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Basic Computer Models for Manpower Planning

by

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The computerized manpower planning models in this thesis are designed to be used in conjunction with a course in the Manpower, Personnel and Training Analysis (MPTA) curriculum at the Naval Postgraduate School. The purpose of these models is to introduce students to some of the basic manpower modeling ideas. The models included here were written in the APL (A Programming Language) programming language and include a Markov Chain model, a model to compute attrition rates from both cohort and census data, a vacancy chain model and a career patterns model.

The programs run on IBM-compatible microcomputers using DOS (Version 2.1 or later), STSC's APL*PLUS System for the PC (Version 9.0 or later) and STSC's STATGRAPHICS (Statistical Graphics System) (Version 4.0 or later). The latter software is needed only for a graphical comparison within the attrition rate model. A user's manual for each model is included in the appendices.

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Basic Computer Models for Manpower Planning

by

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ABSTRACT

The computerized manpower planning models in this thesis are designed to be used in conjunction with a course in the Manpower, Personnel and Training Analysis (MPTA) curriculum at the Naval Postgraduate School. The purpose of these models is to introduce students to some of the basic manpower modeling ideas. The models included here were written in the APL (A Programming Language) programming language and include a Markov Chain model, a model to compute attrition rates from both cohort and census data, a vacancy chain model and a career patterns model.

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THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I would like to express my special thanks to my thesis advisor Professor Paul R. Milch for his guidance and patience in the preparation of this thesis, and to Professor Robert R. Read for his contributions.

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I. INTRODUCTION

A. BACKGROUND

In general, manpower planning is a multi-disciplinary activity concerned with matching the supply of personnel with the jobs available [Ref. 1: p. V].

In recent years, computers have had an increasing role in the operation and administration of the civilian and military services. To make manpower planning by personnel managers less time consuming and applicable to a wider area, computerizing manpower planning models seems to be highly appropriate. The software programs provided in this thesis were designed to be used in conjunction with the course OS4701, entitled "Manpower and Personnel Models". This course is a required course in the Manpower, Personnel and Training Analysis (MPTA) curriculum at the Naval Postgraduate School. The MPTA curriculum, is designed for future leaders of Navy manpower management to ensure that the Navy is recruiting, training, utilizing and retaining personnel in the most effective and efficient way. MPTA is the curriculum that graduates officers skilled in conducting manpower policy analysis and teaches familiarity with current models and methods of MPT analysis [Ref. 2: p. 44]. Although some of the models presented in this thesis have been previously used in the course, this is the first time that a concentrated effort has been made to program them in a completely user friendly way, thoroughly documented and packaged in a uniform format compatible with each other.

The following models are developed to be used on an IBM or compatible PC:

1. Transition Models based on Markov Chain Theory

2. Analysis of Attrition Models

   a. Cohort (Longitudinal) Analysis

   b. Census (Cross-sectional) Analysis

   c. Graphical Comparisons

3. Transition Models based on Renewal Theory (Vacancy model)

   a. One-grade Systems

   b. Multi-grade Systems

4. Career Patterns Models

   a. Career Patterns Model

   b. Career Patterns using Markov Chain Model

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All models were programmed in APL (A Programming Language) with the Graphical Comparisons among the Analysis of Attrition Models (Model 2) requiring STATGRAPHICS (Statistical Graphics System) as well.

Models 1, 3 and 4 were first programmed in Bartholomew and Forbes [Ref. 1] although the language used there was BASIC and the format not particularly user friendly.

The computer system requirements for the programs can be found in Appendix A.

B. THE AVAILABILITY OF COMPUTER PROGRAMS

A copy of the programs presented in this thesis is available from Professor Paul R. Milch at the Naval Postgraduate School (Code OR/Mh), Monterey, CA 93943.

C. COPYRIGHT NOTICE

The workspaces written in this thesis must be used with a registered copy of STSC's APL*PLUS System for PC Computers and in the case of Graphical Comparisons among the Analysis of Attrition Models, a registered copy of STSC's STATGRAPHICS System as well. The workspaces written by the author are placed in the public domain. But some functions used in these workspaces are copyrighted and are the property of STSC, Inc. [Refs. 3,4].

II. TRANSITION MODELS BASED ON MARKOV CHAIN THEORY

A. EXPLANATION OF THE MODEL

For a personnel manager, it is important to be able to estimate the number of personnel who will be available to work in various jobs at some future time periods [Ref. 5: p. 112]. To serve this need, Markov Chain models have often been used to forecast stocks in manpower organizations.

The workspace called MARKOV forecasts future stocks using flow rates and recruitment flows. Based on an initial stocks vector, a recruitment vector and a transition rate matrix, the program computes stocks by using Markov Chain Theory [Ref. 1].

B. TERMINOLOGY, NOTATIONS AND BASIC EQUATIONS

If personnel at an organization are classified into k categories, the number of personnel in category i at time t can be denoted by $n_i(t)$, and the row vector of these numbers denoted by

$$\underline{n}(t) = (n_1(t),...,n_k(t)) .$$

The vector $\underline{n}(t)$ is referred to as the stock or inventory vector at time t. Time is usually considered in discrete increments, i.e., $t = 0,1,2,...$. Also, units can be fiscal years, quarters, months, etc. [Ref. 1: p. 3].

Personnel movements within the organization, from the organization to the outside world and from the outside world to the organization are often referred to as (personnel) flows. In an organization, there are three types of flows, usually categorized as

- internal transfers
- attrition (or wastage)
- recruitment (or accession)

These will be denoted by

$n_{ij}(t-1) =$ the number of personnel moving from category i to category j during the period [t-1, t), for i,j = 1,2,...,k ;

$n_{ik+1}(t-1) =$ the number of personnel leaving the system from category i during the period [t-1, t), for i = 1,2,...,k ;

and

$$n_{0j}(t) = \qquad \text{the number of entering personnel entering the system into category j}$$

during the period [t-1, t) who are still in the organization at time t, for $j = 1,2,...,k$;

for $t = 1,2,...$.

The notation for recruitment seems inconsistent with the notation for the other flows, because the argument is the <u>end</u> rather than the beginning of the period [t-1, t) over which the flow is occurring. This is done deliberately as a reminder that only those recruits are counted who stay at least to the end of the period. The internal flow matrix is defined as

$$\underline{N}(t-1) = \begin{bmatrix} n_{11}(t-1) & . & . & . & n_{1k}(t-1) \\ n_{21}(t-1) & . & . & . & n_{2k}(t-1) \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ n_{k1}(t-1) & . & . & . & n_{kk}(t-1) \end{bmatrix}, \qquad \text{for } t = 1,2,... .$$

The attrition flow vector is

$$\underline{n}_{k+1}(t-1) = (n_{1k+1}(t-1),...,n_{kk+1}(t-1)) , \qquad \text{for } t = 1,2,... .$$

Finally, the recruitment vector is

$$\underline{n}_0(t) = (n_{01}(t),...,n_{0k}(t)) , \qquad \text{for } t = 1,2,... .$$

The Markov Chain model expresses the flows as proportions (or probabilities) in terms of

$$p_{ij} = \frac{n_{ij}(t-1)}{n_i(t-1)} \quad .$$

Here, p_{ij} is thought of as the probability that an individual in category i at the beginning of the period will be in category j at the end of the period. Similarly, the attrition rates are

$$w_i = \frac{n_{ik+1}(t-1)}{n_i(t-1)} \quad ,$$

and w_i is thought of as the probability that a member of category i at the beginning of the period will have left the system by the end of the period. These rates are called transition rates or probabilities of the Markov Chain. The assumption is that the transition probabilities do not depend on time. The transition rate (probability) matrix is

$$\underline{P} = \begin{bmatrix} p_{11} & \cdot & \cdot & \cdot & p_{1k} \\ p_{21} & \cdot & \cdot & \cdot & p_{2k} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ p_{k1} & \cdot & \cdot & \cdot & p_{kk} \end{bmatrix} .$$

The attrition rate vector is

$$\underline{w} = (w_1,..., w_k) .$$

Also, note that necessarily

$$\sum_{j=1}^{k} p_{ij} + w_i = 1 , \qquad \text{for} \quad i = 1,2,...,k .$$

For the recruitment flows, the total recruitment during [t-1, t) will be denoted by

$$R(t) = \sum_{j=1}^{k} n_{0j}(t) , \qquad \text{for} \quad t = 1,2,... .$$

These recruits are then allocated to categories with probabilities $r_1, ..., r_k$ where

$$r_j = \frac{n_{0j}(t)}{R(t)} , \qquad \text{for} \quad j = 1,2,...,k.$$

It is assumed that r_j is independent of t for j = 1,2,...,k .

Also,

$$\underline{r} = (r_1, ..., r_k)$$

is called the recruitment proportion vector and $R(t)\,\underline{r}$ is called the recruitment vector.

Future stocks can be calculated successively using the equation [Ref. 1: p. 88] :

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$$n(t) = \underline{n}(t-1)\underline{P} + R(t)\underline{r} , \qquad \text{for} \quad t = 1, 2, \ldots . \tag{2.1}$$

If $\underline{P}$ and $\underline{r}$ are given and "fixed" knowing the initial stock vector, $\underline{n}(0)$ and the total recruitment, $R(t)$, for $t = 1, 2, \ldots$, future stock vectors, $\underline{n}(t)$, may be computed successively.

There is another equation which connects stocks and flows, using the change in the total system size during the period [t-1, t). First, total system size at time t is denoted as

$$N(t) = \sum_{i=1}^{k} n_i(t) , \qquad \text{for} \quad t = 1, 2, \ldots .$$

Then, the change in total system size over the period [t-1, t) is denoted by

$$M(t) = N(t) - N(t-1) , \qquad \text{for} \quad t = 1, 2, \ldots .$$

The alternative to Equation (2.1) is

$$\underline{n}(t) = \underline{n}(t-1)\underline{Q} + M(t)\underline{r} , \qquad \text{for} \quad t = 1, 2, \ldots \tag{2.2}$$

where

$$\underline{Q} = \underline{P} + \underline{w}'\underline{r}$$

and $\underline{w}'$ is the transpose of $\underline{w}$, i.e., $\underline{w}' = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_k \end{bmatrix}$.

Note that total recruitment during the period [t-1, t) can be calculated using the formula [Ref. 1: p. 94] :

$$R(t) = \sum_{i=1}^{k} n_i(t-1)w_i + M(t) , \qquad \text{for} \quad t = 1, 2, \ldots . \tag{2.3}$$

To ease user input in the model three types of Markov Model are defined :

- hierarchical

- length of service

- general

A system is called hierarchical if the only flows permissible are promotions to the next higher category (if any), attrition, and staying within category. Note that in this case the only non-zero elements in the transition rate matrix, P, are the elements along the main diagonal and immediately above it.

A system is called length of service if an individual must either leave the system or move to the next higher category (if any), except in the last category where he must either stay within that category or leave the system. Note that in this case the only non-zero elements in the transition rate matrix, P, are the elements immediately above the main diagonal and possibly the last element in the main diagonal.

The general case, covers all possible situations, but is designed to be used when the system is neither hierarchical nor length of service. [Ref. 1: pp. 85-102]

In the program, these three cases are used to determine how the transition matrix should be entered by the user. For example, in the hierarchical case, the user may enter only the promotion rates and the attrition rates. The probability transition matrix is then calculated by the model. In case of the length of service model type, the user may enter only the attrition rates. The general case may always be used, but requires more work on part of the user.

There are five recruitment options programmed into the model, making specific assumptions about total recruitment or total system size. In the first three recruitment options, total recruitment, R(t), is the only term changing. The last two options are related to changes in total system size. These options are :

1. Fixed Recruitment:

   R(t) = R, fixed, for t = 1,2,..., using Equation (2.1) .

2. Additive Increase/Decrease In Total Recruitment:

   $R(t) = R + (t - 1) \times INC$, for t = 1,2,..., using Equation (2.1),

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where INC is the constant amount of periodic increase/decrease. This amount can be negative (i.e., INC < 0) as long as $R(t) \geq 0$. For example, INC $= 10$ means 10 more people are recruited in every period, whereas INC $= -5$ means 5 fewer people are recruited in every period.

3. Multiplicative Increase/Decrease In Total Recruitment:

$$R(t) = R \times (FACT)^{t-1} \text{ for } t = 1,2,..., \text{ using Equation (2.1)},$$

where R is the initial total recruitment and $100 \times (FACT - 1)$ is the percent of periodic increase/decrease. For example, FACT $= 1.1$ means a 10% increase in total recruitment per period, and FACT $= 0.9$ means a 10% decrease in total recruitment per period.

4. Additive Increase/Decrease In Total System Size:

$$M(t) = INC, \text{ for } t = 1,2,..., \text{ using Equation (2.2)},$$

where INC is the constant amount of periodic increase/decrease in total system size.

5. Multiplicative Increase/Decrease In Total System Size:

Here, $N(t) = FACT \times N(t - 1)$ so that

$$M(t) = N(0) \times (FACT)^t - N(0) \times (FACT)^{t-1} \text{ for } t = 1,2,..., \text{ using Equation (2.2)},$$

where $100 \times (FACT - 1)$ is the percent of periodic increase/decrease in total system size.

Recruitment Option 2 with INC $= 0$ and Recruitment Option 3 with FACT $= 1$, duplicate the fixed recruitment option (i.e., Recruitment Option 1). Also, in Recruitment Option 4 with INC $= 0$, and Recruitment Option 5 with FACT $= 1$, the total system size is fixed.

In the program, these five options determine whether the recruitment vector or the recruitment proportion vector must be entered by the user. For example, if Recruitment

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Option 2 is used, the user has to enter the recruitment vector and the amount of periodic increase/decrease. See the User's Manual in Appendix B for details.

The program also calculates the steady state (long run) stocks providing the user with the long run numbers or percentages of personnel in each category if the parameters are kept fixed.

Steady state is the state in which the stocks or their relative sizes do not change any more. Equations for each steady state vector for each recruitment option can be found in [Ref. 6].

Steady state is given in terms of numbers of stocks for Recruitment Option 1, Recruitment Options 2 and 4 with INC=0 and Recruitment Options 3 and 5 with FACT=1. In these cases the numbers of personnel in each category settles down to a fixed value.

Steady state is given in terms of percentages (i.e., in distribution only) for Recruitment Options 2 and 4 with INC>0 and Recruitment Options 3 and 5 with FACT>1. In these cases the actual numbers of personnel in each category will increase beyond all bounds. Finally, the steady state stock vector is the zero vector for Recruitment Options 2 and 4 with INC<0 and Recruitment Options 3 and 5 with FACT<1. In these cases the numbers of personnel in each category must eventually become zero.

The user's manual for this workspace is in Appendix B. Also, an example of a terminal session with the Transitions models based on Markov Chain Theory workspace can be found in Appendix F.

III.   ANALYSIS OF ATTRITION MODELS

A.   EXPLANATION OF THE MODEL

Attrition or wastage is the most important flow for manpower planning. Attrition is the result of voluntary as well as involuntary decisions to leave. In either case, attrition creates vacancies and so it provides opportunities for promotions and recruitments. Therefore, successful manpower planning depends on describing and predicting patterns of attrition [Ref. 1: p. 12]. This workspace provides models for detailed attrition analysis.

In order to process data for investigating the pattern of attrition, two kinds of analysis are facilitated with these models. The first one is a Cohort (or Longitudinal) Analysis. Cohort is a group of personnel with common characteristics as to their entrance date to the system   [Ref. 7: p. 64]. The second analysis is Census (or Cross-sectional) Analysis, in which case the data include many different cohorts superimposed at one point in time [Ref. 7: p. 72].

B.   COHORT (LONGITUDINAL) ANALYSIS

Generally, the data is obtained in groups instead of giving the number of completed years of service for each leaver. Therefore, we suppose that the completed lengths of service data are grouped into intervals: $[x_0, x_1), [x_1, x_2),..., [x_k, x_{k+1})$ where x_{k+1} is the maximum completed length of service at (compulsory) retirement. These x's are often equally spaced, but this is not necessary. Next define the quantities :

$L_i =$ the number of cohort members leaving the organization with completed length of service (CLS) in $[x_i, x_{i+1})$, for i = 0,1,2,...,k ;

and

$Z_i =$ the number of cohort members "surviving" to x_i, for i = 0,1,2,...,k + 1.

Z_0 is the original cohort size and $Z_{k+1} = 0$, because x_{k+1} is the compulsory or maximum completed length of service. Note that these quantities may be computed from each other. Namely,

$$L_i = Z_i - Z_{i+1} , \qquad \text{for} \qquad i = 0,1,...,k$$

and

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$$Z_i = \sum_{j=i}^{k} L_j \quad , \qquad \text{for} \quad i = 0,1,\dots \, .$$

Assuming that an individual employee's CLS is uniformly distributed in each interval, $[\, x_i, \;\; x_{i+1})$, the probability that an individual cohort member leaves with CLS in a unit interval within $[\, x_i, \;\; x_{i+1})$ is estimated as

$$\hat{f}_i = \frac{L_i}{c_i Z_0} \quad , \qquad \text{for} \qquad i = 0,1,\dots,k$$

where $c_i = x_{i+1} - x_i$.

The standard error of this estimator is

$$\hat{se}(\hat{f}_i) = \sqrt{\frac{\hat{f}_i(1 - c_i \hat{f}_i)}{c_i Z_0}} \quad , \qquad \text{for} \qquad i = 0,1,\dots,k.$$

For the last group of cohort members (i.e., when $i = k$), calculating this quantity may present some problems since often the upper limit of service x_{k+1} is not known accurately. Therefore, the assumption of uniform distribution of leaving throughout the usually very long interval of $[\, x_k, \;\; x_{k+1})$ is unrealistic. This simply means that the value of $\hat{f}_k$ is often not very reliable. [Ref. 1: p. 18]

The survivor function (i.e., the probability of surviving to x_i) can be estimated as [Ref. 1: p. 18]

$$\hat{G}_i = \frac{Z_i}{Z_0} \quad , \qquad \text{for} \qquad i = 0,1,\dots,k.$$

The standard error of this estimator is

$$\hat{se}(\hat{G}_i) = \sqrt{\frac{\hat{G}_i(1 - \hat{G}_i)}{Z_0}} \quad , \qquad \text{for} \quad i = 0,1,\dots,k \, .$$

The conditional probability of an individual cohort member leaving with CLS in a unit interval within $[\, x_i, x_{i+1})$ given he/she survived to x_i is estimated as

$$\hat{q}_i = \frac{L_i}{c_i Z_i} \quad , \qquad \text{for} \quad i = 0,1,\dots,k.$$

The estimated standard error is [Ref. 1: p. 18]

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$$se(\hat{q}_i) = \sqrt{\frac{\hat{q}_i(1 - c_i\hat{q}_i)}{c_i Z_i}} \quad , \qquad \text{for} \qquad i = 0,1,...,k.$$

The relationship between f_i, G_i, and q_i is expressed by the equations

$$q_i = \frac{f_i}{G_i} \quad \text{and} \quad c_i f_i = G_i - G_{i+1} , \quad \text{for } i = 0,1,...,k.$$

Using these equations, if any one of the sequences $\{f_i, i = 0,1,...,k\}$, $\{G_i, i = 0,1,...,k\}$, and $\{q_i, i = 0,1,...,k\}$ is known, the other two may be computed.

It is also useful to introduce a rate or intensity of leaving, known as a failure rate (or hazard function). This is defined as [Ref. 1: p. 21]

$$m_i = \frac{1}{c_i} \ln \frac{G_i}{G_{i+1}} \quad , \quad for \quad i = 0,1,...,k - 1 ,$$

and is estimated by the corresponding formula using $\hat{G}_i$ and $\hat{G}_{i+1}$.

Further, the quantity

$D_i =$ the expected remaining service for an employee with length of service in $[x_i, x_{i+1})$;

is also introduced. This quantity is estimated as [Ref. 1: pp. 23-24]

$$\hat{D}_i = \frac{1}{\hat{G}_i} \left\{ \sum_{j=1}^{k-1} \frac{\hat{G}_j - \hat{G}_{j+1}}{m_j} + \frac{1}{2} c_k \hat{G}_k \right\} , \quad \text{for } i = 0,1,...,\text{k-1} \qquad (3.1)$$

and for $i = k$ as

$$\hat{D}_k = \frac{1}{2} c_k \qquad (3.2)$$

The user's manual for this analysis is in Appendix C. Also, an example of a terminal session with cohort analysis can be found in Appendix G.

C. CENSUS (CROSS-SECTIONAL) ANALYSIS

In contrast to cohort analysis in which personnel have common characteristics , census analysis includes several cohorts superimposed at one point in time. The intervals $[x_i, x_{i+1})$ for $i = 0,1,...,k$ are referred to as the length of service (LOS) intervals in contrast to the CLS intervals of Cohort Analysis. There are two different forms of data

in Census Analysis, which are called central and transitional data, both of which consist of stocks and leavers data. [Ref. 1: p. 24]

In census analysis, rates are calculated for categories defined by length of service. The scale on which length of service is measured is divided at the points $x_1, x_2, ..., x_k$ and x_{k+1} is the maximum possible length of service.

1. In central data analysis of attrition we define

$S_i =$ the average number of personnel with LOS in $[x_i, x_{i+1})$ during a period,

and

$L_i =$ the number of personnel leaving the organization during a period who had

LOS in $[x_i, x_{i+1})$ at their time of leaving.

for i = 0,1,...,k.

The central attrition rate is then estimated as

$$\hat{m}_i = \frac{L_i}{S_i}$$

with estimated standard error

$$\hat{se}(\hat{m}_i) = \sqrt{\frac{\hat{m}_i}{S_i}}$$

for i = 0,1,...,k.

The estimate of the survivor function (explained in Cohort Analysis) and its estimated standard error are

$$\hat{G}_0 = 1, \qquad \hat{G}_i = \exp-\left\{ \sum_{j=0}^{i-1} c_j \hat{m}_j \right\}, \qquad \text{for} \quad i = 1,2,...k$$

and

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$$\hat{se}(\hat{G}_0) = 0 \ , \qquad \hat{se}(\hat{G}_i) \approx \hat{G}_i \sqrt{\sum_{j=0}^{i-1} \frac{c_j^2 \hat{m}_j}{S_j}} \ , \qquad \text{for} \quad i = 1,2,...,k.$$

The other attrition functions can be calculated as in Cohort Analysis using the formulas :

$$\hat{f}_i = \frac{\hat{G}_i - \hat{G}_{i+1}}{c_i} \quad \text{and} \quad \hat{q}_i = \frac{\hat{f}_i}{\hat{G}_i} \ , \qquad \text{for} \quad i = 0,1,...,k.$$

The expected remaining service for an employee with LOS in $[\ x_i, \ x_{i+1})$ is given by the Equations (3.1) and (3.2) as in Cohort Analysis.

2. In transitional data analysis of attrition, the following definitions are used :

$S_i =$ the number of personnel who have LOS in $[\ x_i, \ x_{i+1})$ at the beginning of a period;

and

$L_i =$ the number of leavers during the period who had LOS in $[\ x_i, \ x_{i+1})$ <u>at the beginning of the period</u>

for i = 0,1,...,k.

The estimated transition attrition rate for the ith interval and its estimated standard error are

$$\hat{w}_i = \frac{L_i}{S_i}$$

and

$$\hat{se}(\hat{w}_i) = \sqrt{\frac{\hat{w}_i(1 - \hat{w}_i)}{S_i}}$$

for i = 0,1,...,k. [Ref. 1: p. 30]

The estimated survivor function, $\hat{G}_i$, can be written as

$$\hat{G}_0 = 1 \ , \quad \hat{G}_1 = (1 - \hat{w}_0)^{c_0} \ , \quad \hat{G}_2 = (1 - \hat{w}_0)^{c_0 + \frac{1}{2}}(1 - \hat{w}_1)^{c_1 - \frac{1}{2}}$$

and in general form,

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$$\hat{G}_{i+1} = (1 - \hat{w}_0)^{c_0 + \frac{1}{2}} \left[(1 - \hat{w}_1)^{c_1} \ldots (1 - \hat{w}_{i-1})^{c_{i-1}} \right] (1 - \hat{w}_i)^{c_i - \frac{1}{2}} ,$$

for $i = 2, 3, \ldots, k-1$.

Actually, these values may be calculated successively using the formulas given for $\hat{G}_0$, $\hat{G}_1$ and

$$\hat{G}_{i+1} = \hat{G}_i (1 - \hat{w}_{i-1})^{\frac{1}{2}} (1 - \hat{w}_i)^{c_i - \frac{1}{2}} , \quad for \quad i = 1, 2, \ldots, k - 1.$$

The estimated standard error of the estimated survivor function is

$$\hat{se}(\hat{G}_i) = \hat{G}_i \sqrt{\frac{(c_0 + \frac{1}{2})\hat{w}_0}{(1 - \hat{w}_0)S_0} + \frac{c_1 \hat{w}_1}{(1 - \hat{w}_1)S_1} + \ldots + \frac{c_{i-2} \hat{w}_{i-2}}{(1 - \hat{w}_{i-2})S_{i-2}} + \frac{(c_{i-1} - \frac{1}{2})\hat{w}i - 1}{(1 - \hat{w}_{i-1})S_{i-1}}}$$

for $i = 1, 2, \ldots, k$. [Ref. 1 : p. 32]

After calculating the estimated survivor function, $\hat{G}_i$, the other attrition functions f_i and q_i are estimated as in the case of central data. Further,

$$\hat{m}_i = \frac{1}{c_i} \ln \frac{\hat{G}_i}{\hat{G}_{i+1}} , \quad for \quad i = 0, 1, \ldots, k.$$

The user's manual for this analysis is in Appendix C. Also, an example of a terminal session with census analysis can be found in Appendix G.

D. GRAPHICAL COMPARISONS

This model is used when the attrition patterns for two groups have to be compared to see whether they differ significantly from one another. This is especially important when comparing two groups to decide whether to combine them or when testing to see if the pattern is changing with time. For this purpose, graphical representations of the data is useful. [Ref. 1: pp. 32-33]

In cohort analysis, comparisons of the estimates of the probability of leaving, $\hat{f}_i$, the survivor functions, $\hat{G}_i$, the conditional probability of leaving, $\hat{q}_i$, and the central rates $\hat{m}_i$, for two sets of data can be made. For central data in census analysis, comparisons of the estimates of the survivor functions, $\hat{G}_i$, the conditional probability of leaving, $\hat{q}_i$, and, the central rates, $\hat{m}_i$, may be performed. For transitional data in census analysis, comparisons of the estimates of the survivor functions, $\hat{G}_i$, and the attrition rates, $\hat{w}_i$, are available.

Graphical analysis is done by comparing the estimates with each other. If the standard errors of the estimates (drawn vertically up and down one standard error through the point estimates) for the two sets of data overlap at most point estimates on the graph, we can conclude that the data are similar and may be combined. If they do not overlap at most points, then there is a significant difference between the two sets of data, and we do not recommend combining them.

The graphical comparison is done by using STATGRAPHICS (Statistical Graphics System) software under APL (A Programming Language) environment.

The user's manual for graphical comparisons is in Appendix C. Also, an example of a terminal session with these comparisons can be found in Appendix G.

IV. TRANSITION MODELS BASED ON RENEWAL THEORY

A. EXPLANATION OF THE MODEL

In many organizations, category sizes are constrained by requirements and/or budgetary considerations. Therefore, category sizes are known in advance or can be estimated on the basis of requirements and the main purpose is to forecast the flows such as promotions, transfers, recruitments, etc. Of course, foremost among flows is attrition which is the key, in most situations in creating vacancies. [Ref. 1: p. 133]

There are two vacancy models presented in this chapter : the one-grade model and the multi-grade model.

B. ONE-GRADE SYSTEMS

The simplest of all vacancy models is one where there is no internal differentiation into categories or where such categorizations are to be ignored. In that case, there are only two kinds of flows, namely attrition and recruitment (or replacements).

First, the following definitions are made :

$f_i =$ the probability of an employee leaving with LOS in the interval $[i, i+1)$;

$G_i =$ the probability of an employee surviving to i ;

$w_i =$ the conditional probability of an employee who survives to i leaving with LOS in the interval $[i, i+1)$;

for $i = 0,1,2,...$.

There are two relationships among these probabilities, namely:

$$f_i = G_i w_i , \quad for \quad i = 0,1,2,...$$

and

$$G_i = (1 - w_0)(1 - w_1)...(1 - w_{i-1}) , \quad for \quad i = 1,2,... .$$

Further, the following conventions will be made :

1. Attrition is thought of as occurring uniformly throughout the interval $[i, i+1)$

2. Recruitment is thought of as occurring at the end of the interval $[i, i+1)$

The latter convention is made mostly for accounting purposes as only at the end of a period is it certain how many of the new recruits stay to the end of the period during which they joined the organization.

We shall separate the one-grade vacancy model into three sub-models. The separation is done according to the assumptions explained below.

For Sub-model 1, the assumptions are :

1. system size is fixed at N at times $t = 0,1,2,...$;

2. all initial employees (i.e., those present at $t = 0$) have zero LOS ;

3. all new recruits enter the system with zero LOS.

We define the replacement (or recruitment) rates

$h_j =$ the rate at which recruits are hired at time j, for $j = 1,2,...$.

This means that

$R_j = Nh_j =$ the number of recruits hired at time j, for $j = 1,2,...$.

Then the replacement rates are computed from the formula [Ref. 1: p. 134] :

$$h_1 = f_0 , \quad h_j = f_{j-1} + h_1 f_{j-2} + \; ... \; + h_{j-1} f_0 , \quad for \;\; j = 2,3,...$$

and the expected number of replacements are

$$R_j = N h_j , \quad for \;\; j = 1,2,... .$$

For Sub-model 2, the assumptions are the same as for Sub-model 1 except that Assumption 2 is replaced with the new assumption :

2.′ there are NS_i number of initial employees with LOS in [i, i+1) interval, for $i = 0,1,2,...$

where $S_i \geq 0$, for $i = 0,1,...$ and $\sum_{i=0}^{\infty} S_i = 1$.

Then, the replacement rates are [Ref. 1: pp. 136-137]

$$h'_1 = \sum_{i=0}^{\infty} \frac{S_i}{G_i} f_i$$

and

$$h'_j = \sum_{i=0}^{\infty} \frac{S_i}{G_i} f_{i+j-1} + (h'_1 f_{j-2} + \; ... \; + h'_{j-1} f_0) , \quad for \;\; j = 2,3,... .$$

The expected number of recruits or replacements at time j are

$$R'_j = Nh'_j \ , \qquad \text{for} \quad j = 1,2,\dots .$$

For Sub-model 3, the assumptions are the same as for Sub-model 2 except that Assumption 1 is replaced with the assumption :

1.′ the initial system size is N(0) and the system size is increasing/decreasing by M(i) at time i, for i = 1,2,... .

Then, the total system size at time j is

$$N(j) = N(0) + M(1) + M(2) + \ \dots \ + M(j) \ , \qquad \text{for} \quad j = 1,2,\dots .$$

$M(i) < 0$ is allowed as long as $N(j) \geq 0$ for all j.

Then the expected number of new recruits to hire at time j is [Ref. 1: p. 137]

$$R''_j = N(0)h'_j + M(1)h_{j-1} + \ \dots \ + M(j-1)h_1 + M(j) \ , \qquad \text{for} \quad j = 1,2,\dots$$

where h_j and h'_j are respectively the replacement rates in Sub-models 1 and 2.

The replacement rates for Sub-model 3 are :

$$h''_j = \frac{R_j}{N(j-1)} \ , \qquad \text{for} \quad j = 1,2,\dots .$$

The steady state recruitment rate in case of Sub-models 1 and 2 is [Ref. 1: p. 137]:

$$\lim_{j \to \infty} h_j = \lim_{j \to \infty} h'_j = \frac{1}{\mu} \ , \qquad \text{where} \quad \mu = \sum_{j=1}^{\infty} j \, f_{j-1} \ .$$

The steady state number of recruits for Sub-models 1 and 2 is :

$$\lim_{j \to \infty} R_j = \lim_{j \to \infty} R'_j = \frac{N}{\mu} \ .$$

The user's manual for this model is in Appendix D. Also, an example of a terminal session with this model can be found in Appendix H.

C. MULTI-GRADE SYSTEMS

In this model, the key is to forecast the stock of vacancies instead of the stock of personnel. This is based on the idea that in a vacancy system, whenever a person moves from one position to another, a vacancy moves in the opposite direction. Thus, there

is a dual relationship between the flows of personnel and the flows of vacancies. [Ref. 1: p. 142]

The multi-grade vacancy model consists of two sub-models. These are :

- Multi-grade vacancy model with non-instantaneous filling of vacancies,
- Multi-grade vacancy model with instantaneous filling of vacancies.

1. Multi-grade Vacancy Model With Non-instantaneous Filling Of Vacancies

It is assumed here that it takes a full period to fill a vacancy that occurs at the beginning of a period. The following definitions are made :

$n_j(t) =$ the number of positions in category j at time t ,

$v_j(t) =$ the number of vacancies in category j at time t ,

$w_j =$ the rate of attrition among employees in category j ,

for j = 1,2,...,k.

$s_{ij} =$ the proportion or probability of vacancies in category i moving to category j during a period, for i,j = 1,2,...,k.

$s_{ik+1} =$ the proportion or probability of vacancies in category i moving outside the system, for i = 1,2,...,k.

Note that

$$\sum_{j=1}^{k} s_{ij} + s_{ik+1} = 1 \ , \qquad \text{for } i = 1,2,...,k.$$

Note also that

$e_j(t) = n_j(t) - v_j(t) =$ the number of employees in category j at time t, for j = 1,2,...,k.

A Markov Model of vacancies is constructed using following vectors and matrices :

The position vector

$$\underline{n}(t) = (n_1(t), ..., n_k(t)) \ ,$$

the vacancy vector

$$\underline{v}(t) = (v_1(t), ..., v_k(t)) \ ,$$

the vacancy transition rate matrix :

$$\underline{S} = \begin{bmatrix} s_{11} & \cdot & \cdot & \cdot & s_{1k} \\ s_{21} & \cdot & \cdot & \cdot & s_{2k} \\ \cdot & & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot \\ s_{k1} & \cdot & \cdot & \cdot & s_{kk} \end{bmatrix}$$

and the diagonal matrix of attrition rates

$$\underline{W} = \begin{bmatrix} w_1 & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & w_2 & \cdot & \cdot & \cdot & 0 \\ \cdot & & 0 & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot & \cdot & w_k \end{bmatrix} .$$

Assume first that the category sizes are fixed for all times, i.e., $\underline{n}(t) = \underline{n} = (n_1, ..., n_k)$, for t = 0,1,2,... .

Then future vacancies may be forecasted using the Markov Model of vacancies :

$$\underline{v}(t) = v(t-1)\,\underline{S}^\star + \underline{R}$$

where $\underline{S}^\star = \underline{S} - \underline{W}$ and $\underline{R} = \underline{n}\,\underline{W}$. [Ref. 1: p. 146]

The expected number of personnel transferred from category i to category j during [t-1, t) can be written as

$$P_{ij}(t) = v_j(t-1)\, s_{ji} \ , \qquad \text{for } i,j = 1,2,...,k \ , \tag{4.1}$$

and the expected number of recruits into category j during [t-1, t) is

$$R_j(t) = P_{k+1,j}(t) = v_j(t-1)s_{j,k+1} \ , \qquad \text{for} \quad j = 1,2,...,k. \tag{4.2}$$

If vacancies can be filled in a fraction, r, of a period (e.g., quarterly instead of yearly), the same formulas may be used, except w_j must first be multiplied by r. As an example, suppose that attrition rates are available on a yearly basis but vacancies take three months (one quarter) to fill. If we want to forecast the number of vacancies for,

say, five years then first the attrition rates should be recomputed by multiplying the old rates by .25. Then vacancies may be forecasted to $5 \times 4 = 20$ periods, each representing a quarter. The number of transfers from category i to category j during the second year is then obtained as :

$$P_{ij} (2^{nd} \text{ year}) = [\, v_j(4) + v_j(5) + v_j(6) + v_j(7) \,] \, s_{ji}$$

for $i = 1,2,...,k,k+1$ and $j = 1,2,...,k$.

If the category sizes are increasing/decreasing at the same rate α , i.e.,

$$n(t) = (1 + \alpha)\, n(t-1) = (1 + \alpha)^{t}\, n(0) , \qquad \text{for } t = 1,2,...$$

where $-1 \leq \alpha \leq 1$, (for example, $\alpha = 0.1$ means 10% increase in all categories and $\alpha = -0.1$ means 10% decrease in all categories), then, future vacancies are computed according to the Markov Model

$$\underline{v}(t) = \underline{v}(t-1)\, \underline{S}^{\star} + (1 + \alpha)^{t-1}\, \underline{R}^{\star} , \qquad \text{for } t = 1,2,...$$

where

$$\underline{S}^{\star} = \underline{S} - \underline{W} , \qquad \underline{W}^{\star} = \begin{bmatrix} w_1 + \alpha & .\ .\ . & 0 \\ 0 & .\ .\ . & 0 \\ . & .\ .\ . & . \\ . & .\ .\ . & . \\ . & .\ .\ . & . \\ 0 & .\ .\ . & w_k + \alpha \end{bmatrix}$$

and

$$\underline{R}^{\star} = \underline{n}(0)\, \underline{W}^{\star} \ . \ [\,\text{Ref. 1: p. 148}\,]$$

Here, the number of employees in category j at time t is

$$e_j(t) = n_j(t) - v_j(t) = (1 + \alpha)^{t} n_j(0) - v_j(t) \qquad \text{for } j = 1,2,...,k$$

and the formulas $P_{ij}(t)$ and $R_j(t)$ are still valid as given by Equations (4.1), (4.2) respectively.

If vacancies may be filled in a fraction of a period, the expected number of transfers may be computed using the same procedure as in the case of a fixed position vector.

The user's manual for this model is in Appendix D. Also, an example of a terminal session with this model can be found in Appendix H.

2. Multi-grade Vacancy Model With Instantaneous Filling Of Vacancies

This model is called instantaneous filling of vacancies, because transfers take place instantaneously when vacancies occur. This can be done either by recruitment from the outside or by transfers from the inside such as promotions, etc.

This assumption means that steady state is reached within one period. So, vacancies are forecasted using steady state formulas. More exactly, the model computes the matrix

$$\underline{D} = (\underline{I} - \underline{S})^{-1}$$

where S is the vacancy transition rate matrix and I is the identity matrix of the same size.

If d_{ij} is the element in the ith row and j^{th} column of $\underline{D}$ then

$d_{ij} =$ the expected length of time a vacancy which enters at category i will spend in category j ;

The definitions of n_j, s_{ij}, w_j are the same as in the previous model above.

Then, the expected number of transfers from category i to category j during any period is [Ref. 1: p. 144]

$$P_{ij} = s_{ji} \sum_{v=1}^{k} n_v\, w_v\, d_{vj}, \qquad \text{for } i,j = 1,2,...,k \qquad (4.3)$$

and the expected number of recruits to category j during any period is :

$$R_j = P_{k+1j} = s_{jk+1} \sum_{v=1}^{k} n_v\, w_v\, d_{vj}, \qquad \text{for } j = 1,2,...,k. \qquad (4.4)$$

If during a period the size of category i increases from n_i to $n_i + m_i$, for $i = 1,2,...,k$ then the Equations (4.3) and (4.4) are replaced by [Ref. 1 p. 145]

$$P_{ij} = s_{ji} \sum_{v=1}^{k} (n_v\, w_v + m_v)\, d_{vj}, \qquad \text{for } i,j = 1,2,...,k \qquad (4.5)$$

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and

$$R_j = P_{k+1j} = s_{jk+1} \sum_{v=1}^{k} (n_v\, w_v + m_v)\, d_{vj}\,, \qquad \text{for} \quad j = 1,2,...,k. \tag{4.6}$$

The user's manual for this model is in Appendix D. Also, an example of a terminal session with this model can be found in Appendix H.

V. CAREER PATTERNS MODELS

A. EXPLANATION OF THE MODEL

In this model, the quantities related to career prospects for individuals within an organization are studied. These quantities are the probability of eventual promotion to the next higher category in a hierarchical system and the mean time to promotion.

B. CAREER PATTERNS MODEL

The promotion rate is the chance of being promoted at a particular time, but it gives little direct information about the career patterns of the people involved. Here, the relationship between them is expressed explicitly.

First, we assume that an individual's probability of promotion, probability of leaving and probability of staying in the same category do not depend on the length of service in that category. In this case, there are no specific promotion zones, i.e., an individual can be promoted at any time in his career.

Considering a single grade in a multi-grade hierarchical system, the promotion rate, staying rate and attrition rate are defined as follows:

$p =$ the probability of promotion during a period;

$s =$ the probability of staying in category during a period;

$w =$ the probability of attrition from the system during a period.

Also, let

$K =$ maximum length of service.

Note that $p > 0$, $s \geq 0$, $w \geq 0$ and $p + s + w = 1$

are also assumed.

Further, define

$P_u =$ the probability of eventual (or ultimate) promotion to the next higher category,

and

$T_p =$ the mean time to promotion of promotees.

Assuming that p, s, and w remain unchanged over all periods, the probability of eventual promotion is

$$P_u = p \ \frac{1 - s^K}{1 - s} \tag{5.1}$$

and the mean time to promotion of promotees is

$$T_p = \frac{1}{1-s} - \frac{1}{2} - \frac{K s^K}{1-s^K} \qquad (5.2)$$

Here it was assumed that individuals are promoted half-way through a period rather than at the end. [Ref. 1: pp. 174-175]

If $K = \infty$, i.e., there is no compulsory retirement or max length of service in category,

$$P_u = \frac{p}{1-s} \qquad (5.3)$$

and

$$T_p = \frac{1}{1-s} - \frac{1}{2} \quad . \qquad (5.4)$$

There are special formulas for careerists, i.e., employees who are determined to stay in the system regardless of promotion. For these people the attrition rate is zero. Let $p^\star$ and $s^\star$ denote their promotion and staying rates, i.e.,

$p^\star = $ the probability of promotion during a period for careerists ;

$s^\star = $ the probability of staying in category during a period for careerists ;

where $p^\star > 0$, $s^\star \geq 0$ and $p^\star + s^\star = 1$.

Then the probability of eventual promotion for careerists is:

$$P_u^\star = 1 - (s^\star)^K \qquad (5.5)$$

and the mean time to promotion for careerists is :

$$T_p^\star = \frac{1}{1-s^\star} - \frac{1}{2} - \frac{K (s^\star)^K}{1-(s^\star)^K} \qquad (5.6)$$

If $K = \infty$,

$$P_u^\star = 1 \quad ,$$

and

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$$T_p^\star = \frac{1}{1 - s^\star} - \frac{1}{2} \quad . \tag{5.7}$$

In the above formulas $p^\star$ and $s^\star$ must be computed from the rates p, s, w based on one of the following three assumptions [Ref. 1: p. 174] :

- if promotion is before attrition in the system, then

$$p^\star = p \; ;$$

- if attrition is before promotion in the system, then

$$p^\star = \frac{p}{1 - w} \; ;$$

- if promotion and attrition are independent and simultaneous in the system, then

$$p^\star = 1 - s^{\frac{p}{1-s}} \quad .$$

Considering that the assumption of constant promotion rate is unrealistic in any real system, the concept of promotion zone is introduced next. Therefore, we divide the length of service in a category into three parts choosing the boundaries a and b. Here the interval (0, a) is called the Below Zone, the interval (a, b) the Promotion Zone and the interval (b, K) the Above Zone.

Let

$p_i =$ the promotion rate,

$s_i =$ the staying rate,

$w_i =$ the attrition rate,

for i = 1,2,3 , where

$i = 1$ refers to the Below Zone,

$i = 2$ refers to the Promotion Zone,

$i = 3$ refers to the Above Zone.

Also for simplicity assume that $p_1 = p_3 = 0$ i.e., there is no chance of promotion in the Below and Above Zones. Further, $p_2 > 0$, $s_i \geq 0$, $w_i \geq 0$, and $p_i + s_i + w_i = 1$, for i = 1,2,3. These rates are called zone specific rates, in contrast to the rates p, s, w which are usually referred to as the grade specific rates.

Then, the probability of eventual promotion is [Ref. 1 : p. 177] :

$$P_u = s_1^a \, p_2 \, \frac{1 - s_2^{b-a}}{1 - s_2} \tag{5.8}$$

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and the mean time to promotion of promotees is [Ref. 1: p. 177] :

$$T_p = a + \frac{1}{1 - s_2} - \frac{1}{2} - \frac{(b - a)\, s_2^{b-a}}{1 - s_2^{b-a}} \tag{5.9}$$

For careerists, the probability of eventual promotion is [Ref. 1 : p. 177] :

$$P_u^{\star} = 1 - (s_2^{\star})^{b-a} \tag{5.10}$$

and mean time to promotion is [Ref. 1 : p. 177] :

$$T_p^{\star} = a + \frac{1}{1 - s_2^{\star}} - \frac{1}{2} - \frac{(b - a)\, (s_2^{\star})^{b-a}}{1 - (s_2^{\star})^{b-a}}$$

The promotion rate for careerists ($p_2^{\star}$) is computed from p_2, s_2, w_2 based on one of the following three assumptions :

- if promotion is before attrition in the system, then

$$p_2^{\star} = p_2 \;;$$

- if attrition is before promotion in the system, then

$$p_2^{\star} = \frac{p_2}{1 - w_2} \;;$$

- if promotion and attrition are independent and simultaneous in the system, then

$$p_2^{\star} = 1 - s_2^{\frac{p_2}{1 - s_2}} \;.$$

If the zone specific rates are not available, they can be approximated from the grade-specific rates using the following formulas [Ref. 1: p. 179] :

$$\hat{p}_2 = p \; \frac{1 - s^K}{s^a - s^b}$$

and

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$$\hat{w}_1 = \hat{w}_2 = w .$$

The user's manual for this model is in Appendix E. Also, an example of a terminal session with this model can be found in Appendix I.

C. CAREER PATTERNS USING MARKOV CHAIN MODEL

An individual's career can also be studied using the Markov Chain Model. In this approach, the system is not necessarily hierarchical but restrictive since there are no promotion zones or maximum length of service, i.e.,

$$a = 0 , \quad \text{and} , \quad b = K = \infty .$$

In this case information is based on the matrix

$$\underline{D} = (\underline{I} - \underline{P})^{-1}$$

where $\underline{P}$ is the transition probability matrix and $\underline{I}$ is the identity matrix of the same size.

If d_{ij} is the element in the ith row and j^{th} column of $\underline{D}$ then d_{ij} is the expected number of times that a category i employee will occupy a category j position in his career over an infinite horizon. The most meaningful of these quantities is :

$d_{ii} =$ the mean time spent in category i prior to promotion to category i+1.

These diagonal elements of $\underline{D}$ are of interest since they are similar to the mean time to promotion of promotees (T_p) calculated on the assumption that

$$a = 0 , \text{and} , \quad b = K = \infty.$$

However, in contrast to the assumption made in deriving Formula (5.4) the Markov Model assumes promotion occurring at the end of an interval. Therefore,

$$d_{ii} = T_p(i) + \frac{1}{2}$$

where the argument i of $T_p(i)$ refers to the category i.

The off-diagonal elements in $\underline{D}$ (i.e., d_{ij}'s with $i \neq j$) are not meaningful, since they include the zero times spent in category j by those who never reach category j. In fact, the $(j,j)^{th}$ diagonal element of $\underline{D}$ gives the conditional time in this category for category i employees, who will reach category j.

Further,

$\sum_{i=1}^{k} d_{ij} =$ the expected time spent in the system by a category i employee where k is the number of categories.

The probability that a category i employee will eventually reach category j is obtained by dividing each element of $\underline{D}$ by the diagonal element in its column, i.e.,

$\pi_{ij} = \dfrac{d_{ij}}{d_{jj}} =$ the probability that a category i employee will eventually reach category j, for j = i+1,...,k.

Note that $\pi_{i,i+1} = P_u(i)$ of Formula (5.3).

$\underline{\Pi}$ is defined as the matrix of π_{ij}'s.

For careerists, similar results can be obtained assuming that $p^{\star} = \dfrac{p}{1-w}$. By dividing each row of the transition probability matrix by its sum, we first define the new transition probability matrix $\underline{P}^{\star}$ with elements

$$p_{ij}^{\star} = \frac{p_{ij}}{1-w_i} \quad , \quad \text{for } i,j = 1,2,...,k.$$

In this matrix, we must first omit those rows and columns whose diagonal element is one. We thus obtain the new transition probability matrix denoted by $\underline{P}^{\star\star}$. [Ref. 1: p. 182] ,

Using this matrix, we calculate the matrix,

$$\underline{D}^{\star} = (\underline{I} - \underline{P}^{\star\star})^{-1} .$$

Then, the mean time spent in category i prior to promotion to category i+1 for careerists is given by $d_{ii}^{\star}$. Again,

$$d_{ii}^{\star} = T_p^{\star}(i) + \frac{1}{2} .$$

Note that $\pi_{ij}^{\star}$ may also be computed, however necessarily $\pi_{ij}^{\star} = 1$, for all j = i+1,...,k, because in a hierarchical system with no retirement careerists are guaranteed to reach all higher grades. $\underline{\Pi}^{\star}$ is defined as the matrix of $\pi_{ij}^{\star}$'s.

The user's manual for this model is in Appendix E. Also, an example of a terminal session with this model can be found in Appendix I.

APPENDIX A.   COMPUTER SYSTEM REQUIREMENTS

STSC APL*PLUS (A Programming Language) system, STSC STATGRAPHICS (Statistical Graphics System) and the created workspaces can be run on any IBM-compatible microcomputers. Computers with hard drive, especially 80286/80386 microcomputers are recommended due to the increase in operating speed. The workspaces (except the Graphical Comparisons among the Analysis of Attrition Models) are also compatible with most floppy disk operating systems. STSC STATGRAPHICS requires at least 640 kilobytes of random access memory (640 K of ram) to load, especially when working in the APL environment [Ref. 3: pp. 1-4].

STSC APL*PLUS and STSC STATGRAPHICS operate with almost any type of video monitor (including monochrome monitor with Hercules-compatible video card). A math co-processor (80287/80387) enhances the system performance further, but it is not required.

The workspaces in this thesis were written using version 9.0 of STSC APL*PLUS, version 4.0 of STSC STATGRAPHICS and version 3.3 of DOS.

STATGRAPHICS is not required for any of the models except the Graphical Methods in the Analysis of Attrition Model.

APPENDIX B.   USER'S MANUAL FOR TRANSITION MODELS BASED ON MARKOV CHAIN THEORY

A.   LOADING THE MODEL

This APL workspace can be used on either a hard disk or a floppy disk. It is recommended to use computers equipped with hard disk because of the increased operating speed.   In this case, it is also recommended that the user create a separate sub-directory on the hard disk for this workspace.

When using the model with a hard disk, the user should select the appropriate subdirectory. Then, by typing MARKOV and pressing the Enter key, APL characters are activated, and the APL.EXE file and the MARKOV.AWS workspace are automatically loaded.

When using the model with a floppy disk, the disk is placed into an appropriate disk drive. Then, by typing MARKOV and pressing the Enter key, APL characters are activated, and the APL.EXE file and the MARKOV.AWS workspace are automatically loaded.

B.   RUNNING THE MODEL

If the user does not want a printout, he types MARKOV again and the program begins to run. If the user wants a printout, he should first type PRINTER ON, and then, follow the same procedure as above. After typing MARKOV, the user gets the following three options to input data :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1.   Data Input Choice 1

To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file. If the user changes his/her mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. Data Input Choice 2

To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below. First the user must choose from the following model types :

1. Markov Hierarchical

2. Markov Length Of Service

3. Markov General

For an explanation of these model types see Section 2.B in this thesis.

Regardless which type is chosen by the user, the program first asks the user to enter the initial stock vector. Then, according to the chosen Markov model type, the user must enter the transition rate matrix in one of the following three ways.

Markov Hierarchical Type : In this case, the user is prompted to enter the promotion rates and then the attrition rates.

Markov Length of Service Type : In this case, the user is prompted to enter the attrition rates only.

Markov General Type : In this case, the user is prompted to enter the transition rate matrix row by row.

Once the transition rate matrix is entered the user must make a choice of one of five Recruitment Options :

1. Fixed Recruitment
2. Additive Increase/Decrease in Total Recruitment
3. Multiplicative Increase/Decrease in Total Recruitment
4. Additive Increase/Decrease in Total System Size
5. Multiplicative Increase/Decrease in Total System Size

If the user chooses the Fixed Recruitment option, the program asks the user to enter the Recruitment vector.

If the user chooses the Additive Increase/Decrease in Total Recruitment option, the program asks the user to enter the Initial Recruitment vector and the additive increase/decrease term (INC).

If the user chooses the Multiplicative Increase/Decrease in Total Recruitment option, the program asks the user to enter the Initial Recruitment vector and the multiplicative increase/decrease factor (FACT).

If the user chooses the Additive Increase/Decrease in Total System Size option, the program asks the user to enter the Recruitment Proportion vector and the additive increase/decrease term (INC).

If the user chooses the Multiplicative Increase/Decrease in Total System Size option, the program asks the user to enter Recruitment Proportion vector and the multiplicative increase/decrease factor (FACT).

Next, the user is asked to enter the type of display for the percentage of stocks, i.e., category size as a percent of total system size; category size as a percent of the original category size; or no percentages. After that, the program goes to the main menu.

3. Data Input Choice 3

To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. The Workspace Main Menu Screen

This is the menu that allows the user to choose from six options, shown in Figure 1 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

a. Main Menu Option 0

If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

```
┌─────────────────────────────────────────────────────────────────────┐
│   0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA            │
│   1   TURN PRINTER ON/OFF             4   FORECAST STOCKS            │
│   2   SEE THE DATA                    5   SEE STEADY STATE           │
└─────────────────────────────────────────────────────────────────────┘
```

Figure 1.   Main Menu Screen for MARKOV.AWS

b. *Main Menu Option 1*

This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

c. *Main Menu Option 2*

This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program then goes back to the main menu.

d. *Main Menu Option 3*

This option provides a chance for the user to change the input data using a change menu on the screen. There are four choices in this menu which are shown in Figure 2.

After the user makes all his/her changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

If the user chooses Option 1 (i.e., changing the initial stock vector), the program asks him/her to enter the initial stock vector. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing the probability transition matrix), the program asks the user to enter the matrix according to the Markov model type selected earlier. The program then returns to the change menu.

If the user chooses Option 3 (i.e., changing the Recruitment option), the program asks the user which Recruitment option he/she wants to choose and then asks him/her to enter the appropriate quantities as explained under the Recruitment Options heading above. The program then returns to the change menu.

```
0   DONE WITH ALL CHANGES
1   INITIAL STOCK VECTOR
2   TRANSITION PROBABILITY MATRIX
3   RECRUITMENT TYPE OR VECTOR
```

Figure 2.   Change Menu for MARKOV.AWS

e.   *Main Menu Option 4*

This option lets the user forecast future stocks. When the user chooses this option, the program asks him/her which period's stocks he/she wants to see. If there are intervening periods, the program asks the user if he/she wants to see stocks for the intervening periods. According to the user's response, the program displays future stocks on the screen as outputs. The program then returns to the main menu.

In some cases the user may want to change the input data and then ask the model to forecast stocks for several additional periods. The program then calculates the next periods' stocks based on the new data. But, if after changing the data, the user wants to see some prior periods' stocks, the program warns him/her and asks if he/she wants to continue this procedure, since the program will then calculate stocks starting from period zero, but using the altered data.

If the user does not want to continue, the program returns back to the main menu screen. If the user does want to continue, the program forecasts stocks based on the altered data. These forecasts, therefore, may differ from the previous forecasts for the same periods. Then, the program returns to the main menu.

f.   *Main Menu Option 5*

This option lets the user see the stocks in steady state. Steady state is the state to which a system comes, after a sufficient time has passed, so the stocks in absolute or percentage terms do not change any more.

If the system is under conditions of positive growth, the steady state exists only in percentage terms.

If the system is under conditions of negative growth, the steady state stocks will be zero.

If the system is under fixed conditions (i.e., fixed recruitment option or fixed total system size), then steady state exists in both absolute numbers and percentage terms.

After displaying the steady state results, the program goes back to the main menu.

C. ERROR TRAPPING

Error trapping is provided at various points of the program to avoid user input mistakes, such as :

- the input data dimension does not fit the program,

- a vector is entered instead of a scalar, or vice versa,

- negative values are entered instead of positive, or vice versa,

- special characters are entered instead of numerical values,

- the user gives inappropriate answers such as YES or NO to questions which require specific answers,

- the sum of the entered values is not in the range specified by the program.

APPENDIX C. USER'S MANUAL FOR ANALYSIS OF ATTRITION MODELS

A. LOADING THE MODEL

In this model, there are two separate workspaces. The first one contains the Cohort Analysis and the Census Analysis. This APL workspace can be used on either a hard disk or a floppy disk. It is recommended to use computers equipped with hard disk because of the increased operating speed. In this case, it is also recommended that the user create a separate sub-directory on the hard disk for this workspace.

When using the model with a hard disk, the user should select the appropriate subdirectory. Then, by typing WASTAGE and pressing the Enter key, APL characters are activated, and the APL.EXE file and the WASTAGE.AWS workspace are automatically loaded.

When using the model with a floppy disk, the disk is placed into an appropriate disk drive. Then, by typing WASTAGE and pressing the Enter key, APL characters are activated, and the APL.EXE file and the WASTAGE.AWS workspace are automatically loaded.

The other workspace includes graphical comparisons for Cohort and Census data that is used with STATGRAPHICS under the APL environment. Detailed information about this workspace is given in section C of this Appendix.

B. RUNNING COHORT ANALYSIS

If the user does not want a printout, he/she types COHORT and the program begins to run. If the user wants a printout, he/she should first type PRINTER ON, and then, follow the same procedure as above. After typing COHORT, the user gets the following three options to input the data :

These options are :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1. **Data Input Choice 1**

    To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file. If the user changes his/her mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

    Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

    If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. **Data Input Choice 2**

    To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below.

    The program first asks the user to enter the start of each completed length of service interval and then, the maximum period possible. Then, the program asks the user if he/she wants to enter the numbers of survivors or the numbers of leavers. After that, depending on user input, the program asks for the numbers of survivors/leavers. The program then goes to the main menu.

3. **Data Input Choice 3**

    To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. **Cohort Analysis Main Menu Screen**

    This is the menu that allows the user to choose from six options, shown in Figure 3 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

    a. *Main Menu Option 0*

        If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

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```
  0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
  1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
  2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS
```

Figure 3.   Main Menu Screen for Cohort Analysis

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

b. *Main Menu Option 1*

This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

c. *Main Menu Option 2*

This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program goes back to main menu.

d. *Main Menu Option 3*

This option provides a chance for the user to change the input data using a change menu on the screen. There are four choices in this menu which are shown in Figure 4.

After the user makes all his/her changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

If the user chooses Option 1 (i.e., changing the completed length of service), the program asks him/her to enter the completed length of service. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing the numbers of survivors/leavers), the program asks the user to enter the numbers of survivors/leavers according to the user choice selected earlier. The program then returns to the change menu.

If the user chooses Option 3 (i.e., changing all the data), the program asks the user to enter all the data that was entered earlier. This option gives the user a chance to make changes in all the data. The program then returns to the change menu.

```
0   DONE WITH ALL CHANGES
1   COMPLETED LENGTH OF SERVICE
2   SURVIVOR/LEAVER VECTOR
3   ALL THE DATA
```

Figure 4. Change Menu for Cohort Analysis

e. *Main Menu Option 4*

This option lets the user look at the estimates of the probabilities/rates. When the user chooses this option, the program calculates the probabilities of leaving, the probabilities of surviving, the conditional probabilities of leaving, the hazard/failure rate function, and the expected remaining service, and displays them on the screen. The program then returns to the main menu.

f. *Main Menu Option 5*

This option lets the user see the estimated standard errors for the estimated probabilities/rates. These are the estimated standard errors of the probabilities of leaving, the probabilities of surviving, and the hazard/failure rate function. After displaying these outputs, the program asks the user if he/she wants to see these errors as a percentage of the estimates. According to the user's choice, the program either displays first the standard errors as a percentage of the estimates and returns to the main menu or the program returns directly to the main menu.

C. RUNNING CENSUS ANALYSIS

If the user does not want a printout, he/she types CENSUS and the program begins to run. If the user wants a printout, he/she should first type PRINTER ON, and then, follow the same procedure as above. After typing CENSUS, the user gets the following three options to input the data :

These options are :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1. Data Input Choice 1

To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file. If the user changes his/her mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. Data Input Choice 2

To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below.

The program first asks the user which type of data is represented by the inputs. The user can choose between Central and Transitional data types. Regardless which data type is chosen by the user, the program asks the user to enter the start of each length of service interval and the, the maximum period possible. If the user chose the Central data type, the program asks the user to enter the numbers of leavers who were in each length of service class on exit. Then, the program asks the user how he/she wants to enter the stock vector. It can be either the average stock vector or the beginning and the ending stock vector. According to the user's choice, the program asks the user to enter the stock vector that way. Then, the program goes to the main menu.

If the user chose the Transitional data type, the program asks the user to enter the numbers of leavers who were in each length of service interval at the beginning of the period. Also, the program asks the user to enter the stock vector at the beginning of the period. The program then goes to the main menu.

3. Data Input Choice 3

To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. Census Analysis Main Menu Screen

This is the menu that allows the user to choose from six options, shown in Figure 5 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

```
  0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA

  1   TURN PRINTER ON/OFF             4   ESTIMATE PROBABILITIES/RATES

  2   SEE THE DATA                    5   SEE ESTIMATED STANDARD ERRORS
```

Figure 5.   Main Menu Screen for Census Analysis

a.   *Main Menu Option 0*

If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

b.   *Main Menu Option 1*

This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

c.   *Main Menu Option 2*

This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program goes back to main menu.

d.   *Main Menu Option 3*

This option provides a chance for the user to change the input data using a change menu on the screen. There are five choices in this menu which are shown in Figure 6.

After the user makes all his/her changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

```
0   DONE WITH ALL CHANGES
1   LENGTH OF SERVICE
2   STOCK VECTOR
3   LEAVERS VECTOR
4   CENTRAL/TRANSITIONAL DATA
```

Figure 6.   Change Menu for Census Analysis

If the user chooses Option 1 (i.e., changing the length of service), the program asks him/her to enter the length of service. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing stock vector), the program asks the user to enter the following inputs.

If the user chose the Central data type, then the program asks the user how he/she wants to enter the average stock vector or the beginning and the ending stock vectors. According to the user's choice, the program asks the user to enter the stock vector. The program then returns to the change menu.

If the user chose the Transitional data type, the program asks the user to enter the stocks at the beginning of the period. After that, the program returns to the change menu.

If the user chooses Option 3 (i.e., changing the numbers of leavers), the program asks the user to enter the following input.

If the user chose the Central data type, the program asks the user to enter the numbers of leavers who were in each length of service class on exit; but if he/she chose the Transitional data type, the program asks the user to enter the numbers of leavers who were in each length of service at the beginning of the period. The program then returns to the change menu.

If the user chooses Option 4 (i.e., changing Central/Transitional data type), the program asks the user which type of data is represented by the inputs. According to the data type, the program asks for the inputs as explained under Data Input Choice 2. The program then returns to the change menu.

e. *Main Menu Option 5*

This option lets the user estimate the probabilities/rates. When the user chooses this option, the program calculates the probabilities of leaving, probabilities of

surviving, conditional probabilities of leaving, central attrition rates, transitional attrition rates, the expected remaining service, and then, displays them on the screen. After that, the program returns to the main menu.

f. Main Menu Option 6

This option lets the user see the estimated standard errors for the estimated probabilities/rates. If the user chose the Central data type, the following errors are displayed : the estimated standard errors of the probabilities of surviving, the conditional probabilities of leaving, the central attrition rates, and the transitional attrition rates.

If the user chose the Transitional data type, the standard errors provided are those of the probabilities of surviving and the transitional attrition rates.

After displaying the outputs, the program asks the user if he/she wants to see these as a percentage of the estimates or not. According to the user's choice, the program either displays the standard errors as a percentage of the estimates, and returns to the main menu or the program returns directly to the main menu.

D. GRAPHICAL COMPARISONS FOR ANALYSIS OF ATTRITION MODELS

1. Loading the workspace

To use this workspace for graphical comparisons, the user must use STATGRAPHICS under the APL environment. The workspace is stored in the file STATUFNS.ASF. STATUFNS is in the Statgraphics system directory, which is set to be in library 24 after loading the system [Ref. 3: pp. E-5 - E-8].

Statgraphics software can be found in the micro-lab of the Operations Research Department at Root 262. The user should choose the STATAPL sub-directory and then by typing STATG, Statgraphics will be loaded automatically in this lab. After loading Statgraphics, the Statgraphics menu appears on the screen. By pressing the Esc key, the user can go to the APL environment. Then, the system function ΔFX is used to read the functions that are stored in the file STATUFNS.ASF by typing $\Delta R \leftarrow FX$ 1002. The Δ sign is the Shift H key and $\leftarrow$ is the left bracket ([ ) key on the standard keyboard. [Ref. 3: p. E-5] After reading the functions, the user must type COHORT for Graphical Comparison of Cohort Analysis, and CENSUS for Graphical Comparison of Census Analysis.

2. Graphical Comparison of Cohort Analysis

If the user types COHORT, the program asks the user to enter the start of each completed length of service interval and then, the maximum period possible. The program then asks the user if he/she wants to enter the numbers of survivors or the numbers

of leavers and after user response the appropriate numbers may be entered. Then, the program asks the user if he/she wants to see the input data.

If the user does not want to see the input data, the program calculates the estimated probabilities/rates and the estimated standard errors that were explained in Cohort Analysis, and asks the user to enter the second set of data.

If the user wants to see the input data, the program displays the input data. Then, asks the user if he/she wants to change the input data. If he/she does not, the program follows the same procedure for inputting the numbers of survivors/leavers of the second set of data. Note that the user is not prompted for CLS intervals for the second set of data, since those must be the same as in the first set of data as above.

If the user wants to make a change in the first set of data, the program asks the user to enter the new data. Then, the user is prompted for the second set of data as explained above.

After the second set of data is entered, the user has the option of making changes as was explained for the first set of data.

The user may then choose from the following list of estimates whose graph to display :

- Probabilities of leaving ($\hat{f_i}$)

- Survivor Functions ($\hat{G_i}$)

- Conditional probabilities of leaving ($\hat{q_i}$)

- Central rates ($\hat{m_i}$)

According to the user's choice of these graphs, the program displays that graph. The requested estimates are then displayed as functions of CLS. For the first set of data, the program plots the values with a "$\star$" sign. For the second set of data, the program plots the values with "$\square$" sign. The standard errors for each value are shown by the half-length of the vertical bars drawn across each point estimate. Each bar extends one standard error above and below the point representing the estimate. The analysis of the graph is explained in [Ref. 1: pp. 32-34].

A beep will warn the user when the graph is complete. Then, the user has two choices. If he/she does not want to get a printout, he/she must press the Esc key. Then,

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the user has the option to see another graph or quit in which case the program returns to DOS.

If he/she wants to get a printout, he/she must press the F4 key to see the print menu and then choose the "Print to Printer" option by pressing the Enter key. The program then provides a printed graph. After the printing is complete, the user must press the Esc key and again the user has the option of seeing another graph or quitting. After selecting the print menu, if he/she does not want to get a printout, he/she may press the Esc key, and the same procedure is followed as above.

3. Graphical Comparison of Census Analysis

If the user types CENSUS, the user must choose between Central and Transitional data types.

Regardless of which choice is made, the user must enter the start of each length of service interval and then the maximum period possible. Then, the program follows one of the following procedures :

1. If the user chose the Central data type, the user must enter the numbers of leavers. The user then has the option entering either the average stock vector or the beginning and the ending stock vectors. Then, the program asks the user if he/she wants to see the input data.

     If the user does not want to see the input data, the program calculates the estimated probabilities/rates and the estimated standard errors that were explained in Census Analysis, and asks the user to enter the second set of data.

     If the user wants to see the input data, the program displays the input data. Then, the user is asked if he/she wants to change the input data. If he/she does not, the user is asked to input the numbers of leavers of the second set of data. The user then has the option entering either the average stock vector or the beginning and the ending stock vectors of the second set of data. Note that the user is not prompted for LOS intervals for the second set of data, since those must be the same as in the first set of data.

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If the user wants to make a change in the first set of data, the program asks the user to enter the new data. Then, the user is asked for the second set of data as explained above.

After the second set of data is entered, the user has the option of making changes as was explained for the first set of data.

The user may then choose from the following list of estimates whose graph to display :

- Survivor Functions ($\hat{G}_i$)

- Conditional probabilities of leaving ($\hat{q}_i$)

- Central rates ($\hat{m}_i$)

According to the user's choice of these graphs, the program displays that graph. The requested estimates are then is displayed as functions of LOS. For the first set of data, the program plots the values with a "$\star$" sign. For the second set of data, the program plots the values with "$\square$" sign. The standard errors for each value are shown by the half-length of the vertical bars drawn across each point estimate. Each bar extends one standard error above and below the point representing the estimate. The analysis of the graph is explained in [Ref. 1: pp. 32-34].

A beep will warn the user when the graph is complete. Then, the user has two choices. If he/she does not want to get a printout, he/she must press the Esc key. Then, the user has the option to see another graph or quit in which case the program returns to DOS.

If he/she wants to get a printout, he/she must press the F4 key to see the print menu and then, choose the "Print to Printer" option by pressing the Enter key. The program then provides a printed graph. After the printing is complete, the user must press the Esc key and again the user has the option of seeing another

graph or quitting. After selecting the print menu, if he/she does not want to get a printout, he/she may press the Esc key, and the same procedure is followed as above.

In case of the graph of the estimated survivor functions $(\hat{G_t})$, the program also asks the user if he/she wants to drop the last LOS cell to get a better resolution for the rest of the graph. If the user chooses this option, another graph of the estimated survivor function $(\hat{G_t})$ is provided on the screen without the last LOS interval. The user then may obtain a printout of this graph the same way as above. Once the user is done graphing the first function, he/she may select another function to graph or else quit in which case the program returns to DOS.

2. If the user chose the Transitional data type, the user must enter the numbers of leavers and the beginning stock vector. Then the program asks the user if he/she wants to see the input data.

If the user does not want to see the input data, the program calculates the estimated probabilities/rates and the estimated standard errors that were explained in Census Analysis, and asks the user to enter the second set of data.

If the user wants to see the input data, the program displays the input data. Then, the user is asked if he/she wants to change the input data. If he/she does not, the user is asked to input the numbers of leavers and the beginning stock vector of the second set of data. Note that the user is not prompted for LOS intervals for the second set of data, since those must be the same as in the first set of data.

If the user wants to make a change in the first set of data, the program asks the user to enter the new data. Then, the user is asked for the second set of data as explained above.

After the second set of data is entered, the user has the option of making changes as was explained for the first set of data.

The user may then choose from the following list of estimates whose graph to display :

- Survivor Functions ($\hat{G}_i$)

- Transitional rates ($\hat{w}_i$)

According to the user's choice of these graphs, the program displays that graph. The requested estimates are then displayed as functions of LOS. For the first set of data, the program plots the values with a "$\star$" sign. For the second set of data, the program plots the values with "$\square$" sign. The standard errors for each value are shown by the half-length of the vertical bars drawn across each point estimate. Each bar extends one standard error above and below the point representing the estimate. The analysis of the graph is explained in [Ref. 1: pp. 32-34].

A beep will warn the user when the graph is complete. Then, the user has two choices. If he/she does not want to get a printout, he/she must press the Esc key. Then, the user has the option to see another graph or quit in which case the program returns to DOS.

If he/she wants to get a printout, he/she must press the F4 key to see the print menu and then, choose the "Print to Printer" option by pressing the Enter key. The program then provides a printed graph. After the printing is complete, the user must press the Esc key and again the user has the option of seeing another graph or quitting. After selecting the print menu, if he/she does not want to get a printout, he/she may press the Esc key, and the same procedure is followed as above.

In case of the graph of the estimated survivor functions ($\hat{G}_i$), the program also asks the user if he/she wants to drop the last LOS cell to get a better resolution for the rest of the graph. If the user chooses this option, another graph of the es-

timated survivor function ($\hat{G}_i$) is provided on the screen without the last LOS interval. The user then may obtain a printout of this graph the same way as above. Once the user is done graphing the first function, he/she may select another function to graph or else quit in which case the program returns to DOS.

E. ERROR TRAPPING

Error trapping is provided at various points of the program to avoid user input mistakes, such as :

- the input data dimension does not fit the program,

- a vector is entered instead of a scalar, or vice versa,

- negative values are entered instead of positive, or vice versa,

- special characters are entered instead of numerical values,

- the user gives inappropriate answers such as YES or NO to questions which require specific answers,

- the sum of the entered values is not in the range specified by the program.

APPENDIX D. USER'S MANUAL FOR TRANSITION MODELS BASED ON RENEWAL THEORY

A. LOADING THE MODEL

In this workspace, there are two vacancy models : the one-grade systems and the multi-grade systems.

This APL workspace can be used on either a hard disk or a floppy disk. It is recommended to use computers equipped with hard disk because of the increased operating speed. In this case, it is also recommended that the user create a separate sub-directory on the hard disk for this workspace.

When using the model with a hard disk, the user should select the appropriate sub-directory. Then, by typing VACANCY and pressing the Enter key, APL characters are activated, and the APL.EXE file and the VACANCY.AWS workspace are automatically loaded.

When using the model with a floppy disk, the disk is placed into an appropriate disk drive. Then, by typing VACANCY and pressing the Enter key, APL characters are activated, and the APL.EXE file and the VACANCY.AWS workspace are automatically loaded.

B. RUNNING THE ONE-GRADE SYSTEMS

If the user does not want a printout, he/she types REPLACE and the program begins to run. If the user wants a printout, he/she should first type PRINTER ON, and then, follow the same procedure as above. After typing REPLACE, the user gets the following three options to input the data :

These options are :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1. Data Input Choice 1

To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file.

If the user changes his/her mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. Data Input Choice 2

To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below.

The program first asks the user to enter the start of each length of service (LOS) interval. If the user wants to run Sub-model 1, he/she should enter 0. If the user wants to run Sub-models 2 or 3, he/she should enter the initial LOS distribution. These Sub-models are explained in Section IV.B of this thesis. The user is then prompted for the probabilities of survival and then, for the system size or, in case of Sub-model 3, system sizes for as many periods as necessary. The program then goes to the main menu.

3. Data Input Choice 3

To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. One-grade Vacancy Model Main Menu Screen

This is the menu that allows the user to choose from six options, shown in Figure 7 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

a. Main Menu Option 0

If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

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0	QUIT PROGRAM/SAVE DATA	3	CHANGE THE DATA
1	TURN PRINTER ON/OFF	4	SEE REPLACEMENT RATES
2	SEE THE DATA	5	SEE EXPECTED NO. OF RECRUITS

Figure 7.   Main Menu Screen for One-grade Systems

b.   *Main Menu Option 1*

This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

c.   *Main Menu Option 2*

This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program goes back to the main menu.

d.   *Main Menu Option 3*

This option provides a chance for the user to change the input data using a change menu on the screen. There are five choices in this menu which are shown in Figure 8.

After the user makes all his/her changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

If the user chooses Option 1 (i.e., changing the initial LOS distribution), the program asks him/her to enter the initial LOS distribution. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing the probabilities of survival), the program asks the user to enter the probabilities of survival. The program then returns to the change menu.

If the user chooses Option 3 (i.e., changing the system size), the program asks the user to enter the system size or sizes. The program then returns to the change menu.

If the user chooses Option 4 (i.e., changing all the data), the program asks the user to enter all the data that was entered earlier. This option gives the user a chance to make changes in all the data. The program then returns to the main menu.

```
0   DONE WITH ALL CHANGES
1   INITIAL LOS DISTRIBUTION
2   PROBABILITIES OF SURVIVAL
3   SYSTEM SIZE
4   ALL THE DATA
```

Figure 8.   Change Menu for One-grade Systems

e. *Main Menu Option 4*

This option lets the user forecast the replacement rates. The program calculates the rates and then, displays them on the screen as outputs. The program then returns to the main menu.

f. *Main Menu Option 5*

This option lets the user see the expected number of replacements. After displaying the outputs, the program goes back to the main menu.

C. RUNNING THE MULTI-GRADE SYSTEMS

If the user does not want a printout, he/she types VACANCY and the program begins to run. If the user wants a printout, he/she should first type PRINTER ON, and then, follow the same procedure as above. After typing VACANCY, the user gets the following three options to input the data :

These options are :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1. Data Input Choice 1

To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file. If the user changes his mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. Data Input Choice 2

To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below.

First the user must choose from the following sub-models :

1. Non-instantaneous filling of vacancies with fixed category sizes

2. Non-instantaneous filling of vacancies with increasing/decreasing category sizes

3. Instantaneous filling of vacancies with fixed category sizes

4. Instantaneous filling of vacancies with increasing/decreasing category sizes

For explanation of these sub-models see Section IV.C of this thesis. The necessary input for these Sub-models is explained below.

If the user chooses Sub-model 1, the user is prompted to enter the initial position vector and the initial vacancy vector. After that, the program asks the user to enter the attrition rate vector and the vacancy transition rate matrix.

The user can enter the vacancy transition rate matrix in two ways. First, he/she may enter this matrix by typing its elements row by row. The second way is by typing the letter "S". In that case, the previously saved transition rate matrix in the workspace is used by the program. The program then goes to the main menu.

If the user chooses Sub-model 2, the program asks the user to enter the same inputs as explained in Sub-model 1. In addition to these inputs, the user is prompted to enter the rate of category size increase/decrease. The program then goes to the main menu.

If the user chooses Sub-model 3, the user is prompted to enter the initial position vector and the attrition rate vector. After that, the program asks the user to enter vacancy transition rate matrix in one of the two ways explained above. The program then goes to the main menu.

If the user chooses Sub-model 4, the program asks the user to enter the same inputs as in Sub-model 3. In addition to these inputs, the program asks for the increase/decrease in the category sizes. This must be a vector of the same size as the initial position vector. The program then goes to the main menu.

3. **Data Input Choice 3**

To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. **Main Menu Screen for Multi-grade Vacancy Model**

   a. *Main Menu Screen for Sub-models 1 and 2*

This is the menu that allows the user to choose from six options, shown in Figure 9 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

(1) Main Menu Option 0. If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

(2) Main Menu Option 1. This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

(3) Main Menu Option 2. This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program goes back to the main menu.

(4) Main Menu Option 3. This option provides a chance for the user to change the input data using a change menu on the screen. There are six choices in this menu which are shown in Figure 10.

After the user makes all his changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

```
┌─────────────────────────────────────────────────────────────────┐
│  0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA          │
│  1   TURN PRINTER ON/OFF             4   FORECAST VACANCIES       │
│  2   SEE THE DATA                    5   SEE STEADY STATE         │
└─────────────────────────────────────────────────────────────────┘
```

Figure 9.   Main Menu Screen for Sub-models 1 and 2

If the user chooses Option 1 (i.e., changing the initial position vector), the program asks him/her to enter the initial position vector. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing the initial vacancy vector), the program asks the user to enter the initial vacancy vector. The program then returns to the change menu.

If the user chooses Option 3 (i.e., changing the attrition rate vector), the program asks the user to enter the attrition rate vector. The program then returns to the change menu.

If the user chooses Option 4 (i.e., changing vacancy transition matrix), the program asks the user to enter the matrix in one of the ways explained above. The program then returns to the change menu.

If the user chooses Option 5 (i.e., changing the rate of the category size increase/decrease), the program asks the user to enter the rate of category size increase/decrease. The program then returns to the change menu.

(5)   Main Menu Option 4.   This option lets the user forecast future vacancies. When the user chooses this option, the program asks him which period's vacancies he wants to see. If there are intervening periods, the program asks the user if he/she wants to see vacancies for the intervening periods. According to the user's response, the program displays future vacancies on the screen as outputs. The program then returns to the main menu.

In some cases the user may want to change the input data and then forecast vacancies for several additional periods. The program then calculates the next periods' vacancies based on the new data. But, if after changing the data, the user wants to see some prior periods' vacancies, the program warns him/her and asks if he/she wants to continue this procedure, since the program will then calculate vacancies starting from period zero, but using the altered data.

58

```
0  DONE WITH ALL CHANGES
1  INITIAL POSITION VECTOR
2  INITIAL VACANCY VECTOR
3  ATTRITION RATE VECTOR
4  VACANCY TRANSITION MATRIX
5  RATE OF CATEGORY SIZE INCREASE/DECREASE
```

Figure 10. Change Menu for Sub-models 1 and 2

If the user does not want to continue, the program returns back to the main menu. If the user does want to continue, the program forecasts vacancies based on the altered data. These forecasts, therefore, may differ from the previous forecasts for the same periods. Then, the program returns to the main menu.

(6) Main Menu Option 5. This option lets the user see the stocks in steady state. Steady state is the state to which a system comes, after a sufficient time has passed, so the vacancies in absolute or percentage terms do not change any more.

If the category sizes are under conditions of positive growth, steady state exists only in percentage terms.

If the category sizes are under conditions of negative growth, steady state vacancies will be zero.

If the category sizes are under fixed conditions, then steady state exists in both absolute numbers and percentage terms.

After displaying the outputs, the program goes back to the main menu.

b. *Main Menu Screen for Sub-models 3 and 4*

This is the menu that allows the user to choose from five options, shown in Figure 11 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

(1) Main Menu Option 0. If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the

```
 0   QUIT PROGRAM/SAVE DATA      3   CHANGE THE DATA
 1   TURN PRINTER ON/OFF         4   SEE EXPECTED NO. OF PERSONNEL FLOWS
 2   SEE THE DATA
```

Figure 11. Main Menu Screen for Sub-models 3 and 4

user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

(2)   Main Menu Option 1.   This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

(3)   Main Menu Option 2.   This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program goes back to the main menu.

(4)   Main Menu Option 3.   This option provides a chance for the user to change the input data using a change menu on the screen. There are five choices in this menu which are shown in Figure 12.

After the user makes all his/her changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

If the user chooses Option 1 (i.e., changing the initial position_vector), the program asks him/her to enter the initial position vector. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing the attrition rate vector), the program asks the user to enter the attrition rate vector. The program then returns to the change menu.

If the user chooses Option 3 (i.e., changing the vacancy transition matrix), the program asks the user to enter the matrix in one of the ways explained above. The program then returns to the change menu.

```
0   DONE WITH ALL CHANGES
1   INITIAL POSITION VECTOR
2   ATTRITION RATE VECTOR
3   VACANCY TRANSITION MATRIX
4   VECTOR OF CATEGORY SIZE INCREASES/DECREASES
```

Figure 12.   Change Menu for Sub-models 3 and 4

If the user chooses Option 4 (i.e., changing vector of category size increase/decrease), the program asks the user to enter the vector of category size increases/decreases. This must be a vector of the same size as the initial position vector. The program then returns to the change menu.

(5) Main Menu Option 4. This option lets the user forecast the expected number of transfers between categories during any period. The program displays the outputs on the screen. The program then returns to the main menu.

D. ERROR TRAPPING

Error trapping is provided at various points of the program to avoid user input mistakes, such as :

- the input data dimension does not fit the program,

- a vector is entered instead of a scalar, or vice versa,

- negative values are entered instead of positive, or vice versa,

- special characters are entered instead of numerical values,

- the user gives inappropriate answers such as YES or NO to questions which require specific answers,

- the sum of the entered values is not in the range specified by the program.

APPENDIX E.   USER'S MANUAL FOR CAREER PATTERNS MODELS

A.   LOADING THE MODEL

In this workspace, there are two models : the Career Patterns Model and the Career Patterns using Markov Chain Model.

This APL workspace can be used on either a hard disk or a floppy disk. It is recommended to use computers equipped with hard disk because of the increased operating speed.   In this case, it is also recommended that the user create a separate sub-directory on the hard disk for this workspace.

When using the model with a hard disk, the user should select the appropriate sub-directory. Then, by typing CAREER and pressing the Enter key, APL characters are activated, and the APL.EXE file and the CAREER.AWS workspace are automatically loaded.

When using the model with a floppy disk, the disk is placed into an appropriate disk drive. Then, by typing CAREER and pressing the Enter key, APL characters are activated, and the APL.EXE file and the CAREER.AWS workspace are automatically loaded.

B.   RUNNING CAREER PATTERNS MODEL

If the user does not want a printout, he/she types CAREER and the program begins to run. If the user wants a printout, he/she should first type PRINTER ON, and then, follow the same procedure as above. After typing CAREER, the user gets the following three options to input the data :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1.   Data Input Choice 1

To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file. If the user changes his/her mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. Data Input Choice 2

To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below.

First the program asks the user if the system has a promotion zone.

If the system does not have a promotion zone, the user is prompted for the following inputs. The program first asks for the retirement point. Then, the user is asked which assumption he/she wants to use to calculate the promotion rate for careerists (i.e., personnel with zero attrition rate). The available assumptions are :

1. Promotion before attrition

2. Attrition before promotion

3. Promotion and attrition simultaneous

The program then asks for the promotion rate in the Promotion Zone and the attrition rates in the Below Zone and in the Promotion Zone. The program then goes to the main menu.

If the system has a promotion zone, the user is prompted to enter the following inputs. The user is first asked for the lower and upper boundaries of the promotion zone. Then, the program asks the user which assumption he/she wants to use to calculate the promotion rate for careerists. The available assumptions were listed above. The program then asks the user whether he/she wants to use the zone specific rates or the category specific rates.

If the user wants to use zone specific rates, the program asks for the promotion rate in the Promotion Zone and then, for the attrition rate in the Below Zone and in the Promotion Zone. The program then goes to the main menu.

If the user wants to use the category specific rates, the program asks the user to enter the retirement point, the promotion rate and the attrition rate for the category. The program then goes to the main menu.

3. **Data Input Choice 3**

To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. **Main Menu Screen for Career Patterns Model**

This is the menu that allows the user to choose from six options, shown in Figure 13 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

a. *Main Menu Option 0*

If making this choice, the user is given the option to save the data. If wanting to save, the user must first enter the drive on which to save the data. After choosing the drive, the user should enter the data file name for the data to be saved. If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data. If not the user must select another data file name. The data is then saved as an APL data file with that name. For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

b. *Main Menu Option 1*

This option lets the user turn the printer on or off. The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on. Simply hitting the Enter key will leave the printer off or turn it off.

c. *Main Menu Option 2*

This option displays the input data. If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed. After displaying the input data, the program goes back to the main menu.

d. *Main Menu Option 3*

This option provides a chance for the user to change the input data using a change menu on the screen. There are eight choices in this menu which are shown in Figure 14.

After the user makes all his changes in the input data, he/she should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

```
┌─────────────────────────────────────────────────────────────────────┐
│  0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA              │
│  1   TURN PRINTER ON/OFF             4   RUN MODEL                    │
│  2   SEE THE DATA                    5   RUN MODEL FOR CAREERISTS     │
└─────────────────────────────────────────────────────────────────────┘
```

Figure 13.   Main Menu Screen for Career Patterns Model

If the user chooses Option 1 (i.e., changing the lower and upper boundaries of promotion zone), the program asks him/her to enter the new boundaries. After that, the program returns to the change menu.

If the user chooses Option 2 (i.e., changing the retirement point), the program asks the user to enter the new retirement point. The program then returns to the change menu.

If the user chooses Option 3 (i.e., changing the assumptions for careerists promotion rate), the program asks the user which assumption he/she wants to use for careerists' promotion rate. The program then goes to the main menu.

If the user chooses Option 4 (i.e., changing the zone specific rates/category specific rates), the program asks the user which one of the aforementioned rates he/she wants to use. Then, according to the chosen rate, the program asks for the appropriate inputs as explained above. The program then goes to the main menu.

If the user chooses Option 5 (i.e., changing the promotion rate), the program asks the user to enter the new promotion rate. The program then goes to the main menu.

If the user chooses Option 6 (i.e., changing the attrition rates), the program asks the user to enter the new attrition rates. The program then goes to the main menu.

If the user chooses Option 7 (i.e., changing all the data), the program then prompts the user to enter all the data that was entered earlier. This option gives the user a chance to make changes in all the data. The program then returns to the main menu.

   e.   *Main Menu Option 4*

This option lets the user estimate the probability of eventual promotion and the mean time to promotion of promotees for all personnel. After displaying these outputs, the program returns to the main menu.

```
0    DONE WITH ALL CHANGES

1    LOWER AND UPPER BOUNDARIES OF PROMOTION ZONE

2    RETIREMENT POINT

3    ASSUMPTIONS FOR CAREERISTS' PROMOTION RATE

4    ZONE SPECIFIC RATES/CATEGORY SPECIFIC RATES

5    PROMOTION RATE

6    ATTRITION RATES

7    ALL THE DATA
```

Figure 14.   Change Menu for Career Patterns Model

f. Main Menu Option 5

This option lets the user estimate the probability of eventual promotion and the mean time to promotion for careerists. After displaying these outputs, the program goes back to the main menu.

C. RUNNING CAREER PATTERNS USING MARKOV CHAIN MODEL

If the user does not want a printout, he/she types MARKOV and the program begins to run. If the user wants a printout, he/she should first type PRINTER ON, and then, follow the same procedure as above. After typing MARKOV, the user gets the following three options to input the data :

1. Enter data from a data file

2. Enter data from the keyboard

3. Make a choice from the main menu

These choices are explained below.

1. Data Input Choice 1

To select choice 1, the user types 1 and presses the Enter key. Then, the program asks the user which drive he/she wants to use from which to load in the data file. If the user changes his/her mind about entering data from a data file, it also gives the user a chance to return to the previous menu by pressing the Enter key.

Once a drive is chosen, the program displays the available APL data files on that drive. After the user chooses a data file to be used, the program reads in the data and goes to the main menu.

If there is no available APL data file on the chosen drive, the program returns to the previous menu and the user may reenter another drive.

2. Data Input Choice 2

To select choice 2, the user types 2 and presses the Enter key. In this case the user will be prompted to input the necessary data as explained below. First the user must choose from the following model types :

1. Markov Hierarchical

2. Markov Length Of Service

3. Markov General

For explanation see Section II.B of this thesis.

Regardless which type is chosen by the user, the program first asks the user to enter the number of categories. Then, according to the chosen Markov model type, the user must enter the transition rate matrix in one of the following three ways.

Markov Hierarchical Type : In this case, the user is prompted to enter the promotion rates and then attrition rates.

Markov Length of Service Type : In this case, the user is prompted to enter the attrition rates only.

Markov General Type : In this case, the user is prompted to enter the transition rate matrix row by row.

In this model, the Recruitment Option is assumed as fixed recruitment by the program. The program then goes to the main menu.

3. Data Input Choice 3

To select choice 3, the user types 3 and presses the Enter key. In this option, the program uses the previously saved data in the workspace. The program then goes directly to the main menu.

4. The Workspace Main Menu Screen

This is the menu that allows the user to choose from six options, shown in Figure 15 and explained below. The user can enter his/her option by typing the number of that option and pressing the Enter key.

```
┌─────────────────────────────────────────────────────────────────┐
│                                                                   │
│   0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA            │
│                                                                   │
│   1   TURN PRINTER ON/OFF           4   D AND PI MATRIX            │
│                                                                   │
│   2   SEE THE DATA                  5   D AND PI MATRIX   FOR CAREERISTS │
│                                                                   │
└─────────────────────────────────────────────────────────────────┘
```

Figure 15.   Main Menu Screen for Career Patterns using Markov Chain Model

a.   *Main Menu Option 0*

If making this choice, the user is given the option to save the data.   If wanting to save, the user must first enter the drive on which to save the data.   After choosing the drive, the user should enter the data file name for the data to be saved.   If this name belongs to a previously saved data file, the user is asked if he/she wants to replace the previously saved data with the new data.   If not the user must select another data file name.   The data is then saved as an APL data file with that name.   For more explanation about APL files see [Refs. 4,8,9].

Whether the user chooses to save or not, the program then asks the user if he/she wants to leave the program, but stay in the APL environment, or leave the APL environment and return to DOS.

b.   *Main Menu Option 1*

This option lets the user turn the printer on or off.   The user must answer affirmatively, by typing "Y", in order to turn the printer on even when the printer is already on.   Simply hitting the Enter key will leave the printer off or turn it off.

c.   *Main Menu Option 2*

This option displays the input data.   If the user chose the "Make a Choice from the main menu" option from the three data input choices, the previously saved data will be displayed.   After displaying the input data, the program goes back to the main menu.

d.   *Main Menu Option 3*

This option provides a chance for the user to change the input data using a change menu on the screen.   There are three choices in this menu which are shown in Figure 16.

```
0   DONE WITH ALL CHANGES
1   TRANSITION PROBABILITY MATRIX
2   ALL THE DATA
```

Figure 16.   **Change Menu for Career Patterns using Markov Chain Model**

After the user makes all his/her changes in the input data, he should choose the Option 0 (i.e., Done with all changes) which returns him/her to the main menu.

If the user chooses Option 1 (i.e., changing the transition probability matrix), the program asks the user to enter the matrix according to the Markov model type selected earlier. The program then returns to the change menu.

If the user chooses Option 2 (i.e., changing all the data), the program asks the user to enter all the data that was entered earlier. This option gives the user a chance to make changes in all the data. The program then returns to the main menu.

e.   Main Menu Option 4

This option calculates the $\underline{D}$ and $\underline{\Pi}$ matrices. For explanation see Section V.C. After, displaying the outputs on the screen, the program returns to the main menu.

f.   Main Menu Option 5

This option calculates the $\underline{D}^{\star}$ and $\underline{\Pi}^{\star}$ matrices for careerists. For explanation see Section V.C. After displaying the outputs on the screen, the program goes to the main menu.

D.   ERROR TRAPPING

Error trapping is provided at various points of the program to avoid user input mistakes, such as :

- the input data dimension does not fit the program,

- a vector is entered instead of a scalar, or vice versa,

- negative values are entered instead of positive, or vice versa,

- special characters are entered instead of numerical values,

- the user gives inappropriate answers such as YES or NO to questions which require specific answers,

- the sum of the entered values is not in the range specified by the program.

APPENDIX F.   TERMINAL SESSION WITH TRANSITION MODELS BASED ON MARKOV CHAIN THEORY

This appendix includes a set of three examples of terminal sessions with the Transition models based on Markov Chain Theory.

Example 1 :   This is a Markov hierarchical system with three categories.   The initial stock vector, the promotion and attrition rates, and the recruitment vector with fixed recruitment option (Recruitment Option 1) are given as input to the model.

The model is then asked to forecast stocks for two years.   Then, the fixed recruitment option is changed to the option of additive increase/decrease in total recruitment (Recruitment Option 2) with an additive increase of five.   The model then forecasts stocks for three more years.   After that, the steady state is displayed.

The computer printout of this example is presented on the following pages.

```
        MARKOV

DO YOU WISH TO
  1:ENTER THE DATA FROM DATA FILE ?
  2:ENTER THE DATA FROM THE KEYBOARD ?
  3:MAKE A CHOICE FROM THE MAIN MENU ?


2


ENTER THE NUMBER OF THE MODEL TYPE
  1     MARKOV HIERARCHICAL
  2     MARKOV LENGTH OF SERVICE
  3     MARKOV GENERAL
1


ENTER INITIAL STOCK VECTOR (N)
250 100 80
ENTER THE PROMOTION RATE VECTOR
THIS VECTOR SHOULD INCLUDE THE PROMOTION RATES
FOR THE FIRST 2 CLASS(ES).
.1 .2
ENTER THE ATTRITION RATE VECTOR
THE 3TH VALUE SHOULD INCLUDE THE TOTAL RATE
FOR THAT STATE DUE TO EITHER PROMOTION OR ATTRITION.
.2 .05 .05
ENTER THE NUMBER OF THE RECRUIT TYPE
  1     FIXED RECRUITMENT VECTOR
  2     ADDITIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
  3     MULTIPLICATIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
  4     ADDITIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
  5     MULTIPLICATIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
1
ENTER RECRUITMENT VECTOR (R)
35 15 10

ENTER THE PERCENT CODE
 0 NO GRADE PERCENTAGES
 1 GRADE SIZE AS PERCENT OF TOTAL SYSTEM SIZE
 2 GRADE SIZE AS PERCENT OF ORIGINAL GRADE SIZE
1

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA            3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF               4   FORECAST STOCKS
     2   SEE THE DATA                      5   SEE STEADY STATE
2

INITIAL STOCK VECTOR
250 100 80

TRANSITION RATE MATRIX
 0.7   0.1   0
 0     0.75  0.2
 0     0     0.95

ATTRITION RATE VECTOR
0.2 0.05 0.05

'RECRUITMENT' OPTION=1
```

```
RECRUITMENT VECTOR
35 15 10

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
     2   SEE THE DATA                        5   SEE STEADY STATE
4

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
2
DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD   CTGRY      STOCKS     PERCENT     RECRUITS
***************************************************
    0        1        250        (58)
             2        100        (23)
             3         80        (19)
          TOTAL       430       (100)
===================================================
    1        1        210        (49)
             2        115        (27)
             3        106        (25)
          TOTAL       431       (100)           60
===================================================
    2        1        182        (42)
             2        122        (28)
             3        134        (31)
          TOTAL       438       (102)           60
===================================================

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
     2   SEE THE DATA                        5   SEE STEADY STATE
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
   0   DONE WITH ALL CHANGES
   1   INITIAL STOCK VECTOR (N)
   2   TRANSITION MATRIX (P)
   3   RECRUIT TYPE OR VECTOR
3
ENTER THE NUMBER OF THE RECRUIT TYPE
   1   FIXED RECRUITMENT VECTOR
   2   ADDITIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
   3   MULTIPLICATIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
   4   ADDITIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
   5   MULTIPLICATIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
2
ENTER RECRUITMENT VECTOR (R)
35 15 10
ENTER ADDITIVE INCREASE/DECREASE (INC)
5

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
   0   DONE WITH ALL CHANGES
   1   INITIAL STOCK VECTOR (N)
```

```
    2   TRANSITION MATRIX (P)
    3   RECRUIT TYPE OR VECTOR
0

                              WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF                4   FORECAST STOCKS
    2   SEE THE DATA                       5   SEE STEADY STATE
2

INITIAL STOCK VECTOR
250 100 80

TRANSITION RATE MATRIX
 0.7  0.1  0
 0    0.75 0.2
 0    0    0.95

ATTRITION RATE VECTOR
0.2 0.05 0.05

'RECRUITMENT' OPTION=2

RECRUITMENT VECTOR
35 15 10

ADDITIVE INCREMENT IN TOTAL RECRUITMENT: INC=5

                              WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF                4   FORECAST STOCKS
    2   SEE THE DATA                       5   SEE STEADY STATE
4

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
5
DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD  CTGRY     STOCKS    PERCENT    RECRUITS
************************************************
    3       1        168      (37)
            2        127      (28)
            3        163      (36)
         TOTAL       459     (107)         70
================================================
    4       1        162      (33)
            2        131      (27)
            3        193      (40)
         TOTAL       486     (113)         75
================================================
    5       1        160      (31)
            2        134      (26)
            3        223      (43)
         TOTAL       517     (120)         80
================================================

                              WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
```

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```
        1   TURN PRINTER ON/OFF              4   FORECAST STOCKS
        2   SEE THE DATA                    5   SEE STEADY STATE
5
PERIOD  CTGRY       STOCKS    PERCENT      RECRUITS
*************************************************
STEADY      1                   (14)
STATE       2                   (13)
            3                   (74)
                               (100)
=================================================

                      WOULD YOU LIKE TO
        0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA
        1   TURN PRINTER ON/OFF             4   FORECAST STOCKS
        2   SEE THE DATA                    5   SEE STEADY STATE
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER


DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
 0  FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
 1 FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1
```

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Example 2 : This is a Markov LOS system, with four categories. The initial stock vector, the attrition rates and the recruitment vector with the option of multiplicative increase/decrease in total recruitment (Recruitment Option 3) with a 5% increase are given as input to the model.

The model is asked to forecast stocks for two years. Then, the Recruitment Option 3 is changed to the option of additive increase/decrease in total system size (Recruitment Option 4) with zero increase. The model then forecasts stocks for three more years. After that, the model calculates the steady state stock vector.

The computer printout of this example is presented on the following pages.

```
        MARKOV

DO YOU WISH TO
   1:ENTER THE DATA FROM DATA FILE ?
   2:ENTER THE DATA FROM THE KEYBOARD ?
   3:MAKE A CHOICE FROM THE MAIN MENU ?


2


ENTER THE NUMBER OF THE MODEL TYPE
   1      MARKOV HIERARCHICAL
   2      MARKOV LENGTH OF SERVICE
   3      MARKOV GENERAL
2

ENTER INITIAL STOCK VECTOR (N)
745 585 325 125
ENTER THE ATTRITION RATE VECTOR
.4 .2 .1 .2
ENTER THE NUMBER OF THE RECRUIT TYPE
   1    FIXED RECRUITMENT VECTOR
   2    ADDITIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
   3    MULTIPLICATIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
   4    ADDITIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
   5    MULTIPLICATIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
2
ENTER RECRUITMENT VECTOR (R)
80 0 0 0
ENTER ADDITIVE INCREASE/DECREASE (INC)
.05

ENTER THE PERCENT CODE
 0 NO GRADE PERCENTAGES
 1 GRADE SIZE AS PERCENT OF TOTAL SYSTEM SIZE
 2 GRADE SIZE AS PERCENT OF ORIGINAL GRADE SIZE
1

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
     2   SEE THE DATA                        5   SEE STEADY STATE
2

INITIAL STOCK VECTOR
745 585 325 125

TRANSITION RATE MATRIX
 0    0.6 0    0
 0    0    0.8 0
 0    0    0    0.9
 0    0    0    0.8

ATTRITION RATE VECTOR
0.4 0.2 0.1 0.2

'RECRUITMENT' OPTION=2

RECRUITMENT VECTOR
80 0 0 0
```

F S

ADDITIVE INCREMENT IN TOTAL RECRUITMENT: INC=0.05
```
                        WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
    2   SEE THE DATA                        5   SEE STEADY STATE
4

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
2
DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD  CTGRY     STOCKS    PERCENT     RECRUITS
****************************************************
    0      1        745       (42)
           2        585       (33)
           3        325       (18)
           4        125        (7)
        TOTAL      1780      (100)
==================================================
    1      1         80        (6)
           2        447       (32)
           3        468       (34)
           4        393       (28)
        TOTAL      1388       (78)          80
==================================================
    2      1         80        (7)
           2         48        (4)
           3        358       (29)
           4        735       (60)
        TOTAL      1221       (69)          80
==================================================


                        WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
    2   SEE THE DATA                        5   SEE STEADY STATE
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0   DONE WITH ALL CHANGES
    1   INITIAL STOCK VECTOR (N)
    2   TRANSITION MATRIX (P)
    3   RECRUIT TYPE OR VECTOR
3
ENTER THE NUMBER OF THE RECRUIT TYPE
    1   FIXED RECRUITMENT VECTOR
    2   ADDITIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
    3   MULTIPLICATIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
    4   ADDITIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
    5   MULTIPLICATIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
4
ENTER RECRUITMENT PROPORTION VECTOR (RPROP)
.75 .25 0 0
ENTER ADDITIVE INCREASE/DECREASE (INC)
0

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
```

F-b

```
    0   DONE WITH ALL CHANGES
    1   INITIAL STOCK VECTOR (N)
    2   TRANSITION MATRIX (P)
    3   RECRUIT TYPE OR VECTOR
0

                            WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA           3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF              4   FORECAST STOCKS
    2   SEE THE DATA                     5   SEE STEADY STATE
2

INITIAL STOCK VECTOR
745 585 325 125

TRANSITION RATE MATRIX
 0    0.6  0    0
 0    0    0.8  0
 0    0    0    0.9
 0    0    0    0.8

ATTRITION RATE VECTOR
0.4 0.2 0.1 0.2

'RECRUITMENT' OPTION=4

RECRUITMENT PROPORTION VECTOR
0.75 0.25 0 0

INITIAL TOTAL SYSTEM SIZE: N(0)=1780

ADDITIVE INCREMENT IN TOTAL SYSTEM SIZE: INC=0

                            WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA           3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF              4   FORECAST STOCKS
    2   SEE THE DATA                     5   SEE STEADY STATE
4

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
5
DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD  CTGRY     STOCKS    PERCENT    RECRUITS
************************************************
    3       1       168       (14)
            2       104        (9)
            3        38        (3)
            4       910       (75)
          TOTAL    1221       (69)        225
================================================
    4       1       206       (17)
            2       170       (14)
            3        83        (7)
            4       763       (62)
          TOTAL    1221       (69)        274
================================================
    5       1       208       (17)
```

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```
         2       193      (16)
         3       136      (11)
         4       685      (56)
      TOTAL     1221      (69)          277
===================================================

                    WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF             4   FORECAST STOCKS
    2   SEE THE DATA                    5   SEE STEADY STATE
5
PERIOD   CTGRY     STOCKS    PERCENT    RECRUITS
★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★
STEADY       1       202      (17)
STATE        2       189      (15)
             3       151      (12)
             4       679      (56)
      TOTAL       1221      (100)         270
===================================================

                    WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF             4   FORECAST STOCKS
    2   SEE THE DATA                    5   SEE STEADY STATE
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER


DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
 0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
 1 FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1
```

Example 3 : This is a Markov General system with two categories. The initial stock vector, the probability transition matrix and the recruitment proportion vector with the option of additive increase/decrease in total system size (Recruitment Option 4) with zero increase are given to the program.

The model then forecasts the stocks for two years. Then, the Recruitment Option 4 is changed to the option of multiplicative increase/decrease in total system size (Recruitment Option 5) with 5% reduction in total system size. The model then forecasts stocks for the next three years. After that, the steady state vector is shown to be zero.

The computer printout of this example is presented on the following pages.

```
        MARKOV

DO YOU WISH TO
  1:ENTER THE DATA FROM DATA FILE ?
  2:ENTER THE DATA FROM THE KEYBOARD ?
  3:MAKE A CHOICE FROM THE MAIN MENU ?

2

ENTER THE NUMBER OF THE MODEL TYPE
  1    MARKOV HIERARCHICAL
  2    MARKOV LENGTH OF SERVICE
  3    MARKOV GENERAL
3

ENTER INITIAL STOCK VECTOR (N)
975 650
ENTER TRANSITION MATRIX (P) BY ROWS
ENTER 1TH ROW
.2  .7
ENTER 2TH ROW
.1  .5
ENTER THE NUMBER OF THE RECRUIT TYPE
  1    FIXED RECRUITMENT VECTOR
  2    ADDITIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
  3    MULTIPLICATIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
  4    ADDITIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
  5    MULTIPLICATIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
4
ENTER RECRUITMENT PROPORTION VECTOR (RPROP)
.8  .2
ENTER ADDITIVE INCREASE/DECREASE (INC)
0

ENTER THE PERCENT CODE
 0 NO GRADE PERCENTAGES
 1 GRADE SIZE AS PERCENT OF TOTAL SYSTEM SIZE
 2 GRADE SIZE AS PERCENT OF ORIGINAL GRADE SIZE
1

                        WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA          3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF             4   FORECAST STOCKS
    2   SEE THE DATA                    5   SEE STEADY STATE
2

INITIAL STOCK VECTOR
975 650

TRANSITION RATE MATRIX
 0.2 0.7
 0.1 0.5

ATTRITION RATE VECTOR
0.1 0.4

'RECRUITMENT' OPTION=4

RECRUITMENT PROPORTION VECTOR
0.8 0.2
```

```
INITIAL TOTAL SYSTEM SIZE: N(0)=1625

ADDITIVE INCREMENT IN TOTAL SYSTEM SIZE: INC=0

                              WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                4   FORECAST STOCKS
      2   SEE THE DATA                       5   SEE STEADY STATE
4


ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
2
DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD  CTGRY      STOCKS     PERCENT     RECRUITS
******************************************************
      0       1        975        (60)
              2        650        (40)
          TOTAL       1625       (100)
======================================================
      1       1        546        (34)
              2       1079        (66)
          TOTAL       1625       (100)        358
======================================================
      2       1        606        (37)
              2       1019        (63)
          TOTAL       1625       (100)        486
======================================================


                              WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                4   FORECAST STOCKS
      2   SEE THE DATA                       5   SEE STEADY STATE
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
      0   DONE WITH ALL CHANGES
      1   INITIAL STOCK VECTOR (N)
      2   TRANSITION MATRIX (P)
      3   RECRUIT TYPE OR VECTOR
3
ENTER THE NUMBER OF THE RECRUIT TYPE
      1   FIXED RECRUITMENT VECTOR
      2   ADDITIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
      3   MULTIPLICATIVE INCREASE/DECREASE IN TOTAL RECRUITMENT
      4   ADDITIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
      5   MULTIPLICATIVE INCREASE/DECREASE IN TOTAL SYSTEM SIZE
5
ENTER RECRUITMENT PROPORTION VECTOR (RPROP)
.6 .4
ENTER INCREASE/DECREASE MULTIPLICATIVE FACTOR (FACT)
.95

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
      0   DONE WITH ALL CHANGES
      1   INITIAL STOCK VECTOR (N)
      2   TRANSITION MATRIX (P)
```

F-1C

```
    3   RECRUIT TYPE OR VECTOR
0
                            WOULD  YOU  LIKE  TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
      2   SEE THE DATA                        5   SEE STEADY STATE
2

INITIAL STOCK VECTOR
975 650

TRANSITION RATE MATRIX
 0.2 0.7
 0.1 0.5

ATTRITION RATE VECTOR
0.1 0.4

'RECRUITMENT' OPTION=5

RECRUITMENT PROPORTION VECTOR
0.6 0.4

INITIAL TOTAL SYSTEM SIZE: N(0)=1625
MULTIPLICATIVE FACTOR IN TOTAL SYSTEM SIZE: FACT=0.95

                            WOULD  YOU  LIKE  TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
      2   SEE THE DATA                        5   SEE STEADY STATE
4

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
5
DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD  CTGRY       STOCKS    PERCENT      RECRUITS
*******************************************************
    3       1         455       (29)
            2        1088       (70)
         TOTAL       1544       (95)          387
=======================================================
    4       1         442       (30)
            2        1025       (70)
         TOTAL       1467       (90)          404
=======================================================
    5       1         419       (30)
            2         974       (70)
         TOTAL       1394       (86)          381
=======================================================

                            WOULD  YOU  LIKE  TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST STOCKS
      2   SEE THE DATA                        5   SEE STEADY STATE
5
PERIOD  CTGRY       STOCKS    PERCENT      RECRUITS
```

F-11

```
**************************************************
STEADY      1           0          (0)
STATE       2           0          (0)
     TOTAL              0          (0)                0
==================================================
```

                          WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   FORECAST STOCKS
     2   SEE THE DATA   5   SEE STEADY STATE
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER

DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
 0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
 1 FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1

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APPENDIX G.   TERMINAL SESSION WITH ANALYSIS OF ATTRITION MODELS

This appendix includes a set of five examples of terminal sessions with the Analysis of Attrition models.

Example 1 : This is an example for Cohort Analysis. The start of each completed length of service interval and number of leavers are given to the model as input. The model then displays the estimates of the probabilities/rates and their estimated standard errors as outputs. Then, the number of leavers is changed and the same outputs are displayed with the new data.

The computer printout of this example is presented on the following pages.

COHORT

DO YOU WISH TO
   1 :   ENTER THE DATA FROM DATAFILE ?
   2 :   ENTER THE DATA FROM THE KEYBOARD ?
   3 :   MAKE A CHOICE FROM THE MAIN MENU ?

2

ENTER THE BEGINNING OF EACH COMPLETED LENGTH OF SERVICE (CLS)
INTERVAL IN ASCENDING ORDER

0 1 2 3 4 5 6

ENTER MAX PERIOD POSSIBLE (TLAST)

10

WOULD YOU LIKE TO ENTER;
   1   THE VECTOR OF SURVIVORS (SUR) ?
   2   THE VECTOR OF LEAVERS (LV) ?

2

ENTER VECTOR OF LEAVERS (LV)

13 6 9 5 4 3 15

                      WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

2

COMPLETED LENGTH OF SERVICE (CLS)
0 1 2 3 4 5 6 10

VECTOR OF LEAVERS (LV)
13 6 9 5 4 3 15

VECTOR OF SURVIVORS (SUR)
55 42 36 27 22 18 15

                      WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

4

TIME	F PDF OF LEAVERS	G SURVIVOR FUNCTION	Q COND PROB OF LEAVING	M RATE FUNCTION	D EXPECTED DURATION
0	.236	1.000	.236	.270	3.804
1	.109	.764	.143	.154	3.834
2	.164	.655	.250	.288	3.391
3	.091	.491	.185	.205	3.363
4	.073	.400	.182	.201	3.018

| 5 | .055 | .327 | .167 | .182 | 2.581 |
| 6 | .068 | .273 | .250 | 2.708 | 2.000 |

```
                          WOULD YOU LIKE TO
      0  QUIT PROGRAM/SAVE DATA        3  CHANGE THE DATA
      1  TURN PRINTER ON/OFF           4  ESTIMATE PROBABILITIES/RATES
      2  SEE THE DATA                  5  SEE ESTIMATED STANDARD ERRORS
```

5

TIME	SE(F)	SE(G)	SE(Q)	SE(M)
****
0	.057	.000	.057	.075
1	.042	.057	.054	.063
2	.050	.064	.072	.096
3	.039	.067	.075	.092
4	.035	.066	.082	.101
5	.031	.063	.088	.105
6	.015	.060	.000	.250

WOULD YOU LIKE TO SEE THESE AS A PERCENTAGE OF THE ESTIMATES ?
TYPE   0   FOR NO
TYPE   1   FOR YES

1

TIME	100×[SE(F)÷F]	100×[SE(G)÷G]	100×[SE(Q)÷Q]
****
0	24.237	.000	24.237
1	38.534	7.502	37.796
2	30.484	9.796	28.868
3	42.640	13.731	40.369
4	48.148	16.514	45.227
5	56.138	19.332	52.705
6	22.019	22.019	.000

```
                          WOULD YOU LIKE TO
      0  QUIT PROGRAM/SAVE DATA        3  CHANGE THE DATA
      1  TURN PRINTER ON/OFF           4  ESTIMATE PROBABILITIES/RATES
      2  SEE THE DATA                  5  SEE ESTIMATED STANDARD ERRORS
```

3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
```
   0    DONE WITH ALL CHANGES
   1    COMPLETED LENGTH OF SERVICE (CLS)
   2    SURVIVOR (SUR)/LEAVER (LV)   VECTOR
   3    ALL THE DATA
```

2

WOULD YOU LIKE TO ENTER;
```
   1  THE VECTOR OF SURVIVORS (SUR) ?
   2  THE VECTOR OF LEAVERS (LV) ?
```

1

ENTER VECTOR OF SURVIVORS (SUR) STARTING WITH INITIAL COHORT SIZE
AND CORRESPONDING TO EACH CLS EXCEPT THE LAST POSSIBLE CLS

```
58 44 30 25 19 19 14

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
   0   DONE WITH ALL CHANGES
   1   COMPLETED LENGTH OF SERVICE (CLS)
   2   SURVIVOR (SUR)/LEAVER (LV)   VECTOR
   3   ALL THE DATA

0

                          WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
      2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS

2

COMPLETED LENGTH OF SERVICE (CLS)
0 1 2 3 4 5 6 10

VECTOR OF LEAVERS (LV)
14 14 5 6 0 5 14

VECTOR OF SURVIVORS (SUR)
58 44 30 25 19 19 14

                          WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
      2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS

4
```

TIME	F PDF OF LEAVERS	G SURVIVOR FUNCTION	Q COND PROB OF LEAVING	M RATE FUNCTION	D EXPECTED DURATION
0	.241	1.000	.241	.276	4.119
1	.241	.759	.318	.383	4.278
2	.086	.517	.167	.182	5.055
3	.103	.431	.240	.274	4.969
4	.000	.328	.000	.000	5.388
5	.086	.328	.263	.305	2.335
6	.060	.241	.250	2.639	2.000

```
                          WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
      2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS

5
```

TIME	SE(F)	SE(G)	SE(Q)	SE(M)
0	.056	.000	.056	.074
1	.056	.056	.070	.103
2	.037	.066	.068	.082
3	.040	.065	.085	.112
4	.000	.062	.000	.000
5	.037	.062	.101	.137

```
6          .014         .056         .000         .250
```

WOULD YOU LIKE TO SEE THESE AS A PERCENTAGE OF THE ESTIMATES ?
TYPE   0   FOR NO
TYPE   1   FOR YES

1

TIME	$100 \times [SE(F) \div F]$	$100 \times [SE(G) \div G]$	$100 \times [SE(Q) \div Q]$
0	23.278	.000	23.278
1	23.278	7.407	22.068
2	42.750	12.685	40.825
3	38.656	15.086	35.590
4	100.000	18.812	100.000
5	42.750	18.812	38.389
6	23.278	23.278	.000

```
                    WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS
```

0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER

DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
   0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
   1   FOR YES: WANT TO LEAVE APL AND RETURN TO DOS

1

Example 2 : This is an example for Census Analysis with central data. The start of each length of service interval, the number of leavers and the beginning and the ending stock vectors are given to the model as input.

The model then displays the estimates of the probabilities/rates, their estimated standard errors and the standard errors as a percentage of the estimates. Then, the stock vector is changed and the same quantities are displayed as outputs.

The computer printout of this example is presented on the following pages.

```
     CENSUS

DO YOU WISH TO
   1 :   ENTER THE DATA FROM DATAFILE ?
   2 :   ENTER THE DATA FROM THE KEYBOARD ?
   3 :   MAKE A CHOICE FROM THE MAIN MENU ?

2

WHICH TYPE OF DATA DO THE INPUTS REPRESENT ?
 1 CENTRAL DATA
 2 TRANSITIONAL DATA

1

ENTER LENGTH OF SERVICE (LOS) (BEGINNING OF EACH TIME INTERVAL)

0 1 2 3 4 5 6 7

ENTER MAX PERIOD OF SERVICE (TLAST)

10

ENTER VECTOR OF LEAVERS (LV) WHO WERE IN EACH LOS CLASS ON EXIT

18 12 9 6 5 8 4 6

ENTER THE NUMBER OF HOW YOU WISH TO ENTER DATA
 1 AVERAGE STOCK VECTOR (S)
 2 BEGINNING AND ENDING STOCK VECTOR (BS AND ES)

2

ENTER THE BEGINNING OF PERIOD STOCK VECTOR (BS)

85 78 52 48 40 35 31 29

ENTER THE END OF PERIOD STOCK VECTOR (ES)

82 75 47 45 39 35 27 26

                         WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
      2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS

2

ENTERED DATA IS CENTRAL DATA.

LENGTH OF SERVICE (LOS) VECTOR
0 1 2 3 4 5 6 7 10

LEAVERS VECTOR (LV)
18 12 9 6 5 8 4 6

BEGINNING STOCKS (BS)
85 78 52 48 40 35 31 29
```

```
END STOCKS (ES)
82 75 47 45 39 35 27 26

STOCK VECTOR (S)
83.5 76.5 49.5 46.5 39.5 35 29 27.5
```

                              WOULD YOU LIKE TO
        0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
        1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
        2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

4

TIME	M CENTRAL ATT. RATE	W TRANS. ATT. RATE	G PROB. OF SURVIVING	F PROB. OF LEAVING	Q COND PROB OF LEAVING	D EXPECTED DURATION
0	.216	.194	1.000	.194	.194	4.480
1	.157	.145	.806	.117	.145	4.442
2	.182	.166	.689	.115	.166	4.113
3	.129	.121	.575	.070	.121	3.837
4	.127	.119	.505	.060	.119	3.298
5	.229	.204	.445	.091	.204	2.677
6	.138	.129	.354	.046	.129	2.241
7	.218	.196	.308	.049	.160	1.500
10	.000	.000	.160	.000	.000	.000

                              WOULD YOU LIKE TO
        0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
        1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
        2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

5

TIME	SE(M)	SE(W)	SE(G)	SE(Q)
0	.051	.041	.000	.041
1	.045	.039	.041	.039
2	.061	.051	.047	.051
3	.053	.046	.052	.046
4	.057	.050	.053	.050
5	.081	.064	.053	.064
6	.069	.060	.051	.060
7	.089	.072	.049	.046
10	.000	.000	.050	.000

```
WOULD YOU LIKE TO SEE THESE AS A PERCENTAGE OF THE ESTIMATES ?
TYPE   0   FOR NO
TYPE   1   FOR YES

1
```

TIME	100×[SE(M)÷M]	100×[SE(W)÷W]	100×[SE(G)÷G]	100×[SE(Q)÷Q]
0	23.570	21.121	.000	21.121
1	28.868	26.663	5.081	26.663
2	33.333	30.395	6.806	30.395
3	40.825	38.248	9.113	38.248

4	44.721	41.951	10.526	41.951
5	35.355	31.469	11.952	31.469
6	50.000	46.631	14.428	46.631
7	40.825	36.533	15.991	28.911
10	.000	.000	31.141	100.000

```
                        WOULD YOU LIKE TO
     0  QUIT PROGRAM/SAVE DATA        3  CHANGE THE DATA
     1  TURN PRINTER ON/OFF           4  ESTIMATE PROBABILITIES/RATES
     2  SEE THE DATA                  5  SEE ESTIMATED STANDARD ERRORS

3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
     0   DONE WITH ALL CHANGES
     1   LENGTH OF SERVICE (LOS)
     2   STOCK VECTOR (S)
     3   LEAVERS VECTOR (LV)
     4   CENTRAL/TRANSITIONAL DATA

2

ENTER THE NUMBER OF HOW YOU WISH TO ENTER DATA
 1 AVERAGE STOCK VECTOR (S)
 2 BEGINNING AND ENDING STOCK VECTOR (BS AND ES)

1

ENTER AVERAGE STOCK VECTOR (S)
(CORRESPONDING EACH TIME INTERVAL)

89 77 55 53 47 43 31 25

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
     0   DONE WITH ALL CHANGES
     1   LENGTH OF SERVICE (LOS)
     2   STOCK VECTOR (S)
     3   LEAVERS VECTOR (LV)
     4   CENTRAL/TRANSITIONAL DATA

0

                        WOULD YOU LIKE TO
     0  QUIT PROGRAM/SAVE DATA        3  CHANGE THE DATA
     1  TURN PRINTER ON/OFF           4  ESTIMATE PROBABILITIES/RATES
     2  SEE THE DATA                  5  SEE ESTIMATED STANDARD ERRORS

2


ENTERED DATA IS CENTRAL DATA.

LENGTH OF SERVICE (LOS) VECTOR
0 1 2 3 4 5 6 7 10

LEAVERS VECTOR (LV)
18 12 9 6 5 8 4 6

STOCK VECTOR (S)
89 77 55 53 47 43 31 25
```

6-7

4

TIME	M CENTRAL ATT. RATE	W TRANS. ATT. RATE	G PROB. OF SURVIVING	F PROB. OF LEAVING	Q COND PROB OF LEAVING	D EXPECTED DURATION
0	.202	.183	1.000	.183	.183	4.698
1	.156	.144	.817	.118	.144	4.643
2	.164	.151	.699	.106	.151	4.344
3	.113	.107	.593	.064	.107	4.029
4	.106	.101	.530	.053	.101	3.453
5	.186	.170	.476	.081	.170	2.786
6	.129	.121	.396	.048	.121	2.257
7	.240	.213	.348	.059	.171	1.500
10	.000	.000	.169	.000	.000	.000

5

TIME	SE(M)	SE(W)	SE(G)	SE(Q)
0	.048	.039	.000	.039
1	.045	.038	.039	.038
2	.055	.046	.046	.046
3	.046	.041	.051	.041
4	.048	.043	.051	.043
5	.066	.055	.051	.055
6	.065	.057	.050	.057
7	.098	.077	.049	.048
10	.000	.000	.055	.000

WOULD YOU LIKE TO SEE THESE AS A PERCENTAGE OF THE ESTIMATES ?
TYPE   0   FOR NO
TYPE   1   FOR YES

1

TIME	100×[SE(M)÷M]	100×[SE(W)÷W]	100×[SE(G)÷G]	100×[SE(Q)÷Q]
0	23.570	21.267	.000	21.267
1	28.868	26.676	4.767	26.676
2	33.333	30.680	6.555	30.680
3	40.825	38.558	8.527	38.558
4	44.721	42.385	9.699	42.385
5	35.355	32.168	10.803	32.168
6	50.000	46.844	12.648	46.844
7	40.825	36.122	14.199	27.876
10	.000	.000	32.644	100.000

```
                    WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA        3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF           4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA                  5   SEE ESTIMATED STANDARD ERRORS

0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER


DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
   0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
   1   FOR YES: WANT TO LEAVE APL AND RETURN TO DOS

1
```

Example 3 : This is an example for Census Analysis with transitional data. The start of each length of service interval, the number of leavers and the stock vector are given to the model as input.

The program then displays the estimates of the probabilities/rates, their estimated standard errors and the standard errors as a percentage of the estimates. Then the stock vector is changed and the same quantities are displayed as outputs.

The computer printout of this example is presented on the following pages.

CENSUS

DO YOU WISH TO
   1 :   ENTER THE DATA FROM DATAFILE ?
   2 :   ENTER THE DATA FROM THE KEYBOARD ?
   3 :   MAKE A CHOICE FROM THE MAIN MENU ?

2

WHICH TYPE OF DATA DO THE INPUTS REPRESENT ?
 1 CENTRAL DATA
 2 TRANSITIONAL DATA

2

ENTER LENGTH OF SERVICE (LOS) (BEGINNING OF EACH TIME INTERVAL)

0 1 2 3 4 5

ENTER MAX PERIOD OF SERVICE (TLAST)

8

ENTER LEAVERS (LV) WHO WERE IN EACH LOS AT THE BEGINNING OF PERIOD

345 312 308 300 295 370

ENTER THE STOCKS (S) AT THE BEGINNING OF THE PERIOD

1450 1248 1220 1190 1175 1105

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

2

ENTERED DATA IS TRANSITIONAL DATA.

LENGTH OF SERVICE (LOS) VECTOR
0 1 2 3 4 5 8

LEAVERS VECTOR (LV)
345 312 308 300 295 370

STOCK VECTOR (S)
1450 1248 1220 1190 1175 1105

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

4

| | W | M | G | F | Q | D |
| TIME | TRANS. ATT. RATE | CENTRAL ATT.RATE | PROB. OF SURVIVING | PROB. OF LEAVING | CON PROB OF LEAVING | EXPECTED DURATION |

```
*******************************************************************************
0        .238          .272          1.000          .238          .238          3.057
1        .250          .280           .762          .186          .244          2.863
2        .252          .289           .576          .145          .251          2.633
3        .252          .291           .431          .109          .252          2.356
4        .251          .290           .323          .081          .252          1.991
5        .335          .388           .241          .055          .229          1.500
8        .000          .000           .075          .000          .000           .000
```

WOULD YOU LIKE TO

      0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
      2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

5

```
TIME         SE(W)        SE(G)
*************************************
 0           .011         .000
 1           .012         .011
 2           .012         .014
 3           .013         .012
 4           .013         .011
 5           .014         .009
 8           .000         .005
```

WOULD YOU LIKE TO SEE THESE AS A PERCENTAGE OF THE ESTIMATES ?
TYPE   0   FOR NO
TYPE   1   FOR YES

1

```
TIME         100×[SE(W)÷W)]           100×[SE(G)÷G]
****************************************************************
 0               4.700                   .000
 1               4.903                  1.467
 2               4.927                  2.348
 3               4.993                  2.865
 4               5.039                  3.315
 5               4.240                  3.719
 8                .000                  6.667
```

                       WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
      2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
      0   DONE WITH ALL CHANGES
      1   LENGTH OF SERVICE (LOS)
      2   STOCK VECTOR (S)
      3   LEAVERS VECTOR (LV)
      4   CENTRAL/TRANSITIONAL DATA

2

G-1

ENTER THE STOCKS (S) AT THE BEGINNING OF THE PERIOD

1645 1433 1321 1289 1150 985

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
     0   DONE WITH ALL CHANGES
     1   LENGTH OF SERVICE (LOS)
     2   STOCK VECTOR (S)
     3   LEAVERS VECTOR (LV)
     4   CENTRAL/TRANSITIONAL DATA

0

                         WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

2

ENTERED DATA IS TRANSITIONAL DATA.

LENGTH OF SERVICE (LOS) VECTOR
0 1 2 3 4 5 8

LEAVERS VECTOR (LV)
345 312 308 300 295 370

STOCK VECTOR (S)
1645 1433 1321 1289 1150 985

                         WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

4

| | W | M | G | F | Q | D |
TIME	TRANS. ATT. RATE	CENTRAL ATT.RATE	PROB. OF SURVIVING	PROB. OF LEAVING	CON PROB OF LEAVING	EXPECTED DURATION
0	.210	.235	1.000	.210	.210	3.305
1	.218	.240	.790	.169	.214	3.054
2	.233	.256	.621	.140	.225	2.754
3	.233	.265	.481	.112	.233	2.416
4	.257	.281	.369	.090	.245	2.005
5	.376	.442	.279	.068	.245	1.500
8	.000	.000	.074	.000	.000	.000

                         WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

5

TIME   SE(W)   SE(G)

```
*********************************
0            .010          .000
1            .011          .010
2            .012          .013
3            .012          .012
4            .013          .011
5            .015          .009
8            .000          .005
```

WOULD YOU LIKE TO SEE THESE AS A PERCENTAGE OF THE ESTIMATES ?
TYPE   0   FOR NO
TYPE   1   FOR YES

1

```
TIME          100×[SE(W)÷W)]       100×[SE(G)÷G]
***********************************************************
0                 4.786               .000
1                 5.007              1.270
2                 4.990              2.029
3                 5.057              2.479
4                 5.020              2.909
5                 4.108              3.313
8                  .000              7.169
```

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   ESTIMATE PROBABILITIES/RATES
     2   SEE THE DATA   5   SEE ESTIMATED STANDARD ERRORS

0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER

DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
   0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
   1   FOR YES: WANT TO LEAVE APL AND RETURN TO DOS

1

Example 4 : This is an example for the graphical comparison of Cohort Analysis rates. Two sets of Cohort data are entered into the model. The model then displays the graph of the estimated probability of leaving.

The computer printout of this example is presented on the following pages.

COHORT
ENTER THE BEGINNING OF EACH COMPLETED LENGTH OF SERVICE (CLS)
INTERVAL IN ASCENDING ORDER
0 1 2 3 4 5 6

ENTER MAX PERIOD POSSIBLE (TLAST)
10

WOULD YOU LIKE TO ENTER;
   1   THE VECTOR OF SURVIVORS (SUR) ?
   2   THE VECTOR OF LEAVERS (LV) ?

2
ENTER VECTOR OF LEAVERS (LV)

220 167 85 35 30 15 44

WOULD YOU LIKE TO SEE THE ENTERED DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
1

COMPLETED LENGTH OF SERVICE (CLS)
0 1 2 3 4 5 6 10

VECTOR OF LEAVERS (LV)
220 167 85 35 30 15 44

VECTOR OF SURVIVORS (SUR)
596 376 209 124 89 59 44

WOULD YOU LIKE TO CHANGE THE FIRST DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
0

ENTER THE SECOND DATA

WOULD YOU LIKE TO ENTER;
   1   THE VECTOR OF SURVIVORS (SUR) ?
   2   THE VECTOR OF LEAVERS (LV) ?

1
ENTER VECTOR OF SURVIVORS (SUR) STARTING WITH INITIAL COHORT SIZE
AND CORRESPONDING TO EACH CLS EXCEPT THE LAST POSSIBLE CLS
675 354 220 184 145 94 77

WOULD YOU LIKE TO SEE ENTERED DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
1

COMPLETED LENGTH OF SERVICE (CLS)
0 1 2 3 4 5 6 10

VECTOR OF LEAVERS (LV)
321 134 36 39 51 17 77

VECTOR OF SURVIVORS (SUR)
675 354 220 184 145 94 77

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WOULD YOU LIKE TO CHANGE THE SECOND DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
0
Reading: DASHPLOT
Reading: DOTPLOT
Reading: LINEPLOT
Reading: BLANKPLOT
Reading: LOGPLOT
Reading: SCATPLOT
Reading: CSCATPLOT
Reading: LINETYPE
Reading: POINTTYPE
Reading: FRAME
Reading: SETCOLOR
Reading: GYþ
Reading: GZþ

WHAT KIND OF GRAPH WOULD YOU LIKE TO SEE ?
TYPE 1 FOR PROBABILITY OF LEAVING (F's)
TYPE 2 FOR SURVIVOR FUNCTIONS (G's)
TYPE 3 FOR COND. PROBABILITY OF LEAVING (Q's)
TYPE 4 FOR ESTIMATED CENTRAL RATES (M's)
4
AFTER DRAWING THE GRAPH, THE PROGRAM WILL WARN YOU
WITH A BEEP SIGN. TO GET PRINTOUT, PRESS 'F4'' TO SEE PRINT
MENU. SELECT 'REDISPLAY GRAPH ON PRINTER''OPTION BY PRESSING THE
'ENTER' KEY. THE PRINT MENU WILL DISAPPEAR UNTIL THE GRAPH IS SENT
TO PRINTER AND THEN THE PRINT MENU WILL REAPPEAR ON THE SCREEN.
THEN PRESS 'ESC' TO RETURN TO THE PROGRAM AGAIN.

IF YOU DON'T WANT TO GET A PRINT OUT AFTER SEEING
THE PRINT MENU ON THE SCREEN, PRESS 'ESC' TO RETURN
TO THE PROGRAM!

PRESS ENTER TO CONTINUE

PROBABILITY OF LEAVING (F)

Length of service (LOS)

G-16
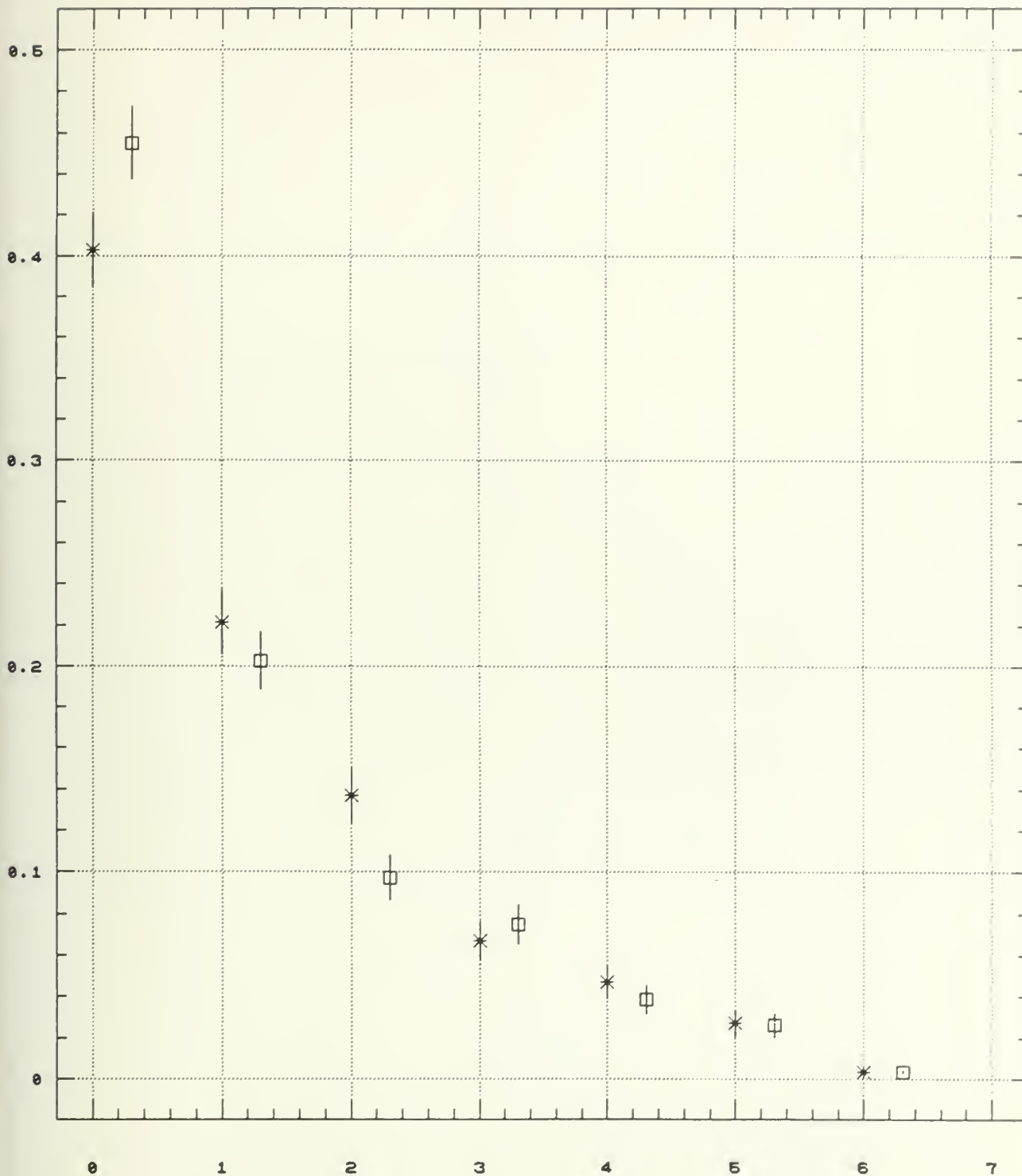
```
WOULD YOU LIKE TO QUIT ?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
FILES UNTIED
```

Example 5 : This is an example for the graphical comparison of Census Analysis rates with central data. Two sets of Census data are entered into the model. The model then displays the graph of the estimated surviving function.

The computer printout of this example is presented on the following pages.

```
CENSUS

WHICH TYPE OF DATA DO THE INPUTS REPRESENT ?
 1 CENTRAL DATA
 2 TRANSITIONAL DATA
1

ENTER LENGTH OF SERVICE (LOS) (BEGINNING OF EACH TIME INTERVAL)
 0 1 2 3 4 5

ENTER MAX PERIOD OF SERVICE (TLAST)
6

ENTER VECTOR OF LEAVERS (LV)
ENTER LEAVERS (LV) WHO WERE IN EACH LOS CLASS ON EXIT
220 167 85 35 30 15

ENTER THE NUMBER OF HOW YOU WISH TO ENTER DATA
 1 AVERAGE STOCK VECTOR (S)
 2 BEGINNING AND ENDING STOCK VECTOR (BS AND ES)
1

ENTER AVERAGE STOCK VECTOR (S)
(CORRESPONDING EACH TIME INTERVAL)
596 376 209 124 89 59

WOULD YOU LIKE TO SEE ENTERED DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
1

ENTERED DATA IS ; CENTRAL DATA.

LENGTH OF SERVICE (LOS) VECTOR
0 1 2 3 4 5 6

LEAVERS VECTOR (LV)
220 167 85 35 30 15

STOCK VECTOR (S)
596 376 209 124 89 59

WOULD YOU LIKE TO CHANGE THE FIRST DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
0

ENTER THE SECOND DATA

ENTER VECTOR OF LEAVERS (LV)
ENTER LEAVERS (LV) WHO WERE IN EACH LOS CLASS ON EXIT
321 134 36 39 51 17

ENTER THE NUMBER OF HOW YOU WISH TO ENTER DATA
 1 AVERAGE STOCK VECTOR (S)
 2 BEGINNING AND ENDING STOCK VECTOR (BS AND ES)
1

ENTER AVERAGE STOCK VECTOR (S)
(CORRESPONDING EACH TIME INTERVAL)
```

675 354 220 184 145 94

WOULD YOU LIKE TO SEE ENTERED DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
1

ENTERED DATA IS ; CENTRAL DATA.

LENGTH OF SERVICE (LOS) VECTOR
0 1 2 3 4 5 6

LEAVERS VECTOR (LV)
321 134 36 39 51 17

STOCK VECTOR (S)
675 354 220 184 145 94

WOULD YOU LIKE TO CHANGE THE SECOND DATA ?
TYPE 0 FOR NO
TYPE 1 FOR YES
0
Reading: DASHPLOT
Reading: DOTPLOT
Reading: LINEPLOT
Reading: BLANKPLOT
Reading: LOGPLOT
Reading: SCATPLOT
Reading: CSCATPLOT
Reading: LINETYPE
Reading: POINTTYPE
Reading: FRAME
Reading: SETCOLOR
Reading: GYþ
Reading: GZþ

WHAT KIND OF GRAPH WOULD YOU LIKE TO SEE ?
TYPE 1 FOR ESTIMATED CENTRAL RATES (M's)
TYPE 2 FOR SURVIVOR FUNCTIONS (G's)
TYPE 3 FOR COND. PROBABILITY OF LEAVING (Q's)
2

THE PROGRAM WILL WARN YOU WITH A BEEP WHEN DRAWING IS FINISHED.

  PRESS 'ESC' IF NO PRINTOUT IS NEEDED.

  TO OBTAIN PRINTOUT, PRESS 'F4' TO SEE PRINT MENU.
  SELECT 'REDISPLAY GRAPH ON PRINTER' BY PRESSING 'ENTER' KEY.
  THE PRINT MENU WILL DISAPPEAR UNTIL THE GRAPH IS SENT TO PRINTER
  AND THEN PRINT MENU WILL REAPPEAR ON THE SCREEN. THEN PRESS 'ESC'
  TO RETURN THE PROGRAM AGAIN.

  IF YOU DON'T WANT TO OBTAIN A PRINTOUT AFTER PRESSING 'F4' KEY,
  PRESS 'ESC' TO RETURN TO PROGRAM.

PRESS ENTER TO CONTINUE.

G-

PRESS ENTER TO CONTINUE.

SURVIVOR FUNCTION (G)

Length of service (LOS)

G-21
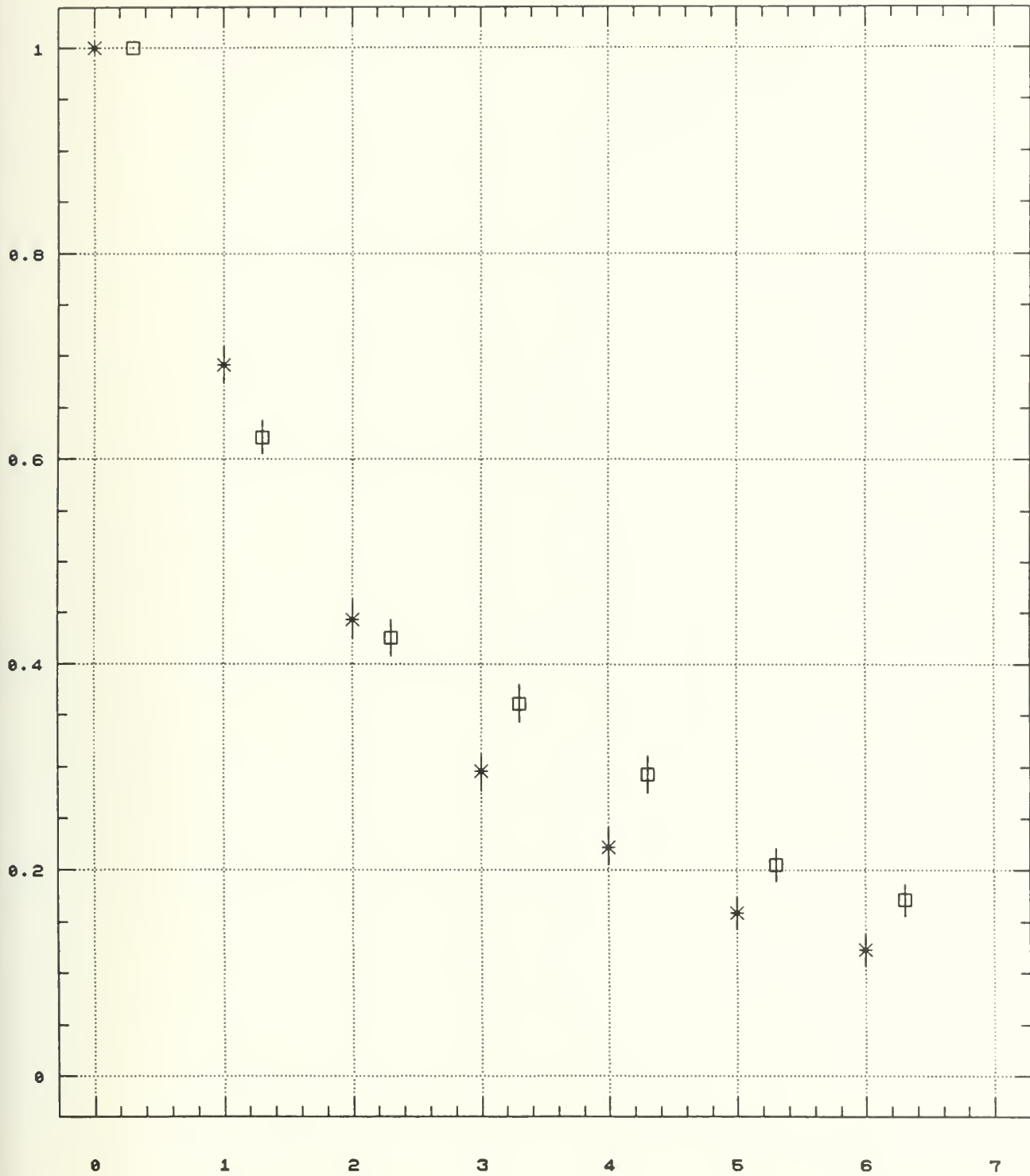
LD YOU LIKE TO DROP THE LAST LOS CELL TO GET BETTER VIEW
 THE GRAPH ?
E 0 FOR NO
E 1 FOR YES
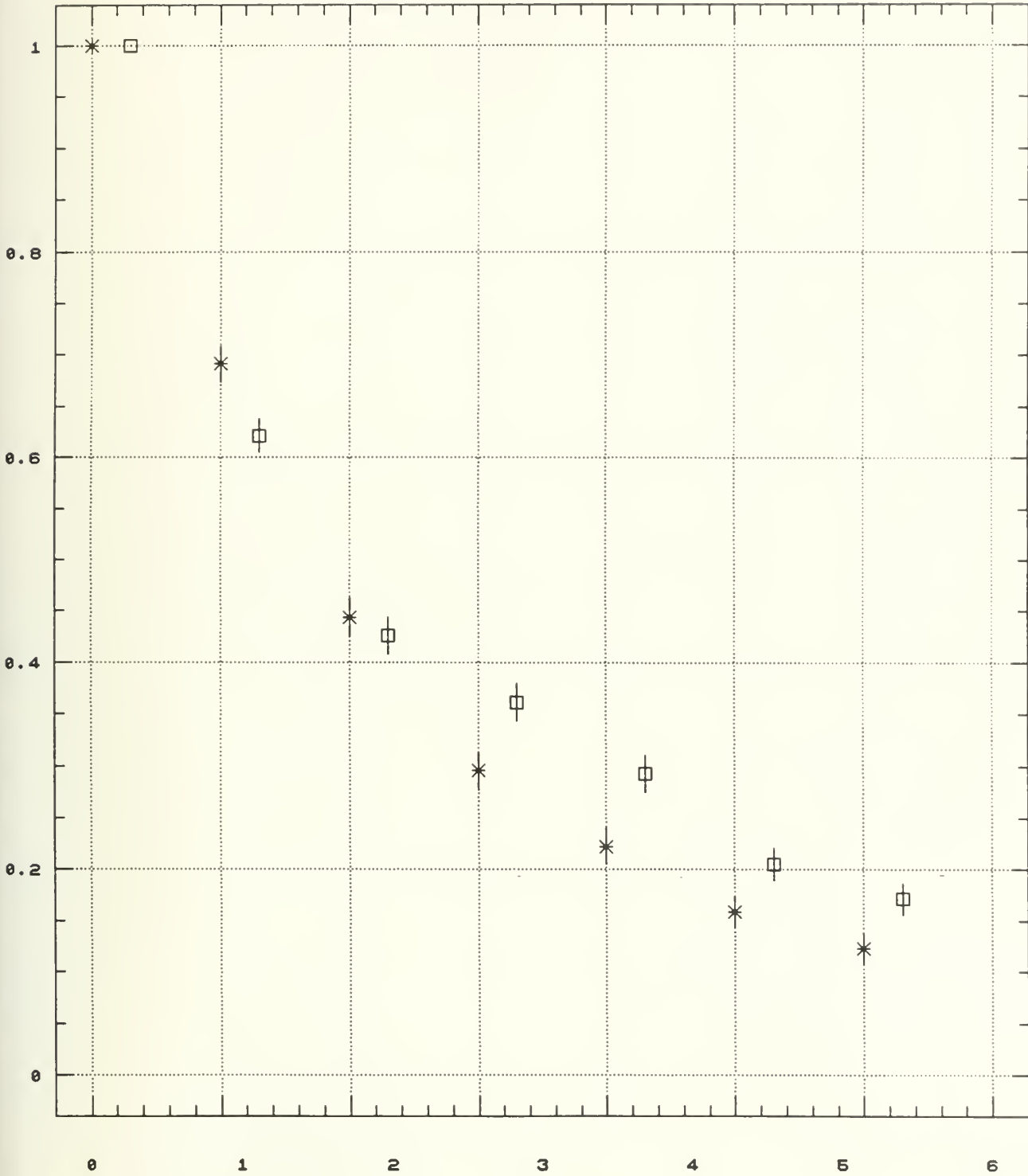
Length of service (LOS)

```
WOULD YOU LIKE TO QUIT ?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
FILES UNTIED
```

APPENDIX H.   TERMINAL SESSION WITH TRANSITION MODELS BASED ON RENEWAL THEORY

This appendix includes a set of three examples of terminal session with the Transition Models based on Renewal Theory workspace.

Example 1 : This is an example for the one-grade vacancy model, including Sub-models 1, 2 and 3.   The start of each length of service interval, the initial LOS distribution (which is "0" in Sub-model 1), the probabilities of survival and the system size or sizes are given to the model as input.   The program then displays the replacement rates and the expected number of recruits.

This example of Sub-model 1 is then changed to Sub-model 2 by entering the initial LOS distribution.   Then, the same quantities are displayed as before.

Sub-model 2 is then changed to Sub-model 3 by reentering the system sizes for the current and the next six years.   The same quantities are then displayed as before.

The computer printout of this example is presented on the following pages.

Example 2 : This is an example for the multi-grade vacancy model with non-instantaneous filling of vacancies. The system has five categories with fixed category sizes. The initial position vector, the initial vacancy vector, the attrition rates and the vacancy transition rate matrix are given to the model as input.

The model then forecasts vacancies for the next two years. The fixed category sizes are then increased by 1% per year.

The model then forecasts vacancies for the next three years. Finally, the steady state vacancy vector is displayed.

The computer printout of this example is presented on the following pages.

REPLACE

DO YOU WISH TO
1: ENTER THE DATA FROM DATAFILE
2: ENTER THE DATA FROM THE KEYBOARD
3: MAKE A CHOICE FROM THE MAIN MENU
2

ENTER THE BEGINNING OF EACH LOS CELLS IN ASCENDING ORDER.
0 1 2 3 4 5 6

TYPE 0 IF ALL INITIAL EMPLOYEES HAVE ZERO LOS. OTHERWISE
TYPE INITIAL LOS DISTRIBUTION (SS), I.E, THE PROPORTIONAL
NUMBER OF INITIAL EMPLOYEES IN EACH LOS CELL GIVEN ABOVE.
0

TYPE PROBABILITIES OF SURVIVAL (G) TO THE
BEGINNING OF EACH LOS INTERVAL GIVEN ABOVE.
1 .9 .7 .6 .4 .2 .1

TYPE CONSTANT SYSTEM SIZE (NN) IF FIXED. OTHERWISE
TYPE SYSTEM SIZE (NN) FOR EACH TIME PERIOD NEEDED,
STARTING WITH CURRENT.
2300

                         WOULD YOU LIKE TO
     0 QUIT PROGRAM/SAVE DATA   3 CHANGE THE DATA
     1 TURN PRINTER ON/OFF   4 SEE REPLACEMENT RATES
     2 SEE THE DATA   5 SEE EXPECTED NO OF RECRUITS
2

LENGTH OF SERVICE CELLS (LOS)
0 1 2 3 4 5 6

INITIAL LOS DISTRIBUTION (SS)
0

PROBABILITIES OF SURVIVAL (G)
1 0.9 0.7 0.6 0.4 0.2 0.1

SYSTEM SIZE (NN)
2300

                         WOULD YOU LIKE TO
     0 QUIT PROGRAM/SAVE DATA   3 CHANGE THE DATA
     1 TURN PRINTER ON/OFF   4 SEE REPLACEMENT RATES
     2 SEE THE DATA   5 SEE EXPECTED NO OF RECRUITS
4

LOS   0   1   2   3   4   5   6
****
RATES   0.100   0.210   0.141   0.266   0.296   0.259   0.292

STEADY   STATE
****
RATE   0.256

                         WOULD YOU LIKE TO
     0 QUIT PROGRAM/SAVE DATA   3 CHANGE THE DATA
     1 TURN PRINTER ON/OFF   4 SEE REPLACEMENT RATES

```
      2 SEE THE DATA                          5 SEE EXPECTED NO OF RECRUITS
  5

  LOS              0        1        2        3        4        5        6
  ★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★
  RECRUITS       230      483      324      612      680      595      671

  STEADY        STATE
  ★★★★★★★★★★★★★★★★★★★★★★
  RECRUITS       590

                          WOULD YOU LIKE TO
      0 QUIT PROGRAM/SAVE DATA               3 CHANGE THE DATA
      1 TURN PRINTER ON/OFF                  4 SEE REPLACEMENT RATES
      2 SEE THE DATA                         5 SEE EXPECTED NO OF RECRUITS
  3

  ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
      0    DONE WITH ALL CHANGES
      1    LENGTH OF SERVICE CELLS (LOS)
      2    INITIAL LOS DISTRIBUTION (SS)
      3    PROBABILITIES OF SURVIVAL (G)
      4    SYSTEM SIZE (NN)
      5    ALL THE DATA

  2

  TYPE 0 IF ALL INITIAL EMPLOYEES HAVE ZERO LOS. OTHERWISE
  TYPE INITIAL LOS DISTRIBUTION (SS), I.E, THE PROPORTIONAL
  NUMBER OF INITIAL EMPLOYEES IN EACH LOS CELL GIVEN ABOVE.
  1600 300 200 100 100 0 0

  ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
      0    DONE WITH ALL CHANGES
      1    LENGTH OF SERVICE CELLS (LOS)
      2    INITIAL LOS DISTRIBUTION (SS)
      3    PROBABILITIES OF SURVIVAL (G)
      4    SYSTEM SIZE (NN)
      5    ALL THE DATA

  0

                          WOULD YOU LIKE TO
      0 QUIT PROGRAM/SAVE DATA               3 CHANGE THE DATA
      1 TURN PRINTER ON/OFF                  4 SEE REPLACEMENT RATES
      2 SEE THE DATA                         5 SEE EXPECTED NO OF RECRUITS
  2

  LENGTH OF SERVICE CELLS (LOS)
  0 1 2 3 4 5 6

  INITIAL LOS DISTRIBUTION (SS)
  0.6957 0.1304 0.087 0.0435 0.0435 0 0
  1600 300 200 100 100 0 0

  PROBABILITIES OF SURVIVAL (G)
  1 0.9 0.7 0.6 0.4 0.2 0.1

  SYSTEM SIZE (NN)
  2300
```

H-2

```
                        WOULD YOU LIKE TO
    0 QUIT PROGRAM/SAVE DATA           3 CHANGE THE DATA
    1 TURN PRINTER ON/OFF              4 SEE REPLACEMENT RATES
    2 SEE THE DATA                     5 SEE EXPECTED NO OF RECRUITS
4

LOS          0       1       2       3       4       5       6
*************************************************************
RATES     0.147   0.219   0.193   0.265   0.282   0.258   0.275

STEADY    STATE
********************
RATE      0.256

                        WOULD YOU LIKE TO
    0 QUIT PROGRAM/SAVE DATA           3 CHANGE THE DATA
    1 TURN PRINTER ON/OFF              4 SEE REPLACEMENT RATES
    2 SEE THE DATA                     5 SEE EXPECTED NO OF RECRUITS
5

LOS          0       1       2       3       4       5       6
*****************************************************************
RECRUITS    339     503     443     611     650     593     633

STEADY        STATE
***********************
RECRUITS        590

                        WOULD YOU LIKE TO
    0 QUIT PROGRAM/SAVE DATA           3 CHANGE THE DATA
    1 TURN PRINTER ON/OFF              4 SEE REPLACEMENT RATES
    2 SEE THE DATA                     5 SEE EXPECTED NO OF RECRUITS
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0    DONE WITH ALL CHANGES
    1    LENGTH OF SERVICE CELLS (LOS)
    2    INITIAL LOS DISTRIBUTION (SS)
    3    PROBABILITIES OF SURVIVAL (G)
    4    SYSTEM SIZE (NN)
    5    ALL THE DATA

4

TYPE CONSTANT SYSTEM SIZE (NN) IF FIXED. OTHERWISE
TYPE SYSTEM SIZE (NN) FOR EACH TIME PERIOD NEEDED,
STARTING WITH CURRENT.
2300 2350 2370 2390 2429 2478 2515

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0    DONE WITH ALL CHANGES
    1    LENGTH OF SERVICE CELLS (LOS)
    2    INITIAL LOS DISTRIBUTION (SS)
    3    PROBABILITIES OF SURVIVAL (G)
    4    SYSTEM SIZE (NN)
    5    ALL THE DATA

0
```

H-3

```
                        WOULD YOU LIKE TO
      0 QUIT PROGRAM/SAVE DATA          3 CHANGE THE DATA
      1 TURN PRINTER ON/OFF             4 SEE REPLACEMENT RATES
      2 SEE THE DATA                    5 SEE EXPECTED NO OF RECRUITS
2

LENGTH OF SERVICE CELLS (LOS)
0 1 2 3 4 5 6

INITIAL LOS DISTRIBUTION (SS)
0.6957 0.1304 0.087 0.0435 0.0435 0 0
1600 300 200 100 100 0 0

PROBABILITIES OF SURVIVAL (G)
1 0.9 0.7 0.6 0.4 0.2 0.1

SYSTEM SIZE (NN)
2300 2350 2370 2390 2429 2478 2515

                        WOULD YOU LIKE TO
      0 QUIT PROGRAM/SAVE DATA          3 CHANGE THE DATA
      1 TURN PRINTER ON/OFF             4 SEE REPLACEMENT RATES
      2 SEE THE DATA                    5 SEE EXPECTED NO OF RECRUITS
4

LOS            0       1       2       3       4       5       6
*******************************************************************
RATES      0.169   0.225   0.201   0.277   0.298   0.269   0.269

STEADY    STATE
********************
RATE       0.256

                        WOULD YOU LIKE TO
      0 QUIT PROGRAM/SAVE DATA          3 CHANGE THE DATA
      1 TURN PRINTER ON/OFF             4 SEE REPLACEMENT RATES
      2 SEE THE DATA                    5 SEE EXPECTED NO OF RECRUITS
5

LOS            0       1       2       3       4       5       6
*******************************************************************
RECRUITS     389     528     476     663     723     666     677

                        WOULD YOU LIKE TO
      0 QUIT PROGRAM/SAVE DATA          3 CHANGE THE DATA
      1 TURN PRINTER ON/OFF             4 SEE REPLACEMENT RATES
      2 SEE THE DATA                    5 SEE EXPECTED NO OF RECRUITS
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER


DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
  0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
  1   FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1
```

H-4

VACANCY

```
DO YOU WISH TO
   1:ENTER THE DATA FROM DATA FILE ?
   2:ENTER THE DATA FROM THE KEYBOARD ?
   3:MAKE A CHOICE FROM THE MAIN MENU ?
2

ENTER THE NUMBER OF THE VACANCY MODEL TYPE
   1   NON-INSTANTANEOUS FILLING OF VACANCIES
          FIXED GRADE SIZES
   2   NON-INSTANTANEOUS FILLING OF VACANCIES
          INCREASING/DECREASING GRADE SIZES
   3   INSTANTANEOUS FILLING OF VACANCIES
          FIXED GRADE SIZES
   4   INSTANTANEOUS FILLING OF VACANCIES
          INCREASING/DECREASING GRADE SIZES
1

ENTER THE INITIAL POSITION VECTOR (N)

4300 3850 3300 2890 2700

ENTER THE INITIAL VACANCY VECTOR (V)

960 545 340 170 90

ENTER THE ATTRITION RATE VECTOR (WV)

.3 .25 .18 .1 .05

DO YOU WANT TO INPUT THE VACANCY TRANSITION MATRIX (S)

      1    ROW BY ROW; OR
      2    BY TYPING THE LETTER S ?
           (S MUST STAND FOR VACANCY TRANSITION MATRIX)

1

ENTER ROW 1!

.25 0 0 0 0

ENTER ROW 2!

.8 .1 .1 0 0

ENTER ROW 3!

0 .85 .1 .05 0

ENTER ROW 4!

0 0 .85 .1 .05

ENTER ROW 5!

0 0 0 1 0
```

WOULD YOU LIKE TO

H-5

```
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST VACANCIES
      2   SEE THA DATA                        5   SEE STEADY STATE
2

VACANCY OPTION SELECTED: 1

INITIAL POSITION VECTOR (N):
4300 3850 3300 2890 2700

INITIAL VACANCY VECTOR (V):
960 545 340 170 90

ATTRITION RATE VECTOR (WV):
0.3 0.25 0.18 0.1 0.05

VACANCY TRANSITION MATRIX (S):
 0.25 0     0     0     0
 0.8   0.1   0.1   0     0
 0     0.85  0.1   0.05  0
 0     0     0.85  0.1   0.05
 0     0     0     1     0

RATE OF CATEGORY SIZE INCREASE/DECREASE (ALPHA): 0

                         WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST VACANCIES
      2   SEE THA DATA                        5   SEE STEADY STATE
4

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
2

DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1
PERIOD  CTGRY    VACANCIES    PERCENT
**********************************************
   0      1         960         (46)
          2         545         (26)
          3         340         (16)
          4         170          (8)
          5          90          (4)
       TOTAL       2105        (100)
==========================================
   1      1        1678         (40)
          2        1170         (28)
          3         766         (18)
          4         396         (10)
          5         139          (3)
       TOTAL       4149        (197)
==========================================
   2      1        2142         (41)
          2        1438         (28)
          3         986         (19)
          4         466          (9)
          5         148          (3)
       TOTAL       5180        (246)
```

H-k

```
==========================================
                        WOULD YOU LIKE TO
        0   QUIT PROGRAM/SAVE DATA            3   CHANGE THE DATA
        1   TURN PRINTER ON/OFF              4   FORECAST VACANCIES
        2   SEE THA DATA                     5   SEE STEADY STATE
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0   DONE WITH ALL CHANGES
    1   INITIAL POSITION VECTOR (N)
    2   INITIAL VACANCY VECTOR (V)
    3   ATTRITION RATE VECTOR (WV)
    4   VACANCY TRANSITION MATRIX (S)
    5   RATE OF CATEGORY SIZE INREASE/DECREASE (ALPHA)
5

ENTER THE RATE ALPHA OF CATEGORY SIZE INCREASE/DECREASE

NOTE:
A POSITIVE NUMBER BETWEEN 0 AND 1 MEANS A RATE OF INCREASE;
A NEGATIVE NUMBER BETWEEN ⁻1 AND 0 MEANS A RATE OF DECREASE.
FOR EXAMPLE:
.1 MEANS A 10 PERCENT INCREASE, ⁻.05 MEANS A 5 PERCENT DECREASE

.01

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0   DONE WITH ALL CHANGES
    1   INITIAL POSITION VECTOR (N)
    2   INITIAL VACANCY VECTOR (V)
    3   ATTRITION RATE VECTOR (WV)
    4   VACANCY TRANSITION MATRIX (S)
    5   RATE OF CATEGORY SIZE INREASE/DECREASE (ALPHA)
0

                        WOULD YOU LIKE TO
        0   QUIT PROGRAM/SAVE DATA            3   CHANGE THE DATA
        1   TURN PRINTER ON/OFF              4   FORECAST VACANCIES
        2   SEE THA DATA                     5   SEE STEADY STATE
2

VACANCY OPTION SELECTED: 2

INITIAL POSITION VECTOR (N):
4300 3850 3300 2890 2700

INITIAL VACANCY VECTOR (V):
960 545 340 170 90

ATTRITION RATE VECTOR (WV):
0.3 0.25 0.18 0.1 0.05

VACANCY TRANSITION MATRIX (S):
 0.25 0     0     0     0
 0.8  0.1   0.1   0     0
 0    0.85  0.1   0.05  0
 0    0     0.85  0.1   0.05
 0    0     0     1     0
```

H-7

RATE OF CATEGORY SIZE INCREASE/DECREASE (ALPHA): 0.01

```
                      WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST VACANCIES
      2   SEE THA DATA                        5   SEE STEADY STATE
4
```

ENTER THE NUMBER OF THE PERIOD YOU WISH TO SEE
5

DO YOU WISH TO SEE THE INTERVENING YEARS?
TYPE 0 FOR NO
TYPE 1 FOR YES
1

PERIOD	CTGRY	VACANCIES	PERCENT
★★			
3	1	2376	(41)
	2	1624	(28)
	3	1088	(19)
	4	515	(9)
	5	178	(3)
TOTAL		5781	(275)
===			
4	1	2526	(41)
	2	1692	(28)
	3	1146	(19)
	4	553	(9)
	5	180	(3)
TOTAL		6099	(290)
===			
5	1	2587	(41)
	2	1742	(28)
	3	1188	(19)
	4	562	(9)
	5	184	(3)
TOTAL		6263	(298)
===			

```
                      WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST VACANCIES
      2   SEE THA DATA                        5   SEE STEADY STATE
5
```

PERIOD	CTGRY	VACANCIES	PERCENT
★★			
STEADY	1		(41)
STATE	2		(28)
	3		(19)
	4		(9)
	5		(3)
			(100)
===			

```
                      WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF                 4   FORECAST VACANCIES
      2   SEE THA DATA                        5   SEE STEADY STATE
0
```
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.

YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER

DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
    0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
    1   FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1

H-9

The expected number of transfers from category 2 to category 3 during the second year is computed as

$$P_{23}(2) = v_3(1) \, s_{32} = 766 \times 0.85 = 651.1 \approx 651 \quad .$$

The expected number of recruits to category 1 during the second year is computed as

$$R_1(2) = P_{61}(2) = v_1(1) \, s_{16} = 1678 \times 0.75 = 1258.5 \approx 1259 \quad .$$

The expected number of transfers from category 3 to category 4 during the fifth year is computed as

$$P_{34}(5) = v_4(4) \, s_{43} = 553 \times 0.85 = 470.05 \approx 470 \quad .$$

The expected number of recruits to category 1 during fifth year is computed as

$$R_1(5) = P_{61}(5) = v_1(4) \, s_{16} = 2526 \times 0.75 = 1894.5 \approx 1895 \quad .$$

Example 3 : This is an example for the multi-grade vacancy model with instantaneous filling of vacancies. The system has five categories with fixed category sizes. The initial position vector, the attrition rates and the vacancy transition rate matrix are given to the program.

The program then forecasts the expected personnel flows in system. Then, the fixed category sizes are changed to the increasing/decreasing category sizes with $m = (100,50, -50,50,0)$, where m is the vector of category size increases/decreases. The program then forecasts the expected number of personnel flows in system.

The computer printout of this example is presented on the following pages.

VACANCY

DO YOU WISH TO
   1:ENTER THE DATA FROM DATA FILE ?
   2:ENTER THE DATA FROM THE KEYBOARD ?
   3:MAKE A CHOICE FROM THE MAIN MENU ?
2

ENTER THE NUMBER OF THE VACANCY MODEL TYPE
   1   NON-INSTANTANEOUS FILLING OF VACANCIES
          FIXED GRADE SIZES
   2   NON-INSTANTANEOUS FILLING OF VACANCIES
          INCREASING/DECREASING GRADE SIZES
   3   INSTANTANEOUS FILLING OF VACANCIES
          FIXED GRADE SIZES
   4   INSTANTANEOUS FILLING OF VACANCIES
          INCREASING/DECREASING GRADE SIZES
3

ENTER THE INITIAL POSITION VECTOR (N)

950 700 650 400 250

ENTER THE ATTRITION RATE VECTOR (WV)

.2 .15 .1 .05 .01

DO YOU WANT TO INPUT THE VACANCY TRANSITION MATRIX (S)

      1   ROW BY ROW; OR
      2   BY TYPING THE LETTER S ?
           (S MUST STAND FOR VACANCY TRANSITION MATRIX)

1

ENTER ROW 1!

0 .2 .1 0 0

ENTER ROW 2!

.1 0 .2 0 0

ENTER ROW 3!

.1 .1 0 0 0

ENTER ROW 4!

.2 0 .2 .3 0

ENTER ROW 5!

.3 .3 0 0 0

                              WOULD YOU LIKE TO
   0 QUIT PROGRAM/SAVE DATA   3 CHANGE THE DATA
   1 TURN PRINTER ON/OFF   4 SEE EXP. NO OF PERSONNEL FLOWS
   2 SEE THE DATA
2

```
VACANCY OPTION SELECTED: 3

INITIAL POSITION VECTOR (N):
950 700 650 400 250

ATTRITION RATE VECTOR (WV):
0.2 0.15 0.1 0.05 0.01

VACANCY TRANSITION MATRIX (S):
 0    0.2 0.1 0    0
 0.1 0    0.2 0    0
 0.1 0.1 0    0    0
 0.2 0    0.2 0.3 0
 0.3 0.3 0    0    0

VECTOR OF CATEGORY SIZE INCREASES/DECREASES (M):
0 0 0 0 0

                        WOULD YOU LIKE TO
  0  QUIT PROGRAM/SAVE DATA          3  CHANGE THE DATA
  1  TURN PRINTER ON/OFF             4  SEE EXP. NO OF PERSONNEL FLOWS
  2  SEE THE DATA
4

                PERSONNEL FLOW MATRIX
                (FROM ROW TO COLUMN)
```

CATEGORY	1	2	3	4	5	ATTRITION
1	0	16	13	6	1	190
2	45	0	13	0	1	105
3	23	33	0	6	0	65
4	0	0	0	9	0	20
5	0	0	0	0	0	3
RECRUITS	158	114	101	9	1	

```
                        WOULD YOU LIKE TO
  0  QUIT PROGRAM/SAVE DATA          3  CHANGE THE DATA
  1  TURN PRINTER ON/OFF             4  SEE EXP. NO OF PERSONNEL FLOWS
  2  SEE THE DATA
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
   0  DONE WITH ALL CHANGES
   1  INITIAL POSITION VECTOR (N)
   2  ATTRITION RATE VECTOR (WV)
   3  VACANCY TRANSITION MATRIX (S)
   4  VECTOR OF CATEGORY SIZE INREASES/DECREASES (M)
4

ENTER THE VECTOR M OF CATEGORY SIZE INCREASES/DECREASES

NOTE: IF ANY COMPONENT OF M IS NEGATIVE USE APL NEGATIVE SIGN!
FOR EXAMPLE: USE (4,10,⁻5,22,⁻9) INSTEAD OF (4,10,-5,22,-9)
100 50 ⁻50 50 0

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
   0  DONE WITH ALL CHANGES
```

H-11

```
    1   INITIAL POSITION VECTOR (N)
    2   ATTRITION RATE VECTOR (WV)
    3   VACANCY TRANSITION MATRIX (S)
    4   VECTOR OF CATEGORY SIZE INREASES/DECREASES (M)
 0
                         WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA            3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF              4   SEE EXP. NO OF PERSONNEL FLOWS
    2   SEE THE DATA
 2

VACANCY OPTION SELECTED: 4

INITIAL POSITION VECTOR (N):
950 700 650 400 250

ATTRITION RATE VECTOR (WV):
0.2 0.15 0.1 0.05 0.01

VACANCY TRANSITION MATRIX (S):
    0    0.2 0.1 0    0
   0.1 0    0.2 0    0
   0.1 0.1 0    0    0
   0.2 0    0.2 0.3 0
   0.3 0.3 0    0    0

VECTOR OF CATEGORY SIZE INCREASES/DECREASES (M):
100 50 ⁻50 50 0

                         WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA            3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF              4   SEE EXP. NO OF PERSONNEL FLOWS
    2   SEE THE DATA
 4

                PERSONNEL FLOW MATRIX
                (FROM ROW TO COLUMN)
```

CATEGORY	1	2	3	4	5	ATTRITION
1	0	24	12	20	1	190
2	69	0	12	0	1	105
3	35	47	0	20	0	65
4	0	0	0	30	0	20
5	0	0	0	0	0	3
RECRUITS	242	166	94	30	1	

```
                         WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA            3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF              4   SEE EXP. NO OF PERSONNEL FLOWS
    2   SEE THE DATA
 0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER
```

```
DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
  0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
  1   FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1
```

APPENDIX I.   TERMINAL SESSION WITH CAREER PATTERNS MODELS

This appendix includes a set of three examples of a terminal session with the career patterns models.

<u>Example 1</u>:   This is an example for a career patterns model with no promotion zone. The retirement point, the assumption that attrition comes before promotion (Assumption 2), the promotion rate and attrition rates are given to the model as input.

The program then displays the probability of eventual promotion, the mean time to promotion of promotees, and the same quantities for careerists.

Then, Assumption 2 is changed to Assumption 3 (promotion and attrition are simultaneous) and the same quantities are displayed.

The computer printout of this example is presented on the following pages.

CAREER

DO YOU WISH TO
 1: ENTER THE DATA FROM DATA FILE ?
 2: ENTER THE DATA FROM THE KEYBOARD ?
 3: MAKE A CHOICE FROM THE MAIN MENU ?

2

DO YOU HAVE PROMOTION ZONES ?
 0: FOR NO
 1: FOR YES

0

ENTER THE RETIREMENT POINT (K)

20

WHICH ASSUMPTION DO YOU WISH TO MAKE IN CALCULATING
PROMOTION RATE (P* OR P2*) OF CAREERISTS
(PERSONNEL WITH ATTRITION RATE ZERO)
 1: PROMOTION BEFORE ATTRITION
 2: ATTRITION BEFORE PROMOTION
 3: PROMOTION AND ATTRITION SIMULTANEOUS

2

ENTER THE PROMOTION RATE FOR CATEGORY (P)
.2

ENTER THE ATTRITION RATE FOR CATEGORY (W)

.15

                          WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF   4   RUN MODEL
    2   SEE THE DATA   5   RUN MODEL FOR CAREERISTS
2

RETIREMENT POINT (K): 20

CHOSEN ASSUMPTION IS ATTRITION BEFORE PROMOTION.

PROMOTION RATE FOR CATEGORY (P): 0.2

ATTRITION RATE FOR CATEGORY (W): 0.15

                          WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF   4   RUN MODEL
    2   SEE THE DATA   5   RUN MODEL FOR CAREERISTS
4

PROBABILITY OF EVENTUAL PROMOTION (PU)   0.571

MEAN TIME TO PROMOTION OF PROMOTEES (TP)   2.354

I-1

```
                              WOULD YOU LIKE TO
       0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
       1   TURN PRINTER ON/OFF                 4   RUN MODEL
       2   SEE THE DATA                        5   RUN MODEL FOR CAREERISTS
5


PROBABILITY OF EVENTUAL PROMOTION OF CAREERISTS (PU*)        0.995
----------------------------------------------------------------------
MEAN TIME TO PROMOTION OF CAREERISTS (TP*)                   3.656



                              WOULD YOU LIKE TO
       0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
       1   TURN PRINTER ON/OFF                 4   RUN MODEL
       2   SEE THE DATA                        5   RUN MODEL FOR CAREERISTS
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0   DONE WITH ALL CHANGES
    1   RETIREMENT POINT (K)
    2   ASSUMPTIONS FOR CAREERISTS PROMOTION RATE
    3   PROMOTION RATE
    4   ATTRITION RATES
    5   ALL THE DATA
2

WHICH ASSUMPTION DO YOU WISH TO MAKE IN CALCULATING
PROMOTION RATE (P* OR P2*) OF CAREERISTS
(PERSONNEL WITH ATTRITION RATE ZERO)
 1: PROMOTION BEFORE ATTRITION
 2: ATTRITION BEFORE PROMOTION
 3: PROMOTION AND ATTRITION SIMULTANEOUS

3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
    0   DONE WITH ALL CHANGES
    1   RETIREMENT POINT (K)
    2   ASSUMPTIONS FOR CAREERISTS PROMOTION RATE
    3   PROMOTION RATE
    4   ATTRITION RATES
    5   ALL THE DATA
0

                              WOULD YOU LIKE TO
       0   QUIT PROGRAM/SAVE DATA              3   CHANGE THE DATA
       1   TURN PRINTER ON/OFF                 4   RUN MODEL
       2   SEE THE DATA                        5   RUN MODEL FOR CAREERISTS
2

RETIREMENT POINT (K): 20

CHOSEN ASSUMPTION IS PROMOTION AND ATTRITION SIMULTANEOUS.

PROMOTION RATE FOR CATEGORY (P): 0.2
```

Example 2 : This is an example for a career patterns model with promotion zone. The lower and upper boundaries of the promotion zone, the assumption that promotion comes before attrition (Assumption 1), the promotion rate and attrition rates in the below and promotion zones are given to the model as input.

The program then displays the probability of eventual promotion, the mean time to promotion of promotees, and the same quantities for careerists.

Then, the zone specific rates are changed to the category specific rates, and the program displays the same quantities as before.

The computer printout of this example is presented on the following pages.

ATTRITION RATE FOR CATEGORY (W): 0.15

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   RUN MODEL
     2   SEE THE DATA   5   RUN MODEL FOR CAREERISTS
4

PROBABILITY OF EVENTUAL PROMOTION (PU)   0.571

MEAN TIME TO PROMOTION OF PROMOTEES (TP)   2.354

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   RUN MODEL
     2   SEE THE DATA   5   RUN MODEL FOR CAREERISTS
5

PROBABILITY OF EVENTUAL PROMOTION OF CAREERISTS (PU*)   0.993

MEAN TIME TO PROMOTION OF CAREERISTS (TP*)   3.936

                        WOULD YOU LIKE TO
     0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
     1   TURN PRINTER ON/OFF   4   RUN MODEL
     2   SEE THE DATA   5   RUN MODEL FOR CAREERISTS
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER

DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
 0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
 1 FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1

I-3

CAREER

DO YOU WISH TO
 1: ENTER THE DATA FROM DATA FILE ?
 2: ENTER THE DATA FROM THE KEYBOARD ?
 3: MAKE A CHOICE FROM THE MAIN MENU ?

2

DO YOU HAVE PROMOTION ZONES ?
 0: FOR NO
 1: FOR YES

1

ENTER LOWER (A) AND UPPER (B) BOUNDARIES OF THE PROMOTION ZONE

5 9

WHICH ASSUMPTION DO YOU WISH TO MAKE IN CALCULATING
PROMOTION RATE (P* OR P2*) OF CAREERISTS
(PERSONNEL WITH ATTRITION RATE ZERO)
 1: PROMOTION BEFORE ATTRITION
 2: ATTRITION BEFORE PROMOTION
 3: PROMOTION AND ATTRITION SIMULTANEOUS

1

WOULD YOU LIKE TO USE
 1: ZONE SPECIFIC RATES
 2: CATEGORY SPECIFIC RATES

1
ENTER THE PROMOTION RATE IN PROMOTION ZONE (P2)

.09

ENTER THE ATTRITION RATES IN BELOW ZONE (W1) AND
IN PROMOTION ZONE (W2)

.15 .06

                        WOULD YOU LIKE TO
    0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
    1   TURN PRINTER ON/OFF   4   RUN MODEL
    2   SEE THE DATA   5   RUN MODEL FOR CAREERISTS
2

LOWER (A) AND UPPER (B) BOUNDARIES OF THE PROMOTION ZONE ARE:
A=5   B=9

CHOSEN ASSUMPTION IS PROMOTION BEFORE ATTRITION.

MODEL USES THE ZONE SPECIFIC RATES.

PROMOTION RATE IN PROMOTION ZONE (P2): 0.09

ATTRITION RATE IN BELOW ZONE (W1): 0.15

ATTRITION RATE IN PROMOTION ZONE (W2): 0.06

I-4

```
                         WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA           3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF              4   RUN MODEL
      2   SEE THE DATA                     5   RUN MODEL FOR CAREERISTS
4


PROBABILITY OF EVENTUAL PROMOTION (PU)         0.127
-----------------------------------------------------
MEAN TIME TO PROMOTION OF PROMOTEES (TP)       6.798



                         WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA           3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF              4   RUN MODEL
      2   SEE THE DATA                     5   RUN MODEL FOR CAREERISTS
5


PROBABILITY OF EVENTUAL PROMOTION OF CAREERISTS (PU*)    0.314
--------------------------------------------------------------
MEAN TIME TO PROMOTION OF CAREERISTS (TP*)               6.882



                         WOULD YOU LIKE TO
      0   QUIT PROGRAM/SAVE DATA           3   CHANGE THE DATA
      1   TURN PRINTER ON/OFF              4   RUN MODEL
      2   SEE THE DATA                     5   RUN MODEL FOR CAREERISTS
3

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
   0   DONE WITH ALL CHANGES
   1   LOWER (A) AND UPPER (B) BOUNDARIES OF PROMOTION ZONE
   2   ASSUMPTIONS FOR CAREERISTS PROMOTION RATE
   3   ZONE SPECIFIC RATES/CATEGORY SPECIFIC RATES
   4   PROMOTION RATE
   5   ATTRITION RATES
   6   ALL THE DATA
3

WOULD YOU LIKE TO USE
 1: ZONE SPECIFIC RATES
 2: CATEGORY SPECIFIC RATES

2

ENTER THE RETIREMENT POINT (K)

12

ENTER THE PROMOTION RATE FOR CATEGORY (P)
.08

ENTER THE ATTRITION RATE FOR CATEGORY (W)

.09
```

I-5

ENTER THE NUMBER OF THE DATA YOU WOULD LIKE TO CHANGE
```
   0   DONE WITH ALL CHANGES
   1   LOWER (A) AND UPPER (B) BOUNDARIES OF PROMOTION ZONE
   2   RETIREMENT POINT (K)
   3   ASSUMPTIONS FOR CAREERISTS PROMOTION RATE
   4   ZONE SPECIFIC RATES/CATEGORY SPECIFIC RATES
   5   PROMOTION RATE
   6   ATTRITION RATES
   7   ALL THE DATA
0
```

LOWER (A) AND UPPER (B) BOUNDARIES OF THE PROMOTION ZONE ARE:
$A=5$ $B=9$

CHOSEN ASSUMPTION IS PROMOTION BEFORE ATTRITION.

MODEL USES APPROXIMATION FORMULAS FOR CALCULATING
PROMOTION AND ATTRITION RATES.

RETIREMENT POINT (K): 12

PROMOTION RATE FOR CATEGORY (P): 0.08

ATTRITION RATE FOR CATEGORY (W): 0.09

PROBABILITY OF EVENTUAL PROMOTION (PU)   0.445

MEAN TIME TO PROMOTION OF PROMOTEES (TP)   6.345

PROBABILITY OF EVENTUAL PROMOTION OF CAREERISTS (PU*)   0.816

MEAN TIME TO PROMOTION OF CAREERISTS (TP*)   6.496

I-6

```
      2  SEE THE DATA                     5  RUN MODEL FOR CAREERISTS
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER


DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
 0   FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
 1 FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1
```

I-7

Example 3 : This is an example for a career patterns using Markov Chain model. It is a Markov Hierarchical system with three categories. The number of categories, the promotion and attrition rates are given to the model as input. The program displays the $\underline{D}$ and $\underline{\Pi}$ matrices for all personnel and $\underline{D}^{\star}$ and $\underline{\Pi}^{\star}$ matrices for careerists.

The computer printout of this example is presented on the following pages.

MARKOV

DO YOU WISH TO
  1:ENTER THE DATA FROM DATA FILE ?
  2:ENTER THE DATA FROM THE KEYBOARD ?
  3:MAKE A CHOICE FROM THE MAIN MENU ?

2

ENTER THE NUMBER OF THE MODEL TYPE
  1   MARKOV HIERARCHICAL
  2   MARKOV LENGTH OF SERVICE
  3   MARKOV GENERAL
1

ENTER NUMBER OF CATEGORIES (K)
3
ENTER THE PROMOTION RATE VECTOR
THIS VECTOR SHOULD INCLUDE THE PROMOTION RATES
FOR THE FIRST 2 CLASS(ES).
.25 .15
ENTER THE ATTRITION RATE VECTOR
THE 3TH VALUE SHOULD INCLUDE THE TOTAL RATE
FOR THAT STATE DUE TO EITHER PROMOTION OR ATTRITION.
.1 .05 .01

                          WOULD YOU LIKE TO
  0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
  1   TURN PRINTER ON/OFF   4   D AND PI MATRICES
  2   SEE THE DATA   5   D AND PI MATRICES FOR CAREERISTS
2

NUMBER OF CATEGORIES IS: 3

TRANSITION RATE MATRIX
 0.65 0.25 0
 0   0.8 0.15
 0   0   0.99

ATTRITION RATE VECTOR
0.1 0.05 0.01

                          WOULD YOU LIKE TO
  0   QUIT PROGRAM/SAVE DATA   3   CHANGE THE DATA
  1   TURN PRINTER ON/OFF   4   D AND PI MATRICES
  2   SEE THE DATA   5   D AND PI MATRICES FOR CAREERISTS
4

          D MATRIX IS:

CATEGORIES   1   2   3
------------   -   -   -
1   2.857   3.571 53.571
2   0.000   5.000 75.000
3   0.000   0.000 100.000

I-8

```
        PI MATRIX IS:
        --------------
CATEGORIES          1          2          3
------------        -          -          -
1                1.000      0.714      0.536
2                0.000      1.000      0.750
3                0.000      0.000      1.000


                  WOULD YOU LIKE TO
     0  QUIT PROGRAM/SAVE DATA      3  CHANGE THE DATA
     1  TURN PRINTER ON/OFF         4  D AND PI MATRICES
     2  SEE THE DATA                5  D AND PI MATRICES FOR CAREERISTS
5



        D* MATRIX IS:
        --------------
CATEGORIES          1          2
------------        -          -
1                3.597      6.329
2                0.000      6.329


        PI* MATRIX IS:
        ---------------
CATEGORIES          1          2
------------        -          -
1                1.000      1.000
2                0.000      1.000


                  WOULD YOU LIKE TO
     0  QUIT PROGRAM/SAVE DATA      3  CHANGE THE DATA
     1  TURN PRINTER ON/OFF         4  D AND PI MATRICES
     2  SEE THE DATA                5  D AND PI MATRICES FOR CAREERISTS
0
YOU HAVE THE OPTION OF SAVING THIS DATA IN CHOSEN DRIVE.
YOU WILL FIRST BE ASKED IF YOU WANT TO USE THIS OPTION OR NOT.

TYPE 'Y' AND HIT ENTER IF YOU WANT TO SAVE DATA OR JUST HIT ENTER


DO YOU WANT TO LEAVE APL AND RETURN TO DOS ?
 0  FOR NO: WANT TO LEAVE PROGRAM BUT STAY IN APL
 1 FOR YES: WANT TO LEAVE APL AND RETURN TO DOS
1
```

I-9

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