$$S = (701 + 100C)H + 200H^2 + 3200.$$

Unfortunately, for some MOSs, H can be in excess of 100. Thus the number of computer words required for those MOSs is in excess of 2,073,300. This number is also far greater than the number of words which are available within the core of the CDC CYBER 175 computer.

The value of H is not directly related to the number of Marines to be tracked. For example, in an MOS there may be twenty Marines to retrack, but no two of them may be eligible for the same tracks. Thus, in this MOS, H is at least equal to twenty. On the other hand, there may be 100 RDM assignees in that same MOS, but they may all be eligible for the same tracks. Thus, H is equal to twenty-one for this MOS.

In general, if there were no retrackees, then each MOS's quadratic programming problem could be solved in core. Normally, the RDM assignees can be assigned to one or two distinct sets of tracks. Thus, ignoring the number of objective constraints, the quadratic programming problem generated by the RDM assignees alone requires approximately 5,402 computer words. This problem will easily fit in core.

To obtain a problem which can be solved in core, TOUR II partitions each MOS's track assignment problem into two problems: one for retrackees and one for RDM assignees. The RDM assignees' problem is solved using the iterative, optimal algorithm described above. The retrackees' problem, however, is too large to be solved using that algorithm. Therefore, the retrackees are assigned tracks via a different algorithm.

Retrackees are assigned individually, rather than as a group. Each retrackee is assigned a track which, given all previous retracking assignments, meets certain acceptability requirements (these requirements are discussed below). This track assignment ignores, however, all subsequent retracking assignments. As a result, the retrackees' assignments, taken as a group, may not be optimal. Similarly, the retrackees and the RDM assignees, taken as a combined group, may not be optimal.

While the set of retracking assignments may not be optimal, their effect upon the overall solution is generally small. Unless the model user has requested that all of the Marines with a particular MOS be retracked, the number of retrackees in that MOS, relative to the number of RDM assignees, should be small. Therefore, since the number of such assignments is relatively small, their overall effect upon the quality of the solution should also be small. Hence, the overall solution should be near, although not necessarily equal to, an optimal solution.

If the model user requests that all Marines in a particular MOS be retracked, then the number of retrackees in that MOS will be much larger than the number of RDM assignees in that MOS. Consequently, unless some care is exercised, the combined tracking solutions for that MOS could be significantly different from an optimal solution.

To avoid solutions which differ significantly from the optimal, TOUR II solves each MOS's retracking problem in two steps. In the first step, TOUR II determines the optimal allocation of retrackees without regard for tracking constraints. This is done by projecting the number of retrackees in each time period and grade group, and then making separate allocations for each time period and grade group. In the second step, in which the tracks are assigned, these track-free allocations are employed as a guide.

A retrackee is assigned the first eligible track encountered by TOUR II which, when the retrackee is projected in that track, would not produce staffing in excess of the track-free allocations in any month. If there is no such track, then the retrackee is assigned a track which, given all previous retracking assignments, will produce the most proportionate fill of the staffing goals. For a retrackee who has been user selected (i.e., whose track is not broken), the first track considered is the retrackee's current track. In this way, TOUR II promotes the objective of minimizing the number of new tracks which are assigned. This objective is further promoted by the fact that the retrackees whose tracks are not broken are assigned tracks prior to those retrackees whose tracks are broken.

In addition to providing a highly desirable, though presumably unattainable solution, the track-free allocations enable the retracker to consider the upper and lower staffing bounds. Each track-free allocation is made in accordance with those bounds.* As a result, the retracker is biased toward honoring the staffing bounds.

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* Since it is not possible to anticipate arrivals when making the track-free allocations, the upper and lower flow bounds are not considered.

APPENDIX

Technical Description of the TOUR Optimization Algorithm

This appendix discusses the mathematical foundations of the solution approach used to optimally allocate RDM assignees. The algebraic equations defining the problem are developed, along with a discussion of the solution approach.

The basic tour optimization problem can be formulated for each MOS in terms of track flows, staffing goals, and actual staffing at tour categories during each time period. Ignoring grade groupings, the actual staffing at a tour category during a given time period is equal to (1) the sum of the solution tracks flowing through that tour category in that time period, plus (2) the projected number of currently tracked on-board Marines remaining in that tour category, plus (3) future accessions who will also be on-board in that tour category for that time period. Thus, the difference between the staffing goal and the actual staffing can be expressed as

$$(1)\quad \Delta_{ip} = s_{ip} - c_{ip} - \sum_{k=1}^{n} \delta_{ipk}\, x_k$$

where

Δ_{ip} = the difference at tour category "i" during time period "p"

s_{ip} = the staffing goal at tour category "i" during time period "p"

c_{ip} = the projected number of currently tracked Marines and future accessions who will be on-board at tour category "i" during time period "p"

x_k = the flow over track "k"

δ_{ipk} = 1 or 0 as track "k" does or does not, respectively, flow through tour category "i" during time period "p"

n = the number of tracks.

The objective of the TOUR II optimal allocator is to determine the flows along the various tracks which will minimize the weighted sum of squares of the differences between the staffing goals and the actual staffing. Algebraically, this is equivalent to finding the values of $x_1, \ldots, x_n$ which minimize the value of the objective function f where

$$(2) \quad f = \sum_{i=1}^{m} \sum_{p=1}^{h} \frac{(\Delta_{ip})^2}{s_{ip}}$$

where

m = the number of tour categories

h = the number of time periods.

The value of f must be minimized subject to the constraints that the flows upon the tracks must be non-negative, and that the sum of the flows upon the tracks associated with a particular enlistment term must equal the number of recruits classified with that enlistment term. The TOUR II optimal allocator accommodates three distinct enlistment terms (any number of distinct enlistment terms could be accommodated); therefore, these constraints can be expressed as

$$(3) \quad x_k \geq 0, \quad 1 \leq k \leq n$$

$$(4) \quad \sum_{k=1}^{n_1} x_k = \beta_1$$

$$(5) \quad \sum_{k=n_1+1}^{n_2} x_k = \beta_2$$

$$(6) \quad \sum_{k=n_2+1}^{n_3} x_k = \beta_3$$

where

β_1 = the number of recruits within the first enlistment term classification

β_2 = the number of recruits within the second enlistment term classification

β_3 = the number of recruits within the third enlistment term classification

n_1 = the number of tracks associated with enlistment term classification 1

n_2 = n_1 plus the number of tracks associated with enlistment term classification 2

n_3 = $n_1 + n_2$ + the number of tracks associated with enlistment term classification 3 ($n_3 = n$).

The three constraint equations (4), (5), and (6) can be represented in the expression for the function f by solving them respectively for x_{n_1}, x_{n_2}, and x_{n_3} and substituting the values in equations (1) and (2) to obtain

$$(7)\quad f = \sum_{i=1}^{m} \sum_{p=1}^{h} \frac{\left(s_{ip} - c_{ip} - \sum_{k \neq n_1, n_2, n_3} \mu_{ipk} \, x_k + \delta_{ipn_1} \beta_1 + \delta_{ipn_2} \beta_2 + \delta_{ipn_3} \beta_3\right)^2}{s_{ip}}$$

where

$$\mu_{ipk} = \begin{cases} \delta_{ipk} - \delta_{ipn_1}; & 1 \le k \le n_1 - 1 \\ \delta_{ipk} - \delta_{ipn_2}; & n_1 + 1 \le k \le n_2 - 1 \\ \delta_{ipk} - \delta_{ipn_3}; & n_2 + 1 \le k \le n_3 - 1. \end{cases}$$

It can be shown that, ignoring the non-negative constraint (3), that f obtains a minimum value, and that it obtains this minimum value whenever the partial derivatives of f with respect to the flows are all zero. That is:

$$(8)\quad 0 = \frac{\partial f}{\partial x_\ell} = 2 \sum_{i=1}^{m} \sum_{p=1}^{h} (-\mu_{ip\ell}) \frac{s_{ip} - c_{ip} - \sum_{k \neq n_1, n_2, n_3} \mu_{ipk}\, x_k + \delta_{ipn_1}\beta_1 + \delta_{ipn_2}\beta_2 + \delta_{ipn_3}\beta_3}{s_{ip}}$$

for all ℓ, $1 \leq \ell \leq n; \ell \neq n_1, \ell \neq n_2, \ell \neq n_3$.

The equations of the form (8) are linear equations in the variables $x_1, \ldots,$ $x_{n_1-1}, x_{n_1+1}, \ldots, x_{n_2-1}, x_{n_2+1}, \ldots, x_{n_3-1}$ and can be represented in the form

$$(9)\quad \sum_{k \neq n_1, n_2, n_3} a_{\ell k}\, x_k = b_\ell, \quad 1 \leq \ell \leq n, \ell \neq n_1, \ell \neq n_2, \ell \neq n_3$$

where

$$a_{\ell k} = \sum_{i=1}^{m} \sum_{p=1}^{h} \frac{\mu_{ip\ell}\, \mu_{ipk}}{s_{ip}^2}, \text{ and}$$

$$b_\ell = \sum_{i=1}^{m} \sum_{p=1}^{h} \mu_{ip\ell} \frac{s_{ip} - c_{ip} + \delta_{ipn_1}\beta_1 + \delta_{ipn_2}\beta_2 + \delta_{ipn_3}\beta_3}{s_{ip}}$$

These equations can be solved to determine the optimum (or an optimum if the solution is not unique) flow on the various tracks. However, it can occur that the optimum value will occur with one or more negative track flows; thus violating constraint (3). In this latter case, it can be shown that the optimum, constrained solution will be obtained with one or more of the track flows equal to zero.

In addition to constraints upon the numbers of recruits, the TOUR II optimal allocator considers constraints upon the flows through various tour categories. These additional constraints are required to express even flow restrictions for deploying units, and to manage the overall distribution of personnel shortages and excesses. These constraints may be expressed as:

$$(10)\ \Delta_{ip} \leq u_{ip}$$

$$(11)\ \Delta_{ip} \geq l_{ip}$$

where u_{ip} = the upper bound on the flow through tour category "i" during time period "p"

l_{ip} = the corresponding lower bound.

Through an extension of the solution procedure discussed above, constraints of the types (10) and (11) may be imposed, together with constraints upon the total numbers of recruits, to obtain an optimum flow upon the various tracks. Again, it may occur that the optimum solution will be infeasible (i.e., it will involve a negative flow upon one or more tracks). However, while there will always be feasible solutions available for the equations (4) through (6),* the imposition of additional constraints may make it impossible to obtain a feasible solution. Indeed, such an expanded set of constraints might be inconsistent, having no solution, feasible or infeasible, at all.

Ignoring, for the moment, the problem of dealing with inconsistent or infeasible constraints, two alternative programming techniques are available for minimizing the value of the function f subject to the constraints (3) through (6), (10), and (11). The first approach calls for obtaining solutions to linear equations, similar in nature to equation type (9), until a minimum, constrained solution is obtained. The second approach calls for obtaining constrained solutions and adjusting them until a minimum value for the equation (2) is found.

Solving linear equations of the type (9) can be done rapidly on a computer in a number of different ways. However, if the solution obtained contains a negative flow, then great effort may have to be expended to find an optimal, constrained solution. Once an optimal solution with a negative flow has been found, it is known that the optimal, feasible solution will contain at least one zero flow. The difficulty arises in determining which flows will be zero. The most general approach is to try all the various combinations of zero flows which can be obtained from the variables to see which produces the smallest value of the function f. This approach is impractical, however, with the number of variables which would be involved in the problem at hand (the number of variables is equal to the number of tracks, about 100, plus the number of inequalities; thus the number of combinations of zero flows would be in excess of 2^{100}). In addition, this approach is of no help if the system of constraints is infeasible or inconsistent.

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* As one example of a feasible solution, assign all two-year enlistees to the same two-year track, all three-year enlistees to the same three-year track, and all four-year enlistees to the same four-year track.

The second alternative programming technique is better suited to the problem at hand, and is employed in the TOUR II optimal allocator. With this technique, an initial, feasible solution is obtained, and then modified, iteratively, improving the value of the objective function at each iteration, until an optimal solution is obtained.* This approach has certain distinct programming advantages over the explicit solution technique discussed above. First, if the solution time should become excessive for a particular problem, the procedure may be interrupted to obtain a feasible, less accurate, approximation to the optimum solution. The explicit technique may not be interrupted, since it does not obtain a feasible solution until the problem is solved optimally. The second advantage of the iterative approach is that it can be extended to deal with infeasible or inconsistent constraints.

The primary problem with the iterative technique for solving the tour optimization problem is that an initial, feasible solution must be found to start the solution process. If we are only dealing with the constraints (3) through (6), then an initial, feasible solution is trivially obtained. If additional constraints are imposed, however, an initial feasible solution is more difficult to obtain. In fact, there may be no such solution.

Fortunately, the iterative technique may be extended to develop an initial, feasible solution, or, if no such solution is possible, to modify the constraints until such a solution can be found. The procedure for obtaining a feasible solution involves the introduction of slack variables.

The inequalities (10) and (11) may be reformulated as equalities of the form

$$(12)\quad \Delta_{ip} + s_{ip} = u_{ip}$$

$$(13)\quad \Delta_{ip} - t_{ip} = l_{ip}$$

where s_{ip} and t_{ip}

are slack variables introduced for the purpose of writing the inequalities as equalities. So long as the values of these slack variables are non-negative, the corresponding inequalities will be satisfied. On the other hand, if the value of one or more slack variables is negative, the current solution is infeasible.

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* More properly, the solution obtained is an approximation to an optimal solution. This approximation may be as close to the optimal value as desired. However, the closer the approximation, the greater the execution time to solve the problem.

By formulating an optimization problem in terms of the values of the slack variables, an initial, feasible solution may be obtained. The optimization function for this problem is the sum of the squares of the negative slack variables, and the objective is to minimize the value of this function. The constraints are of the types (3), (4), (5), (6), (12), and (13). Thus, the track flows are required to be non-negative, but the slack variables may be negative. An initial, feasible solution to this problem can be obtained since any feasible solution to equations (4) through (6) is also a feasible solution for this problem. Starting with such a feasible solution, if the objective function can be driven to zero, then a feasible solution has been found to the tour optimization problem. If the function cannot be driven to zero, then no feasible solution exists for the problem.

When no feasible solution exists to the TOUR II optimization problem, a simple, optimal procedure is available for relaxing the original constraints to permit a feasible solution. This procedure is, after a least-squares fit of the original bounds has been obtained, to set all negative slack variables to zero and adjust the corresponding bounds so that the equalities of equations (12) and (13) are preserved. Thus, lower bounds are reduced and upper bounds are increased, and an initial, feasible solution is obtained to the modified constraints. Then an optimal solution for the original objective function, f, is obtained subject to these new, modified constraints. Since the values of all variables, including slack variables, obtained in this latter solution are non-negative, this solution preserves the least-squares fit to the original, infeasible constraints.

A set of user-supplied bounds priorities is used to develop an initial, feasible solution. These priorities permit the user some control over the manner in which bounds are relaxed. The first step in establishing an initial, feasible solution is to meet, as closely as possible, the bounds with the highest priority. Then, in descending priority sequence, the bounds at each lower level priority are met as closely as possible. However, at each lower level the least-squares fit to the bounds at all higher levels is imposed as a constraint. Thus, for example, the fit of the bounds at level three cannot influence the fit at levels one or two. This procedure allows the user to control modifications of the constraints so that the more important bounds, such as those regulating flow into deploying units, are met in preference to other, less important bounds.

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