LIPRO 2.0: AN APPLICATION OF A DYNAMIC DEMOGRAPHIC PROJECTION MODEL TO HOUSEHOLD STRUCTURE IN THE NETHERLANDS

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PREFACE

This book originated from the research project "The impact of changing household structure on future social security expenditure in the Netherlands", carried out for the Netherlands Ministry of Social Affairs and Employment by the Netherlands Interdisciplinary Demographic Institute (NIDI) during the years 1988-1990. A major component of this research project consisted of the development of a multidimensional household projection model. The model has been implemented in the computer program *LIPRO 2.0*. Although originally written as a program for making household projections, LIPRO 2.0 can in fact be used for a wide range of multidimensional demographic computations.

Realizing that the proof of the pudding is in the eating, we have included several chapters on an illustrative application of the model to household structure and social security in the Netherlands. However, the emphasis in this book is on the methodological and computational aspects of the LIPRO model. Almost half of the book is devoted to a detailed description of the operation of the LIPRO computer program. The program itself is on the diskette included in the back cover.

The LIPRO program (or rather: set of programs) has been written in Borland's Turbo Pascal 5.0. It can be run on MS/DOS personal computers or compatibles. A mathematical co-processor, a hard disk, and a memory of 640 kb are required. If the mathematical co-processor is absent, a recompiled version of the program can be supplied.

Although the use of the LIPRO programs is free of charge (except for the price of this book), and indeed warmly encouraged, we would like to urge anyone intending to publish results obtained with LIPRO to include a proper reference to this manual. In addition, neither the authors nor the NIDI can accept any responsibility for damage as a result of errors in the software or its documentation, let alone as a result of improper use of the software. We welcome any (written) suggestions for improvement of the program or the manual, but as yet there are no guarantees that the funds will be available to produce regular updates of the LIPRO package.

Several people have made valuable contributions during the production of the program and the book. In the course of intensive collaboration with demographers at the Central School of Planning and Statistics in Warsaw, Irena Kotowska discovered many bugs in a previous version of the program and also made many useful suggestions for improvement. At the NIDI, Frans Willekens urged us to give high priority to user-friendliness in programming; his enthusiasm in promoting demographic software has been a great stimulus. Suzanne Wolf did most of the calculations for the household projections. She made numerous suggestions for improving the software and prepared all the figures included in this book. Joan Vrind contributed to the final layout of the manuscript, and Angie Pleit-Kuiper edited our non-native use of the English language.

Part of the text of this book was written after the second author had left the NIDI to join the Norwegian Central Bureau of Statistics. The facilities provided by this organization, allowing us to finish this book, are gratefully acknowledged.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART I

INTRODUCTION

1. AIMS AND SCOPE

1.1 Introduction

Household projection models developed in demography over the past few decades are predominantly of the headship rate type. This modelling strategy rests on the principle of comparative statics. The development of households by number and type is described by the development of number and type of their heads, being household or family "markers" (Brass, 1983), on the basis of analysing trends in proportions of individuals who occupy the position of household or family head within some broader defined population categories. Analysis as well as projection rely on data referring to the situation at specific points in time. Thus, the headship rate method describes the results of dynamic processes between the time points in terms of changing headship rates, these dynamic processes themselves remaining a black box. Like the labour force participation rate in labour force studies, the headship rate is not a rate in the demographic ("occurrence-exposure") sense, and its analytical use reflects a focus on changes in *stocks*, rather than a focus on *flows*.

In spite of this disadvantage, the headship rate method is often used, and it owes much of its popularity to two factors. The method is easy to apply and its data demands are modest. Also, the method has been refined gradually, for instance, to take into account aspects of household members (Linke, 1988). However, the *static* nature of the headship rate method and its extensions have led to a number of attempts to develop *dynamic* household models, as it is the dynamic processes of household formation and dissolution that really cause changes in the cross-sectionally observed stock numbers of households, and not the other way around.

Early attempts to construct dynamic household models were largely of an *ad hoc* nature, as we will see in the model review in chapter 2. Data availability and certain practical solutions to modelling problems were largely responsible for this *ad hoc* situation. But in recent years, better data on household dynamics became available for some countries, and, at the same time, a coherent and very general methodology for the modelling and projection of dynamic demographic aspects of a population was developed: multidimensional demography, mainly due to Rogers, Ledent, and Willekens. It is the purpose of this book to describe the construction of a very general dynamic household model, based on the insights of multidimensional demography, and to apply that model to trace the present and the future household situation in the Netherlands. What are the consequences of increasing rates of divorce for the number of one-parent families? How many additional one-person households would there be if young adults were to leave the parental home at a lower age? These and similar questions may be answered by using a dynamic household model, and by running that model on the basis of various "scenarios" regarding its exogenous variables. A static model would provide little insight in these matters.

Changes in household structures may have profound consequences for several other aspects of society. For example, consumption, housing, labour force participation, commuting, and tax revenues are affected by household dynamics. In the present study, the consequences for *social security expenditures* are investigated. Some of these expenditures are very sensitive to demographic changes, including shifts in household structures. The application of the household model to social security enables the investigation of the possible bias in studies into the link between demography and social security which do not take account of household dynamics.

1.2 | Problem formulation

This book reports the findings of the research project "The impact of changing household structures on future social security expenditure in the Netherlands", which was carried out at the Netherlands Interdisciplinary Demographic Institute (NIDI) with financial support from the Netherlands Ministry of Social Affairs and Employment. The problem formulation of this project is as follows.

> What is the impact of demographic developments, in particular shifts in the age structure and household composition, on future social security expenditure in the Netherlands?

The problem was investigated in a number of steps:

1. the construction of a dynamic model for the projection of the population broken down by age, sex, and household position;
2. the collection of data on the quantitative aspects of household formation and dissolution;
3. the collection of data for a number of demographically relevant types of social security expenditures, broken down by age, sex, and household position ("social security user profiles");
4. the formulation of various scenarios for possible demographic futures of the Netherlands’ population;

5. the computation of a projection of the population of the Netherlands by age, sex, and household position;
6. the projection of social security expenditures selected under item 3 on the basis of the future demographic estimates computed under item 5.

Many of the sections and chapters which follow are based on a research report written in Dutch (Van Imhoff and Keilman, 1990a). However, in the present book the emphasis is more on methodology, and less on application and numerical results, than in the Dutch report. For instance, in the research report three types of social security were investigated: public old age pensions, social welfare, and child allowance. The latter is not discussed in the present book, because it is insensitive to changes in household structure (although the size and the age structure of the population *does* have an impact on child allowance). Moreover, the present book contains an extensive presentation of the methodology that was used to answer the research questions, and a major part of the book contains a user guide for the computer program which was developed within the project.

1.3 | LIPRO

Within the project, a flexible model was developed for multidimensional demographic projection, called LIPRO ("LIfestyle PROjections"). The LIPRO model contains a number of methodological innovations. In part II of this book we show how existing constant intensities models have been extended to include entries (for instance, due to immigration or childbearing). Moreover, LIPRO contains a very general algorithm to deal effectively with the problems that arise because the behaviour of various individuals belonging to the same household is interrelated. In traditional demography this is known as the two-sex problem: the number of males who marry in a certain period should equal the number of marrying females. In LIPRO the problem has been reformulated in a much more general manner as a so-called consistency problem. The solution we propose can handle the relation between two or more adults, and that between children and parents, under processes of household formation and household dissolution.
The computer program which was written in the context of the project is called LIPRO 2.0 - it is included on floppy disk in this book. A harddisk and a memory of 640 Kb are required to run LIPRO 2.0. In addition, the enclosed standard version of LIPRO requires the presence of a mathematical co-processor. Other versions than the standard one are also available (see chapter 13).

1.4 | Outline of this book

This book consists of four major parts: Introduction, Theoretical issues, Application, and LIPRO user's guide. Chapter 2 concludes the introductory part of the book. In that chapter existing household projection models are reviewed, and we formulate major developments that can be traced in the literature on household modelling. Issues concerning the concept and the definition of a household are also addressed.

Part II contains a comprehensive treatment of the theoretical issues relevant to understanding how the demographic projection program LIPRO works. A general characterization of multidimensional projection models is given in chapter 3. Chapter 4 contains a description of the exponential (constant intensities) model which has its roots in statistics and the theory of Markov processes, and the linear model which was developed within demography. LIPRO 2.0 has an option to choose between these two versions of the multidimensional projection model. The consistency problem is formulated in very general terms in chapter 5, and we present an algorithm to solve it. Chapter 6 discusses some issues in multidimensional life table analysis. Multidimensional demographic models require a multitude of input parameters. Life tables provide the possibility to calculate summary indicators for these parameters, which in turn may be used effectively when scenarios for the input parameters of the projection model are formulated.

In part III we apply the general model sketched in part II to the future household dynamics in the Netherlands, and we trace its consequences for some social security expenditures. First, in chapter 7 a specification is given of the various household positions an individual may occupy during his or her life. Although the emphasis in the current book is on the individual person and the household events this person experiences, the specification of household positions also enables us to identify types of households which correspond with individual household positions. A considerable part of chapter 7 is devoted to the identification of household events and consistency relations. The estimation of the input parameters on the basis of data from various sources is treated in detail in chapter 8. The larger part of the input rates was estimated using retrospective information on current and past household status of the members of some 47,000 private households in 1985 in the Netherlands. But in spite of the detailed and massive nature of this survey, some approximating assumptions had to be made. Therefore, the input parameters were constrained in such a way that LIPRO produced demographic results which correspond to official demographic statistics for the years 1986-1990. Chapter 9 presents five demographic scenarios which were used for the projections. A demographic scenario describes a possible trajectory of future demographic development. Results of the household projections are given in chapter 10. Here it is demonstrated how the five scenarios differ with respect to projected household composition of the population of the Netherlands until the year 2050. An enormous growth in the number of individuals living in a one-person household is persistent in all scenarios. Chapter 10 also discusses the effects of alternative model specifications (exponential versus linear model, with and without consistency) for the demographic results. Finally, the link between social security and demographic developments is taken up in chapter 11. It contains a review of the literature on the interrelation between social security and demography, a discussion of the estimation of social security user profiles for public old age pensions and social welfare, and a brief presentation of the illustrative social security projections. Our findings suggest a much steeper increase in future expenditures for old age pensions in the Netherlands than previous studies did, mainly because we find larger numbers of elderly persons living alone (who receive a higher pension than elderly persons living with a partner). Chapter 11 also discusses the usefulness of incorporating household position in the demographic model, in addition to age and sex. Chapter 12 contains a summary of parts I to III of the book, as well as some questions that still require research.

Part IV of the book constitutes a complete user's guide to LIPRO 2.0. Although it can be read independently from parts I to III, the reader is assumed to have a basic understanding of the theoretical issues presented in part II. The various program features are discussed using examples from the application of the LIPRO model presented in part III.
The introductory chapter 13 includes a discussion of hardware requirements, program installation, the use of menus, issuing commands, the LIPRO editor, and the various types of program output. Chapter 14 ("Getting started") introduces the reader to LIPRO's main menu. In chapter 15 it is discussed how demographic input data (intensities, occurrence-exposure rates, initial population) are entered into the program. The implementation of the consistency algorithm and the formulation of scenarios is taken up in chapters 16 and 17, while chapter 18 explains how to carry out a demographic projection with LIPRO. Chapters 19 and 20 contain a discussion of various issues, including the presentation of projection results, the analysis of multidimensional life tables, and the exporting of data for use by other programs. Finally, chapter 21 introduces the reader to a program which links results of demographic projections to a user profile. Social security user profiles are used as an example here, but other applications (e.g. consumption or tax revenues) are possible too.

2. HOUSEHOLD MODELS: A SURVEY

2.1 | Concepts

The household is one of the many operationalizations of the concept of a living arrangement. Other examples are marital status and family type. The trichotomy marital status, family type, and household type runs parallel to Ryder's distinction between the conjugal dimension, the cosanguineal dimension and the co-residence dimension of family demography (see Ryder, 1985, 1987). In this order, these alternative operationalizations describe living arrangements ranging from a less to a more complex type of structure. First, the conjugal and the marital status perspective explore the formation and dissolution of marital unions. Second, the cosanguineal and the family relationship explore links between parents and children. Kinship studies can be placed within this framework too. Finally, we consider the household, that is a group of individuals, familial and non-familial, which is at least identified by a co-residence criterion (and possibly by other criteria as well, cf. below). A more formal definition will be given later in this chapter.

Households are the most complex type of primary units, embracing all the aspects of the less complex definitions of the above classification. A married couple with their children and living as an isolated co-resident group can be viewed as one specific household type. Other household types, for instance, isolated co-resident conjugal units (childless couples), may also be included in one or more of the three operationalizations of living arrangements.

In a certain sense, kin and household are each other's opposite. A household is a co-resident group regardless of cosanguineal or affinal ties; by kin we refer to a group of relatives regardless of their residence (see De Vos and Palloni, 1989, p. 175). The latter authors note that the household and the family had been often equated, until the extent of cohabitation was sufficient to force many researchers to make a distinction.

2.2 | Definitions

The United Nations recommend three possibilities for the definition of a household in population and housing censuses.

- The "housekeeping-unit" concept: a private household is either (i) a one-person household, that is, a person who lives alone in a separate housing unit or who occupies, as a lodger, a separate room of a housing unit but does not join with any of the other occupants of the housing unit to form part of a multi-person household; or (ii) a multi-person household, that is, a group of two or more persons who combine to occupy a whole or part of a housing unit and who provide themselves with food and possibly other necessities of life.
- The "household-dwelling" concept: a private household is the aggregate number of persons occupying a housing unit. This is equivalent to the co-resident group described above.
- Institutional households and other communal relationships: an institutional household is comprised of groups of persons living together, who usually share their meals and are bound by a common objective and are generally subject to common rules, for example, groups of persons living together in dormitories of schools and universities, hospitals, old age homes and other welfare institutions, religious institutions, prisons, military camps, and so on.

The housekeeping-unit definition of a household is applied in this book, the main reason being the fact that our household data, provided by the Netherlands Central Bureau of Statistics (see chapter 8), follow this convention. As the household-dwelling definition of a household does not involve any housekeeping criteria, the latter definition is less restrictive than the housekeeping-unit definition. Institutional households will not be considered in this book.

An inventory carried out by the Economic Commission for Europe in the early 1980s indicated that about two-thirds of the ECE countries employ the housekeeping definition in their data collection. However, none of the definitions given above is without problems. For instance, difficulties arise for persons with more than one dwelling (Linke, 1988; Schwarz, 1988), for persons who are not related to the family (subtenants, service personnel), and so on. Schmid (1988) argues that the scoring of non-related persons present in the household has a considerable effect on the enumeration of people in households.

Household models not only provide insight into the development of numbers of *households of various types*, but also of numbers of *individuals classified by household position*. It is very important to make a proper distinction between these two levels of aggregation. Individuals who belong to the *same* household may occupy *different* household positions. For example, in the LIPRO model (which is to be discussed in chapter 7), one of the household types is "married couple with children and possibly with other co-resident adults" (household type MAR+ in section 7.2). A person who belongs to this household may occupy either of the following three household positions: (i) married adult living with spouse; (ii) child living with both parents; (iii) non-family related adult. LIPRO deals primarily with individuals and the household events they experience. Numbers of households are derived from projected numbers of persons in the various household positions.

2.3 | A typology of household models

Given the research questions to be addressed in this book, a model for the projection of the population broken down by age, sex, and household position is required for the demographic part of this study. Models of this kind may be classified according to two dimensions: the static/dynamic dichotomy on the one hand, and a dimension related to the link between demographic variables and non-demographic variables on the other hand. In the latter dimension we distinguish between purely demographic models, and models which include both demographic and non-demographic (most often socioeconomic) variables. This classification is broader than that of Bongaarts (1983, p. 32), who considers purely demographic models only.

In the research project described in this book the focus is on *purely demographic dynamic* household models. The advantage of dynamic household models relative to static models will be discussed in sections 2.4 and 2.5. The emphasis on purely demographic models does not imply that we regard the impact of economic, social, psychological, legal, and cultural processes on household structures to be of secondary importance. However, within household demography, little is known of formal demographic household events occurring to individuals in changing household structures. Therefore, we think that *structural issues* in household modelling have to be resolved before any *substantive* relationships can be adequately studied. Formal relationships between demographic entities have to be analysed as a prelude to the examination of causal issues. A thorough analysis of patterns, disaggregated by demographic and household characteristics, may itself bring forth explanatory variables which should be considered. The issue of modelling explanatory factors in the context of household projection models will be taken up in chapter 12.
Examples of household models containing non-demographic variables which "explain" household variables are the Cornell model in the USA (Caldwell *et al.*, 1979), the IMPACT model in Australia (Sams and Williams, 1982), the model developed at the Policy Studies Institute in Great Britain (Ermisch, 1983), the model of the Sonderforschungsbereich 3 in Frankfurt, Germany (Galler, 1988), the UPDATE model for households in small areas in England (Duley

et al., 1988), and the NEDYMAS model constructed by Nelissen for the Netherlands (Nelissen and Vossen, 1989). These models are much less developed in terms of household structures than the LIPRO model to be described in the following chapters.

The review contained in sections 2.4 and 2.5 is restricted to *operational household models*. Marital status models and family models will not be discussed here. Family models were constructed by Bongaarts (1981, 1987) for general applications, by Rallu (1985) for France, and by Kuijsten (1986, 1988) for the Netherlands. A review of marital status projection models was given by Keilman (1985b). A number of family and household models have been proposed in the literature, but no operational version of them exists, to the best of our knowledge. Examples are the models of Webber (1983), Muhsam (1985), Ledent *et al.* (1986), and Murphy (1986).

2.4 | Static household models

Headship rate models are among the oldest models to project households. They are the typical representatives of the class of static, purely demographic, household models. The idea is to extrapolate proportions of household heads in population categories defined by a certain combination of age, sex, and possibly marital status. An independent projection of the population by age and sex (and marital status) facilitates a projection of the future number of households, broken down by demographic characteristics of the head of the household.
The prototype of this method was published in 1938 by the United States National Resources Planning Committee. It became internationally accepted after the 1950 round of censuses. Kono (1987) and Linke (1988) discuss the headship rate model in detail, including its extensions, such as the household membership rate model. The household composition model proposed by Akkerman (1980) adds the age of the household members as an extra dimension to the headship rate model. (However, it should be noted that Akkerman’s model is not widely used, possibly due to numerical problems that may arise. See, for instance, Keilman and Van Dam, 1987, p. 26).

The headship rate method for the projection of households has several characteristic features: it is a simple and practical method for which the necessary data are frequently available. Projections can be updated easily. However, its static character is often judged a disadvantage: the model is unable to deal with the dynamics of household formation and dissolution. The headship rate method reflects a focus on changes in household structures at *subsequent points in time* (comparative statics), whereas truly dynamic models simulate household events *over a certain period.* Like the labour force participation rate in labour market studies, the headship rate is not a rate in the demographic ("occurrence-exposure") sense. It is a proportion, while dynamic models are constructed on the basis of transition probabilities or intensities (see chapter 4).

2.5 | Dynamic household models

Dynamic household models deal, in one way or another, with processes of household formation and household dissolution. They can be used to answer questions such as: "If children would leave the parental home two years later than is the case presently, how would this influence household structures?" or "How would a 25 percent increase in divorce rates affect the number of one-parent families?". Traditional static models say little about such matters.

The history of dynamic household models is much younger than that of the headship rate models, as the first dynamic household models were developed after the mid-1970s. Three dynamic household models will be discussed here briefly to illustrate the most important recent developments in household modelling: the model developed by Möller for the Federal Republic of Germany; the Swedish model constructed by Hårsman, Snickars, Holmberg, and others; and finally the LIPRO model built at the NIDI, which will be presented in detail in chapters 7 to 12. The following draws largely on an earlier review (Keilman, 1988).

Möller (1979, 1982) describes a household projection model which was developed at the "Institut für Angewandte Systemforschung und Prognose" (ISP) in Hanover, Federal Republic of Germany. The model was applied in a study of future consumption patterns in the FRG. It starts from results of a population projection model which simulates future population structures by age and sex. Then the model further breaks down the population into dependent children, married adults, and unmarried adults. Using an assumption on headship rates, the number of households is calculated on the basis of male adults and unmarried female adults. This means that adult males and unmarried adult females are always considered as the head of a household. Given the number of households, the model finally determines their distribution by number of children present using parity-specific fertility curves by age of the mother, and "home-leaving" curves by age of the child.

The dynamic character of the ISP model is very limited as it relies on only one household event: leaving home by young adults. Other household features are introduced by means of traditional ratio and headship rate methods.

During the late 1970s and early 1980s, a dynamic household model was constructed by Hårsman, Snickars, Holmberg and others in Sweden. To date, several versions and applications of the model exist and the original ideas have been updated many times. We shall discuss the model version described in a comprehensive report by Dellgran *et al.* (1984), as well as in Holmberg (1987).

Bugge (1984) applies the method to Norwegian data and Zelle (1982) uses a comparable approach for Austria. Hårsman and Snickars (1983) provide a useful summary of the model.

The Swedish model follows individuals, classified by household status, over a discrete time interval. Its key instrument is a matrix of probabilities describing transitions in household statuses, these transitions being experienced by individuals between the beginning and the end of the time interval. Household status is defined as household size (1, 2, $\cdots$, 5+) and whether or not a household contains dependent children. This yields a total of nine household types.

The model first adjusts an originally observed transition matrix to a number of external and internal constraints. After the adjustment of the transition matrix, the population is projected forward in time over one interval. This procedure is repeated for the whole projection period.

An example of the constraints which the transition matrix has to satisfy is that at each point in time the number of dependent children in two-person households must be equal to the number of adults in that category. Furthermore, the adjusted transition matrix should resemble the original matrix as closely as possible. This is achieved by an optimization routine.

To facilitate a comparison of household models, the most important aspects of the LIPRO model are summarized here. More detailed descriptions are given in later chapters.

Many of the efforts to construct LIPRO ran parallel to the development of other dynamic household models in the Netherlands. Hooimeijer and Linde (1988) provide a useful summary. In the LIPRO application which is presented in chapter 7, the population in private households is broken down according to age, sex, and household position. For the latter characteristic, 11 positions are used: three for children, four for persons who live with a partner, one for persons who live alone (one-person households), one for heads of a one-parent family, and two for other household positions (see section 7.2). These 11 household positions identify 69 possible household events that individuals may experience as they move from one household position to another. Besides household events, the model describes birth, death, emigration, and immigration (section 7.3). An event is expressed in LIPRO in terms of an occurrence-exposure rate (for each relevant combination of age and sex), representing the intensity with which the event occurs to an individual.

An important part of LIPRO is the so-called consistency algorithm (section 7.4). The purpose of this algorithm is to guarantee consistency in the numbers of events which members of the same household experience. For instance, the number of males who marry during a certain period must equal the number of females who marry, and similarly for new consensual unions. And when a married man with children dies, both his wife and his children must be moved to the position one-parent family (head and child, respectively).

2.6 | Comparison

A number of major developments can be traced in the literature on household modelling.

From static to dynamic models
More and more emphasis is given to the development of dynamic household models. Changes in household structures cannot be studied adequately with static models. Models of the latter type are widely used at present, particularly because of their simplicity. But innovations in household modelling take place in the area of dynamic models.

From households to individuals
The interest is shifted from a description of numbers of households (of various types) to a description of (events occurring to) individuals (broken down by household position). Headship rate models represent the first tradition, the ISP model takes an intermediate position, while the Swedish model and LIPRO emphasize the individual. Related to this development is that the notion of "head of household" gradually loses significance.

More states and more events
Within the class of dynamic household models, an increasing number of household positions and household events (or transitions) can be noted. The only household event in the ISP model is leaving the parental home. The Swedish model has nine household positions and it deals implicitly with 41 events. LIPRO's state space contains 11 positions and the model describes 69 events.

Growing data requirements
Data requirements increase with growing model complexity. Headship rate models only require proportions of head of households within population classes (stock data). At the other end of the spectrum we find LIPRO, for which, in the present application, information is necessary on the 69 types of events which individuals may experience (flow data). The Swedish model and the ISP model have lower data demands than LIPRO. The high demands of modern dynamic household models are an important factor in the slow development and the relatively scarce application of these models.

PART II

THEORETICAL ISSUES

3. A CHARACTERIZATION OF MULTIDIMENSIONAL PROJECTION MODELS

Dynamic demographic projection models describe the development over time of a population. A population consists of a number of *individuals* (or alternative units of analysis), broken down by certain demographic characteristics (e.g. age, sex, marital status, geographic location, household status, and the like). This multidimensional breakdown of the population defines a *state space*. A vector in the state space is called a *state vector*; its elements consist of numbers of individuals at one point in time, broken down by demographic characteristics.

Theory and applications of multidimensional models (sometimes called multistate models) have appeared in the demographic literature since the mid-1970s. Most applications have focussed on multiregional models (e.g. Rogers, 1975; Willekens and Drewe, 1984; Keilman, 1985a; Rogers and Willekens, 1986; Ledent and Rees, 1986) and marital status models (e.g. Schoen and Nelson, 1974; Krishnamoorthy, 1979; Schoen and Land, 1979; Willekens *et al.*, 1982; Gill and Keilman, 1990). Other applications include working life tables and fertility by parity. For additional references, see Gill and Keilman (1990, p. 124). The application to household dynamics is relatively new (cf. chapter 2). Most of the papers referred to above concern life tables rather than projection models. In the present book, the focus is on projection models (cf. the literature review in chapter 2). Hoem and Funck Jensen (1982) give a comprehensive review of the general multidimensional life table and projection model, as well as its Markov process formulation.

The research that gave rise to the construction of the LIPRO program belongs to the research project "The impact of changing living arrangements on social security expenditures in the Netherlands" which has been carried out at the NIDI with financial support from the Netherlands Ministry of Social Affairs and Employment. In this project a multidimensional household projection model was developed; the household projections generated by this model are subsequently used to trace future expenditures on social security.

The development over time of the population can be described in terms of *events*: immediate jumps from one cell in the state vector to another. Examples of events are: marriage, divorce, leaving the parental home, internal migration. It is possible for an individual to experience several events within one single projection interval; of course, the probability of multiple events increases with the length of the projection interval.

The population under consideration is not closed: some individuals leave the population (death, emigration), others enter the population (birth, immigration). Such jumps into, or out of, the population are also termed events. In order to distinguish this latter type of events from the type discussed in the previous paragraph, jumps across the boundaries of the population will be termed *external events* as opposed to *internal events*. External events comprise *exits* and *entries*. Exits can be subdivided according to destination, entries according to origin.

A different classification of events is by *endogenous* and *exogenous* events. An endogenous event is an event that is "explained" within the demographic model itself. In purely demographic models, the occurrence of events is explained by, first, the number of individuals occupying a certain state during a certain interval of time, and, second, the probability that a given individual will experience some event. Consequently, events are endogenous whenever the number of events is dependent on the distribution of individuals within the population over the various characteristics. All internal events and all exits are endogenous. Entries are in part endogenous (births), in part exogenous (immigration).

These various types of events have been illustrated in Table 3.1.

In LIPRO, the state space is defined by the number of categories in each dimension of the state space, as well as by the labels attached to these categories. These variables are stored together in the *definition file*. The following variables are involved:

NSEX	The number of sexes. Its possible values are 1 (no distinction between males and females) and 2.
NAGE	The number of age groups
NWAGE	The width of the age groups
NPOS	The number of internal positions (or states, for short)
NOUT	The number of destinations for exits (external positions). Its two possible values are 1 (mortality) and 2 (mortality and emigration).
NIN	The number of origins for exogenous entries. Its two possible values are 0 (no immigration) and 1 (immigration).
LSEX	The labels for the sexes. If NSEX=2, the first sex corresponds to females, the second to males.
LAGE	The labels for the age groups. Group 1 corresponds to the age group born during the projection interval (endogenous entries). Group 2 refers to the youngest age group present at the beginning of the projection (or observation) interval.

LPOS	The labels for the internal positions
LOUT	The labels for the destinations for exits (external positions)
LIN	The labels for the origins for exogenous entrants

Table 3.1. Classification of events

<table>
<tr><th></th><th></th><th></th><th colspan="2">position after the event</th></tr>
<tr><th></th><th></th><th></th><th>internal positions</th><th>external positions</th></tr>
<tr><th></th><th></th><th></th><th>#1 #2 #3 .. etc.</th><th>dead rest world</th></tr>
<tr><td rowspan="3">position before event</td><td>internal positions</td><td>#1
#2
#3
.
etc.</td><td>internal events</td><td>exits</td></tr>
<tr><td rowspan="2">external positions</td><td>not yet born</td><td>endogenous entries</td><td>irrelevant</td></tr>
<tr><td>rest of the world</td><td>exogenous entries</td><td>irrelevant</td></tr>
</table>

4. THE EXPONENTIAL AND THE LINEAR MODEL[1]

As stated in chapter 3, in purely demographic models, the occurrence of events is explained by, first, the number of individuals occupying a certain cell in the state vector during a certain interval of time, and, second, the probability that a given individual will experience some event.

The relationship between the number of individuals in a certain cell, on the one hand, and the number of events experienced by these individuals, on the other, can be described by means of a so-called *Markov equation*. Here one implicitly assumes that the probability that an individual in position i will, within an infinitesimal interval of time, experience a direct jump into position j, is equal to a constant times the length of the infinitesimal time interval. Formally:

$$\lim_{dt \to 0} \frac{\Pr[I(t+dt)=j \mid I(t)=i]}{dt} = m_{ij}(t)$$

Here $m_{ij}(t)$ is a constant dependent on time t, and on i and j (the position before and after the event, respectively). This constant is termed the *instantaneous intensity* or *rate* for the jump from i to j. When $m_{ij}(t) = m_{ij}$ for all t within the observation interval, the resulting model is known as the *exponential model* or the *constant intensities model* (Gill and Keilman, 1990).

The data that underlie the calculations for one single projection interval are the constant intensities m_{ij}, the distribution of the population across positions at the start of the projection interval, and the numbers of the exogenous entries. In section 4.2 we will formulate the full exponential model in matrix notation. This formulation generalizes earlier work by Gill (1986) on Markov models for closed populations to include the case of open populations.

The exponential model gives rise to quite complex expressions, requiring iterative evaluation techniques. For computational simplicity, it is often assumed

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[1] Some of the material covered in this chapter can also be found in Van Imhoff (1990a).

that *all* events are uniformly distributed over the projection interval. This so-called *linear integration* hypothesis (Hoem and Funck Jensen, 1982) allows the projection to be carried out in one single computation step. The corresponding model is known as the *linear model*.

Although its computational simplicity is obviously a great advantage, the drawbacks of the linear model should not be underestimated. First, the assumption of uniformly distributed events can *only* be justified on the grounds of computational convenience; it is not based on any statistical theory, like the theory of Markov processes underlies the exponential model. Second, and even worse, in some cases the linear model may lead to impossible results, viz. negative numbers of individuals in some cells of the cross-classification table (Gill and Keilman, 1990). The exponential model does not have this unpleasant property.

The organization of this chapter is as follows. Section 4.1 gives some introductory remarks and spells out the notation. In section 4.2 the exponential model is derived, and the linear model is formulated in section 4.3. In section 4.4 we briefly indicate how the reverse calculations are performed, i.e. computing rates from events, rather than events from rates. The final section contains some technical information on the way in which the computer program performs special matrix operations.

4.1 | Preliminaries

Throughout this chapter the following symbols will be used:

$\mathbf{I}$	the identity matrix.
ι	a *row* vector consisting of only ones.
T	operator for transposition of a vector or matrix.
Diag[**v**]	operator for the formation of a diagonal matrix with the elements of vector **v** on the diagonal.
x	index for age group. The index takes values from 1 to NAGE. x=1 refers to the age group of individuals born during the projection interval.
s	index for sex. 1=female, 2=male.
t	calendar time at the start of the projection interval.
h	the length of the projection interval, assumed to be equal to the width of the age groups.
NPOS	the number of additional demographic positions considered (e.g. regions, household positions, marital statuses, etc.).
NOUT	the number of destinations for exits. In most applications NOUT will be equal to 2 (death, emigration).

NIN	the number of origins for exogenous entries. In most applications NIN will be equal to 1 (immigration).
$\ell(s,x,t)$	x=1···NAGE, s=1,NSEX. A *row* vector with the number of individuals of sex s and age x at time t, ordered by position. The vector ℓ has dimension (1 by NPOS).
$\mathbf{M}_i(s,x,t)$	x=1···NAGE, s=1,NSEX. A (NPOS by NPOS) matrix with intensities for *internal* events. The element (a,b) is the intensity of the jump (event) from position a to position b. The diagonal elements of the matrix are equal to 0 (to retain one's original position is not an event).
$\mathbf{M}_e(s,x,t)$	x=1···NAGE, s=1,NSEX. A (NPOS by NOUT) matrix with intensities for *exits*.
$\mathbf{M}_b(s,x,t)$	x=1···NAGE, s=1,NSEX. A (NPOS by NPOS) matrix with birth intensities (endogenous entries). The element (a,b) is the intensity of the event that a woman in position a gives birth to a child of sex s that will enter position b.
$\mathbf{M}(s,x,t)$	x=1···NAGE, s=1,NSEX. The (NPOS by NPOS) matrix $\mathbf{M}(s,x,t)$ is a transformation of the matrices $\mathbf{M}_i(s,x,t)$ and $\mathbf{M}_e(s,x,t)$, defined by $\mathbf{M}(s,x,t) = \mathbf{M}_i(s,x,t) - \mathrm{Diag}\,[\,\mathbf{M}_i(s,x,t)\cdot\iota^T + \mathbf{M}_e(s,x,t)\cdot\iota^T\,]$ The matrix $\mathbf{M}(s,x,t)$ differs from matrix $\mathbf{M}_i(s,x,t)$ in that its diagonal does not contain zeros, but the negative of the intensity of all events (both internal events and exits) that result in a jump out of the corresponding position.
$\mathbf{O}(s,x,t;h)$	x=1···NAGE, s=1,NSEX. A (NIN by NPOS) matrix with numbers of exogenous entries, ordered by origin and by position of destination. The age group x refers to the age that the entrants had at time t, not age at time of entry.

In order to be able to formulate the differential equations describing the development of the population over time, an assumption is needed on the distribution over time of the *events of entry* during the projection interval. We will assume here that this distribution is *uniform*.

For the exogenous entries (immigration), this assumption can be justified by pointing out that the number of potential immigrants is very large compared to the intensity of immigration: thus the event "immigration" has a negligible effect on the number of individuals exposed to the risk of immigration. Hence, the assumption of a uniform distribution for immigration is, in practice, equivalent to the assumption of a constant immigration intensity.

For the number of births, the assumption of a uniform distribution can hardly be justified on theoretical grounds. Given the solution to the differential equations for the female population of childbearing age, an exact distribution of births can be obtained, at least in principle (all on the maintained assumption of the Markov specification). However, these exact solutions are mathematically unmanageable. Therefore, the uniformity assumption may be considered an *approximation* of the exact distribution of births.

Finally, note that the model is formulated in terms of *row* vectors. The traditional notation in demographic texts based on column vectors (e.g. Keyfitz, 1968) would lead to unnecessarily complicated expressions (Gill and Keilman, 1990).

4.2 | Formulation of the exponential model

4.2.1. Formulas for age groups x > 1

For age groups x, x>1, the combination of the Markov assumption and the assumption of uniformly distributed immigration gives rise to the following differential equation:

$$\frac{d}{d\tau}\,\ell(s,x+\tau,t+\tau) = \ell(s,x+\tau,t+\tau)\cdot\mathbf{M}(s,x,t) + (1/h)\cdot\iota\cdot\mathbf{O}(s,x,t;h) \tag{4.1}$$

This is a non-homogeneous matrix differential equation. The homogeneous part is a straightforward transformation of the well-known Kolmogorov forward differential equation, multiplying both sides of the equation by $\ell(s,x,t)$. The non-homogeneous part is added in order to account for exogenous entries.

The general solution to the homogeneous part of the equation (4.1) is:

$$\ell(s,x+\tau,t+\tau) = \mathbf{C}\cdot e^{\mathbf{M}(s,x,t)\cdot\tau} \tag{4.2}$$

The exponential of a square matrix is defined in terms of its Taylor power series. **C** is a vector of integration constants.

A particular solution to the non-homogeneous differential equation is the following constant solution:

$$\ell(s,x+\tau,t+\tau) = -\,(1/h)\cdot\iota\cdot\mathbf{O}(s,x,t;h)\cdot\mathbf{M}^{-1}(s,x,t) \tag{4.3}$$

For the moment we will assume that the inverse of **M** exists; in section 4.2.3 we will return to this issue.

From the initial conditions that $\ell(s,x+\tau,t+\tau)$ for $\tau=0$ should equal $\ell(s,x,t)$, the values of the constants of integration **C** follow, giving the following general solution:

$$\ell(s,x+\tau,t+\tau) = \ell(s,x,t)\cdot e^{\mathbf{M}(s,x,t)\cdot\tau} +$$

$$+ (1/h)\cdot\iota\cdot\mathbf{O}(s,x,t;h)\cdot\mathbf{M}\text{-}1_{(s,x,t)}\cdot\{\ e^{\mathbf{M}(s,x,t)\cdot\tau} - \mathbf{I}\ \} \qquad (4.4)$$

so that, in particular

$$\ell(s,x+h,t+h) = \ell(s,x,t)\cdot e^{\mathbf{M}(s,x,t)\cdot h} +$$

$$+ (1/h)\cdot\iota\cdot\mathbf{O}(s,x,t;h)\cdot\mathbf{M}^{-1}(s,x,t)\cdot\{\ e^{\mathbf{M}(s,x,t)\cdot h} - \mathbf{I}\ \} \qquad (4.5)$$

The vector of *person years* (or *sojourn times*) spent by all individuals in the various positions is defined by:

$$\mathbf{L}(s,x,t;h) = \int_0^h \ell(s,x+\tau,t+\tau)\ d\tau \qquad (4.6)$$

Substitution of (4.4) into (4.6) and using (4.5) yields:

$$\mathbf{L}(s,x,t;h) = \{\ \ell(s,x+h,t+h) - \ell(s,x,t) - \iota\cdot\mathbf{O}(s,x,t;h)\ \}\cdot\mathbf{M}^{-1}(s,x,t) \qquad (4.7)$$

The number of endogenous events can now be computed from the vector of person years and the intensity matrices. For the numbers of *internal events*, *exits*, and *births* within the projection interval we have, respectively:

$$\mathbf{N}_i(s,x,t;h) = \mathrm{Diag}[\mathbf{L}(s,x,t;h)]\cdot\mathbf{M}_i(s,x,t) \qquad (4.8)$$

$$\mathbf{N}_e(s,x,t;h) = \mathrm{Diag}[\mathbf{L}(s,x,t;h)]\cdot\mathbf{M}_e(s,x,t) \qquad (4.9)$$

$$\mathbf{N}_b(s,x,t;h) = \mathrm{Diag}[\mathbf{L}(1,x,t;h)]\cdot\mathbf{M}_b(s,x,t) \qquad (4.10)$$

Note that the latter equation uses person years for females only (s=1).
For the highest, open-ended age group, the population at the end of the projection interval is obtained by combining the survivors of age groups (NAGE-1) and NAGE.

4.2.2. Formulas for the youngest age group

For age group x=1, the number of entries during the projection interval equals the sum of the total number of births and the number of immigrants born between the start of the projection interval and the moment of immigration. The total number of births, classified by position of the mother and position of the baby, can be obtained from (4.10):

$$\mathbf{B}(s,t;h) = \sum_{x=2}^{NAGE} \mathbf{N}_b(s,x,t;h) \qquad (4.11)$$

This leads to the following differential equation in matrix form:

$$\frac{d}{d\tau}\ \ell(s,1+\tau,t+\tau) = \ell(s,1+\tau,t+\tau)\cdot\mathbf{M}(s,1,t) + \\ + (1/h)\cdot\iota\cdot\mathbf{O}(s,1,t;h) + (1/h)\cdot\iota\cdot\mathbf{B}(s,t;h) \tag{4.12}$$

The general solution can be found in a way analogous to solving (4.1), the initial conditions now being that $\ell(s,1+\tau,t+\tau)$ for $\tau=0$ should equal zero. The solution is:

$$\ell(s,1+\tau,t+\tau) = \{\ (1/h)\cdot\iota\cdot\mathbf{O}(s,1,t;h) + (1/h)\cdot\iota\cdot\mathbf{B}(s,t;h)\ \}\ \cdot \\ \cdot\ \mathbf{M}^{-1}(s,1,t)\cdot\{\ e^{\mathbf{M}(s,1,t)\cdot\tau} - \mathbf{I}\ \} \tag{4.13}$$

so that

$$\ell(s,1+h,t+h) = \ell(s,2,t+h) = \{\ (1/h)\cdot\iota\cdot\mathbf{O}(s,1,t;h) + (1/h)\cdot\iota\cdot\mathbf{B}(s,t;h)\ \}\ \cdot \\ \cdot\ \mathbf{M}^{-1}(s,1,t)\cdot\{\ e^{\mathbf{M}(s,1,t)\cdot h} - \mathbf{I}\ \} \tag{4.14}$$

The vector of *person years* spent by all newly-born individuals in the various positions is defined by:

$$\mathbf{L}(s,1,t;h) = \int_0^h \ell(s,1+\tau,t+\tau)\ d\tau \tag{4.15}$$

Substitution of (4.13) into (4.15) and using (4.14) yields:

$$\mathbf{L}(s,1,t;h) = \{\ \ell(s,2,t+h) - \iota\cdot\mathbf{O}(s,1,t;h) - \iota\cdot\mathbf{B}(s,t;h)\ \}\cdot\mathbf{M}^{-1}(s,1,t) \tag{4.16}$$

The number of endogenous events can now be computed from the vector of person years and the intensity matrices, as above (cf. (4.8)-(4.9)).
To conclude, the computation scheme for the newly-born individuals is equivalent to that of the older age groups, provided that:

- the initial population $\ell(s,1,t)$ is set equal to zero;
- the number of births $\iota\cdot\mathbf{B}(s,t;h)$ (endogenous entries) is added to the number of immigrants $\iota\cdot\mathbf{O}(s,1,t;h)$ (exogenous entries).

4.2.3. Formulas for a singular intensity matrix

Until now, we have assumed that the intensity matrix M is non-singular, so that its inverse exists. This assumption cannot be maintained if there are so-called *absorbing states* or *absorbing subsets of states*. An absorbing state is a state from which no jumps are possible, i.e. the corresponding row of the M matrix is zero. One might be inclined to think that such a situation is impossible, since at least the event "death" could be experienced from any internal position. (Remember that the state of being "dead" is not considered as an internal state here, since exits due to mortality are explicitly permitted). However, if the data survey from which the intensities are derived does not contain observations on some positions for some age groups, then such zero rows occur for empirical reasons. Thus, empirically (though not theoretically), states may be absorbing for some age groups.

For this reason, LIPRO contains a procedure that performs the calculations for the projection in the special case of a singular intensity matrix. Gill (1986) offers a comprehensive computation scheme for an intensity matrix **M** of any rank. However, his formulas are only valid for *closed* Markov models, i.e. they cannot be applied to the general case which includes events of entry and exit. The LIPRO procedure generalizes Gill’s solution to include the case of uniformly distributed entries into the population.

Initially, the computer program proceeds under the assumption of a non-singular intensity matrix. The generalized Gill procedure is invoked only if the ordinary procedure breaks down as a result of the singularity of **M**. In that case, a message to this respect will be displayed on the screen.

In a nutshell, the Gill procedure consists of two major steps. First, the state space is compressed by collapsing all states that belong to some absorbing subset into one single state. When the vector of sojourn times for this absorbing macro-state has been computed, the sojourn times for the individual component states are calculated by working backwards. The details of the calculation scheme, as well as the formal proof of its validity, are given in Appendix 4A.

4.3 | Formulation of the linear model

In the linear model, the concept of an occurrence-exposure rate (o-e rate) plays a key role. The o-e rate for an immediate jump (event) from state i to state j is defined as the ratio of the number of jumps from i to j within a certain interval of time, and the corresponding sojourn time spent in state i during that interval. An o-e rate (notation $m_{ij}(s,x,t;h)$) is the discrete-time analogue of the continuous-time jump intensity $m_{ij}(s,x,t)$ used in the exponential model. Hence it will be obvious that o-e rates may be arranged in matrices with formats similar to their exponential counterparts. Within the context of the exponential model, the o-e rate $m_{ij}(s,x,\tau;h)$ is equal to the intensity $m_{ij}(s,x,\tau)$ for all τ between t and t+h.

We start with the relationship between events, sojourn times (for the moment still unknown) and occurrence-exposure rates. This relationship is given in equations (4.8)-(4.10).

Analogous to the o-e matrix **M**, we can define the matrix **N** of immediate jumps between positions:

$$\mathbf{N}(s,x,t;h) = \mathbf{N}_i(s,x,t;h) - \mathrm{Diag}\ [\ \mathbf{N}_i(s,x,t;h)\cdot\iota^T + \mathbf{N}_e(s,x,t;h)\cdot\iota^T\ ] \tag{4.17}$$

The diagonal of **N** contains the negative of the number of jumps out of the corresponding internal position. It follows that

$$\mathbf{N}(s,x,t;h) = \mathrm{Diag}[\mathbf{L}(s,x,t;h)]\cdot\mathbf{M}(s,x,t;h) \tag{4.18}$$

By definition we have, from the so-called *accounting equation*:

$$\ell(s,x+h,t+h) = \ell(s,x,t) + \iota\cdot\mathbf{O}(s,x,t;h) + \iota\cdot\mathbf{N}(s,x,t;h) \tag{4.19}$$

For the youngest age group, the initial population $\ell(s,x,t)$ is zero and the vector of immigrants $\iota\cdot\mathbf{O}(s,x,t;h)$ includes the number of births.

By assumption, events and entries are uniformly distributed over the projection interval. Then the vector of *person years* equals:

$$\mathbf{L}(s,x,t;h) = \tfrac{1}{2}h\cdot\{\ \ell(s,x,t) + \ell(s,x+h,t+h)\ \} \tag{4.20}$$

Substitution of (4.19) and (4.18) into (4.20) yields:

$$\mathbf{L}(s,x,t;h) = h\cdot\ell(s,x,t) + \tfrac{1}{2}h\cdot\iota\cdot\mathbf{O}(s,x,t;h) + \tfrac{1}{2}h\cdot\mathbf{L}(s,x,t;h)\cdot\mathbf{M}(s,x,t;h) \tag{4.21}$$

From (4.21) it follows that:

$$\mathbf{L}(s,x,t;h) = \{\ h\cdot\ell(s,x,t) + \tfrac{1}{2}h\cdot\iota\cdot\mathbf{O}(s,x,t;h)\ \}\ \cdot\{\ \mathbf{I} - \tfrac{1}{2}h\cdot\mathbf{M}(s,x,t;h)\ \}^{-1} \tag{4.22}$$

Combining (4.19), (4.18) and (4.22) yields $\ell(s,x+h,t+h)$. It is easily seen that this computation scheme is equivalent to solving (4.18)-(4.20) directly for $\ell(s,x+h,t+h)$, leading to the well-known formula:

$$\begin{aligned}\ell(s,x+h,t+h) = {} & \ell(s,x,t)\cdot\{\ \mathbf{I} + \tfrac{1}{2}h\cdot\mathbf{M}(s,x,t;h)\ \}\cdot\{\ \mathbf{I} - \tfrac{1}{2}h\cdot\mathbf{M}(s,x,t;h)\ \}^{-1} + \\ & + \iota\cdot\mathbf{O}(s,x,t;h)\cdot\{\ \mathbf{I} - \tfrac{1}{2}h\cdot\mathbf{M}(s,x,t;h)\ \}^{-1}\end{aligned} \tag{4.23}$$

These expressions hold for both absorbing and non-absorbing states.

4.4 | Computing rates from events

Sections 4.2 and 4.3 dealt with the computation of events and person years, given the initial population and the intensities or the o-e rates.
There are two stages at which the reverse computation has to be made, i.e. determining the rates and the person years, given observations on events and initial population. These stages are:

a. estimation of rates from empirical observations on events;
b. computation of adjusted rates, given adjusted events. This stage occurs if LIPRO's consistency algorithm (see chapter 5) is invoked and adjusted rates are desired.

In the case of the linear model, the reverse calculation can be made in one step. Using (4.17), (4.19), and (4.20), the vector of person years **L**(s,x,t;h) can be easily calculated from events and initial population. The matrices of rates then follow immediately from equations (4.8) to (4.10).
In the case of the exponential model, an iterative computation scheme has to be adopted. This scheme is due to Gill and Keilman (1990). The steps in this computation scheme are the following:

1. take an initial guess for the person years **L**.
   In LIPRO, the initial guess usually is the solution corresponding to the linear model, calculated from (4.17) to (4.20). However, in stage b above (calculation of adjusted rates from adjusted events), the user may specify that the initial guess should be taken from the vector of person years corresponding to the exponential model given the unadjusted rates. Experience has shown that the "linear model initial guess" is generally faster, except in cases where the differences between unadjusted and adjusted events are very small.
2. calculate the rates **M** from the events **N** and the current guess for the person years **L**, by solving (4.8) to (4.10).
3. calculate an updated guess for **L** by applying the exponential model to the rates obtained in step 2.
4. calculate the norm of the change in vector **L**.
5. repeat steps 2-4 until convergence of the vector **L**.
   In LIPRO, iterations stop when either the Euclidian norm calculated under step 4 becomes less than a user-supplied convergence criterion, *or* steps 2-4 have been repeated a certain maximum number of times. In the latter case, LIPRO will print a message if no convergence was achieved.

4.5 | On the computation of exp[X] and inv[X]

The exponent exp[**X**] of a square matrix **X** is computed by Taylor series expansion:

$$\exp[\mathbf{X}] = \mathbf{I} + \mathbf{X} + (1/2!)\cdot\mathbf{X}^2 + (1/3!)\cdot\mathbf{X}^3 + \cdots$$

This infinite power series is truncated after a finite number of steps. More specifically, the iterations halt if after n steps the norm of the last term in the power series is less than a convergence criterion CRIT supplied by the user, i.e.

$$\text{Norm } [\ (1/n)!\cdot X^n\ ] < \text{CRIT}$$

The computation of the inverse matrix inv[**X**] or $\mathbf{X}^{-1}$ of a square matrix **X** is a special case of the more general problem of solving a system of linear equations:

$$\mathbf{a}\cdot\mathbf{X} = \mathbf{b}$$

with matrix **X** and vector **b** known, and vector **a** unknown. LIPRO contains a subroutine that solves this linear system by eliminating subsequent rows of the matrix **X** (Gaussian elimination). Before actually eliminating a row, the subroutine checks whether the pivotal element can be increased in absolute value by interchange of columns (permutation of the matrix **X**, in order to minimize rounding errors). If the pivotal element is equal to zero, then the matrix **X** is singular and its inverse is undefined. Because of rounding errors, the pivotal element will hardly ever be exactly zero. Therefore, a parameter SMALL is passed to the subroutine. The matrix **X** is considered singular whenever a pivotal element is less than SMALL in absolute value during the elimination process.

APPENDIX: Calculating sojourn times for a Markov process with uniform entries and intensity matrix of any rank

This Appendix gives the details of the generalized Gill procedure, referred to in section 4.2.3, for calculating sojourn times in the exponential model when the intensity matrix M is singular.

Consider a constant intensity Markov process for an open population. Given are data on the following variables:

$\ell(0)$	a (1 by n) vector with the initial population, classified by initial state, where n is the number of states;
M	an (n by n) matrix with intensities;
b	a (1 by n) vector with the number of immigrants per unit of time, classified by the state into which they immigrate. Immigrations (or births) are assumed to be uniformly distributed over time;
h	the length of the projection interval.

The population develops over time according to:

$$\frac{d}{d\tau}\ \ell(\tau) = \ell(\tau)\cdot\mathbf{M} + \mathbf{b} \qquad (4A.1)$$

It is assumed that the set of all n states is absorbing. In other words, individuals do not leave the population. This assumption sounds more restrictive then it really is. For instance, for events like "death" or "emigration", one can (temporarily) define internal states as "dead" or "emigrated" and rearrange the intensity matrix **M** in such a way that the absorption property is achieved. Then, since the population is closed to exits, the intensity matrix **M** satisfies:

$$\mathbf{M}\cdot\iota^T = 0 \qquad (4A.2)$$

where ι is a row vector consisting of ones only, and T denotes transposition. (4A.1) and (4A.2) together define a Markov process with constant intensity matrix and uniformly distributed entries, i.e. the exponential model of section 4.2. The cumbersome expression "constant intensity Markov process with uniformly distributed entries" will be abbreviated to "CIMUE process" throughout this appendix.
From (4A.1) and (4A.2) it follows that the total population (aggregated over all states), denoted by N, is given by:

$$N(\tau) = N(0) + \tau\cdot\mathbf{b}\cdot\iota^T \qquad (4A.3)$$

Integration of (4A.1) yields:

$$\ell(\tau) = \ell(0)\cdot\exp[\mathbf{M}\tau] + \mathbf{b}\cdot\{\ \mathbf{I}\tau + (\mathbf{M}\tau^2/2!) + (\mathbf{M}^2\tau^3/3!) + \cdots\ \} \qquad (4A.4)$$

where the exponent of a square matrix is defined in terms of its Taylor power series; the fact that (4A.4) indeed solves (4A.1) can be checked by simple differentiation. In particular:

$$\ell(h) = \ell(0)\cdot\exp[\mathbf{M}h] + \mathbf{b}\cdot\{\ \mathbf{I}h + (\mathbf{M}h^2/2!) + (\mathbf{M}^2h^3/3!) + \cdots\ \} \qquad (4A.5)$$

The vector of sojourn times until time t is defined as:

$$\mathbf{L}(t) = \int_0^t \ell(\tau)\, d\tau \qquad (4A.6)$$

From (4A.4) to (4A.6) we obtain:

$$\mathbf{L}(h)\cdot\mathbf{M} = \ell(0)\cdot\exp[\mathbf{M}h] - \ell(0) + \mathbf{b}\cdot\{\ (\mathbf{M}h^2/2!) + (\mathbf{M}^2h^3/3!) + \cdots\ \} =$$

$$= \ell(h) - \ell(0) - \mathbf{b}h \qquad (4A.7)$$

And from (4A.6) and (4A.3):

$$\mathbf{L}(h)\cdot\iota^T = \int_0^h \ell(\tau)\cdot\iota^T\, d\tau = \int_0^h N(\tau)\, d\tau = N(0)\cdot h + ½\cdot h^2\cdot\mathbf{b}\cdot\iota^T \qquad (4A.8)$$

The problem is how to calculate the vector of sojourn times **L**(h). If the rank of **M** is equal to (n-1), then (4A.7) and (4A.8) together constitute a system of (n+1) linear equations of rank n in n unknowns, which can be solved. However, **M** may well have rank less than (n-1). In fact, the difference between Dim[**M**] (=n) and Rank[**M**] is equal to the number of disjoint absorbing subsets of states which may range from 1 (only the full set of states $1\cdots n$ is absorbing) to n (each state is absorbing). Thus, in the general case we have

$$0 \le \text{Rank}[\mathbf{M}] \le n-1 \tag{4A.9}$$

The problem of calculating **L**(h) for the general case of **M** having any rank is solved in Appendix 3 to the Gill (1986) paper. This appendix generalizes Gill's solution to include the case of uniformly distributed entries into the population (the special case of a population that is closed with respect to both exits and entries is obtained by putting **b**=0 in (4A.1)). The method outlined below is more general than the solution discussed by Van Imhoff (1990a) which requires that each absorbing subset of states consists of one state only.

The algorithm proposed here uses two theorems which will be presented first. Subsequently, the appendix explains the various steps in the calculation as they are carried out by the LIPRO computer program.

Theorem 1

Consider the CIMUE process defined by (4A.1) and (4A.2). Assume, without loss of generality, that the n states have been ordered in such a way that the first r states constitute an absorbing subset of states, $1 \le r \le n$. An (n by r) transformation matrix $\mathbf{P}^*$ exists that collapses the first r states into one absorbing state. Let

$$\ell^*(0) = \ell(0)\cdot\mathbf{P}^* \tag{4A.10}$$

$$\ell^*(\tau) = \ell(\tau)\cdot\mathbf{P}^* \tag{4A.11}$$

$$\mathbf{b}^* = \mathbf{b}\cdot\mathbf{P}^* \tag{4A.12}$$

$$\mathbf{M}^* = (\mathbf{P}^*)^T\cdot\mathbf{M}\cdot\mathbf{P}^* \tag{4A.13}$$

Then the process

$$\frac{d}{d\tau}\,\ell^*(\tau) = \ell^*(\tau)\cdot\mathbf{M}^* + \mathbf{b}^* \tag{4A.14}$$

is also a CIMUE process.

Proof of theorem 1
If the first r states of the original process constitute an absorbing subset, then the matrix **M** can be written as:

$$\mathbf{M} = \begin{bmatrix} \mathbf{M}_{11} & \mathbf{0} \\ \mathbf{M}_{21} & \mathbf{M}_{22} \end{bmatrix} \qquad (4A.15)$$

The matrix $\mathbf{P}^*$ has the following form:

$$\mathbf{P}^* = \begin{bmatrix} \iota^T & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{bmatrix} \qquad (4A.16)$$

The matrix $\mathbf{M}^*$ then equals:

$$\mathbf{M}^* = \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{M}_{21} \cdot \iota^T & \mathbf{M}_{22} \end{bmatrix} \qquad (4A.17)$$

Now from (4A.11) and (4A.1):

$$\frac{d}{d\tau}\, \ell^*(\tau) = \frac{d}{d\tau}\, \ell(\tau) \cdot \mathbf{P}^* = \ell(\tau) \cdot \mathbf{M} \cdot \mathbf{P}^* + \mathbf{b} \cdot \mathbf{P}^* =$$

$$= \ell(\tau) \cdot \mathbf{P}^* \cdot (\mathbf{P}^*)^T \cdot \mathbf{M} \cdot \mathbf{P}^* + \mathbf{b}^* = \ell^*(\tau) \cdot \mathbf{M}^* + \mathbf{b}^*$$

which establishes (4A.14). □

Theorem 2 (generalization of Gill, 1986)
For any CIMUE process, let $\mathbf{L}(\tau)$ denote the vector of sojourn times until time τ. Let $\mathbf{Z}(t)$ be defined by:

$$\mathbf{Z}(t) = \int_0^t \mathbf{L}(\tau)\, d\tau \qquad (4A.18)$$

Then:

$$\mathbf{Z}(t) \cdot \mathbf{M} = \mathbf{L}(t) - t \cdot \ell(0) - \tfrac{1}{2} \cdot t^2 \cdot \mathbf{b} \qquad (4A.19)$$

$$\mathbf{Z}(t) \cdot \iota^T = \tfrac{1}{2} \cdot t^2 \cdot N(0) + (1/3) \cdot t^3 \cdot \mathbf{b} \cdot \iota^T \qquad (4A.20)$$

Proof of theorem 2
(4A.19) follows from (4A.18), (4A.6) and (4A.7). (4A.20) follows from (4A.18) and (4A.8). $\square$

With these two theorems proven, an outline of the calculations can be provided.

Step 1
Determine the (n by n) access matrix **A** defined by:

A_{ij} with $i \neq j$ = 1 $\Leftrightarrow$ state i has access to state j
0 otherwise
A_{ii} = 1 $\Leftrightarrow$ state i has access to any other state
0 otherwise (i.e. state i is absorbing)

State i is said to have access to state j if either $\mathbf{M}_{ij}>0$ (direct access) or state i has access to some third state k which has access to state j (indirect access). This suggests the following iterative procedure for the construction of the access matrix **A**:

1. set $\mathbf{A}=0$.
2. for all $i,j=1\cdots n$, set $A_{ij}=1$ whenever $M_{ij}\neq 0$ (direct access).
3. set IFLAG=0.
4. for each $i=1\cdots n$, consider all rows $j\neq i$ for which $A_{ij}=1$. For all $k=1\cdots n$, if $A_{jk}=1$ and $A_{ik}=0$, then set $A_{ik}=1$ and IFLAG=1 (new indirect access found).
5. if IFLAG=1, return to step 3.

Step 2
Determine the number of disjoint absorbing subsets of states, as well as the elements of these subsets and the states not belonging to any subset. For each state $i=1\cdots n$, there exist three possibilities:

1. $A_{ii}=0$. Then state i is absorbing and belongs to an absorbing subset containing state i only.
2. $A_{ii}=1$ and for all states $j\neq i$ to which state i has access ($A_{ij}=1$), the rows $A_{j\cdot}$ are the same as $A_{i\cdot}$. In other words: all states to which i has access also have access to state i ($A_{ji}=1$) and, in addition, do not have access to any state to which state i does not have access (there is no k for which $A_{jk}=1$ and $A_{ik}=0$). Then state i and all the states to which i has access together constitute a communicating absorbing subset of states.
3. Otherwise state i does not belong to an absorbing subset of states.

Let r be the resulting number of disjoint absorbing subsets and s the number of states not belonging to any absorbing subset. Construct the allocation vector B defined by:

$B_i =$ k, $k \le r$ $\Leftrightarrow$ state i belongs to subset k
k, $k > r$ $\Leftrightarrow$ state i is the (k-r)-th state not belonging to any subset ($r < k \le r+s$)

Step 3
Construct the n by (r+s) transformation matrix $\mathbf{P}^*$ defined by:

$P^*_{ij} =$ 1 $\Leftrightarrow$ $B_i = j$
0 otherwise

The matrix $\mathbf{P}^*$ transforms the original n-state CIMUE process (to be referred to as the O-process) into an (r+s)-state CIMUE process (to be referred to as the *-process) by collapsing each of the disjoint absorbing subsets of states into a single absorbing state. In addition, the states are reordered in such a way that the absorbing states come first.
By virtue of theorem 1, the *-process is a CIMUE process. Therefore, all expressions derived for the O-process also hold true for the *-process, after transformation of the process variables by means of the matrix $\mathbf{P}^*$.

Step 4
Construct the (r+s) by (1+s) transformation matrix $\mathbf{P}^{**}$ defined by:

$P^{**}_{ij} =$ 1 $\Leftrightarrow$ $(j=1 \wedge i \le r) \vee (j>1 \wedge i-r=j-1)$
0 otherwise

The matrix $\mathbf{P}^{**}$ transforms the (r+s)-state *-process into a (1+s)-state **-process by collapsing the r absorbing states of the *-process into a single absorbing state.

Step 5
Calculate the final population for the O-process according to (4A.5):

$$\ell(h) = \ell(0)\cdot\exp[\mathbf{M}h] + \mathbf{b}\cdot\{\, \mathbf{I}h + (\mathbf{M}h^2/2!) + (\mathbf{M}^2h^3/3!) + \cdots \}$$

Construct the initial population, final population, vector of immigration density, and intensity matrix for the *-process and the **-process:

$$\begin{aligned}
\ell^*(0) &= \ell(0)\cdot\mathbf{P}^* \\
\ell^*(h) &= \ell(h)\cdot\mathbf{P}^* \\
\mathbf{b}^* &= \mathbf{b}\cdot\mathbf{P}^* \\
\mathbf{M}^* &= (\mathbf{P}^*)^T\cdot\mathbf{M}\cdot\mathbf{P}^*
\end{aligned}$$

$$\begin{aligned}
\ell^{**}(0) &= \ell^*(0)\cdot\mathbf{P}^{**} \\
\ell^{**}(h) &= \ell^*(h)\cdot\mathbf{P}^{**} \\
\mathbf{b}^{**} &= \mathbf{b}^*\cdot\mathbf{P}^{**} \\
\mathbf{M}^{**} &= (\mathbf{P}^{**})^T\cdot\mathbf{M}^*\cdot\mathbf{P}^{**}
\end{aligned}$$

Step 6
Solve $\mathbf{L}^{**}(h)$ from the following system of equations:

$$\mathbf{L}^{**}(h)\cdot\mathbf{M}^{**} = \ell^{**}(h) - \ell^{**}(0) - h\cdot\mathbf{b}^{**}$$

$$\mathbf{L}^{**}(h)\cdot\iota^T = N(0)\cdot h + \tfrac{1}{2}\cdot h^2\cdot\mathbf{b}\cdot\iota^T$$

This is a system of (2+s) equations in (1+s) unknowns. The system is solvable because, by construction, $\mathbf{M}^{**}$ is a Markov matrix with Rank[$\mathbf{M}^{**}$] = Dim[$\mathbf{M}^{**}$] - 1 = s, or, equivalently, because the **-process contains one and only one absorbing subset of states, i.e. state 1. Compare the theorem in Appendix 1 to Gill (1986).

Step 7
Applying theorem 2 to the **-process, we have the following system of equations:

$$\mathbf{Z}^{**}(h)\cdot\mathbf{M}^{**} = \mathbf{L}^{**}(h) - h\cdot\ell^{**}(0) - \tfrac{1}{2}\cdot h^2\cdot\mathbf{b}^{**}$$

$$\mathbf{Z}^{**}(h)\cdot\iota^T = \tfrac{1}{2}\cdot h^2\cdot N(0) + (1/3)\cdot h^3\cdot\mathbf{b}\cdot\iota^T$$

Again, with $\mathbf{L}^{**}(h)$ known from step 6, this system of rank (1+s) can be solved for the (1+s) elements of $\mathbf{Z}^{**}(h)$.

Step 8
Applying the first part of theorem 2 to the *-process, we have the following system of (r+s) equations:

$$\mathbf{L}^*(h) = h\cdot\ell^*(0) + \tfrac{1}{2}\cdot h^2\cdot\mathbf{b}^* + \mathbf{Z}^*(h)\cdot\mathbf{M}^*$$

The vector $\mathbf{Z}^*(h)$ is unknown. However, by construction, its last s elements are equal to the last s elements of $\mathbf{Z}^{**}(h)$ which are known from step 7. Furthermore, the first r rows of $\mathbf{M}^*$ are equal to zero so that we can write:

$$\mathbf{Z}^*(h)\cdot\mathbf{M}^* = [\ \mathbf{0} \quad \mathbf{Z}^{**}(h)\ ]\cdot\mathbf{M}^*$$

where the row vector **0** has length r-1.
Now the system becomes

$$\mathbf{L}^*(h) = h\cdot\ell^*(0) + \tfrac{1}{2}\cdot h^2\cdot\mathbf{b}^* + [\ \mathbf{0} \quad \mathbf{Z}^{**}(h)\ ]\cdot\mathbf{M}^*$$

which can be solved for $\mathbf{L}^*(h)$ in a straightforward way.

Step 9
From the transformation

$$\mathbf{L}^*(h) = \mathbf{L}(h)\cdot\mathbf{P}^*$$

it can be deduced:

- for each absorbing subset i, $i=1\cdots r$: the total sojourn time spent in the states belonging to this subset, which equals $L_i^*(h)$.
- for each state j not belonging to an absorbing subset ($B_j=r+i$, with $i=1\cdots s$): the sojourn time spent in this state, $L_j(h)$, which equals $L_{r+i}^*(h)$.

At the present stage, the s elements of the vector **L**(h) corresponding to states not belonging to an absorbing subset are known. These elements are stored into the (1 by s) vector $\mathbf{L}^0(h)$.
For each of the absorbing subsets i, $i=1\cdots r$, we can now proceed as follows:

1. denote the vector of unknown sojourn times for the n^i states belonging to subset i by the (1 by n^i) vector $\mathbf{L}^i(h)$. Construct the corresponding vectors of initial population $\ell^i(0)$, final population $\ell^i(h)$, and immigration density $\mathbf{b}^i$.
2. construct the (n^i by n^i) matrix that is obtained by deleting all rows and colums from matrix **M** that do *not* correspond to states in subset i. Denote this matrix by $\mathbf{M}^{ii}$.
3. construct the (s by n^i) matrix that is obtained by deleting all columns of matrix **M** that do *not* correspond to states in subset i, and by deleting all rows that do *not* correspond to any of the the s states not belonging to any absorbing subset. Denote this matrix by $\mathbf{M}^{0i}$.
4. from the definition of absorbing subset i, the equations in (4A.7) that correspond to the states belonging to subset i can be written as:

$$\mathbf{L}^i(h)\cdot\mathbf{M}^{ii} + \mathbf{L}^0(h)\cdot\mathbf{M}^{0i} = \ell^i(h) - \ell^i(0) - h\cdot\mathbf{b}^i \qquad (4A.21)$$

(4A.21) is a system of n^i equations of rank $(n^i\text{-}1)$ in the n^i unknown elements of $\mathbf{L}^i(h)$. An additional independent equation can be obtained from the transformation equation referred to above:

$$\mathbf{L}^i(h)\cdot\iota^T = L_i^*(h) \tag{4A.22}$$

From (4A.21) and (4A.22), $\mathbf{L}^i(h)$ can be solved.

Going through steps 1-4 for each of the absorbing subsets completes the computation of $\mathbf{L}(h)$.

5. THE CONSISTENCY ALGORITHM

The central endogenous variables in dynamic demographic projection models are the numbers of events: immediate jumps from one cell in the state vector to another. Except for trivial breakdowns of individuals (e.g. by age and sex only), these demographic models give rise to problems of *consistency*. Consistency can be defined as a situation in which the endogenous variables satisfy certain *constraints* (Keilman, 1985a).

Such constraints may arise from various sources. Some constraints stem from the *nature of the cross-classification* chosen. For instance, if individuals are classified by sex and marital status, then a natural constraint on the number of events would be that the total number of males experiencing a jump into the married state should equal the number of females experiencing such a jump; this is the well-known two-sex problem in nuptiality models (Keilman, 1985b). Other constraints may occur because of *interrelationships between different models*. For instance, numbers of events computed from regional models may be required to add up to the corresponding numbers in the national population forecast. Keilman (1985a) terms these two types of consistency as *internal* and *external* consistency, respectively.

The existence of constraints on the endogenous variables gives rise to a *consistency problem* as soon as the variables fail to meet the constraints. In the approach followed here, solving the consistency problem amounts to adjusting the initially calculated numbers of events in such a way that the constraints are satisfied. The procedure by which these adjustments are realized will be termed a *consistency algorithm*.

Generally speaking, inconsistencies between numbers of events can be said to be caused by inadequate modelling. For example, the two-sex problem typically arises because of the use of sex-specific nuptiality rates, disregarding the interaction between the sexes in the marriage market (Pollard, 1977). This is not to say that there are no good reasons for such inadequate modelling. Our knowledge of the determinants of the outcome of the bargaining process in the marriage market is so limited that using sex-specific rates is probably the best we can do.

Even more complex interactions between individuals occur in household projection models. Here, household formation, household dissolution, and household change are the result of interactions between two or more individuals. There are good reasons why household projection models should take the individual as the unit of analysis, instead of the household itself (McMillan and Herriot, 1985; Keilman and Keyfitz, 1988). But the other side of the coin is that, precisely because of the "wrong" unit of analysis, the consistency problem appears in full force. This is not to say that modelling households instead of individuals would altogether remove problems of consistency, but they would certainly be smaller. This chapter presents a very general characterization of the consistency problem, as well as a slightly less general algorithm to solve it. We will restrict ourselves to the main features of the consistency algorithm; proofs and additional technical details will be given elsewhere (Van Imhoff, 1992).

Section 5.1 spells out the notation used throughout this chapter. Section 5.2 gives the general formulation of the consistency problem. Section 5.3 investigates the properties of the solution to the consistency problem for the special (and analytically convenient) case of linear first-order conditions. Section 5.4 discusses the relationship between adjusted numbers of events and the underlying model parameters (jump intensities or occurrence-exposure rates).

5.1 | Notation

The following notation will be used throughout this chapter:

$\mathbf{I}$	the identity matrix, with ones on the diagonal and all off-diagonal elements equal to zero;
ι	a *row* vector consisting of ones only;
^{T}	operator for transposition of a vector or matrix;
$\dot{\mathbf{x}}$	operator for the formation of a diagonal matrix with the elements of vector $\mathbf{x}$ on the diagonal;
$f_{\mathbf{x}}$	if $f(\mathbf{x})$ is a scalar function of vector $\mathbf{x}$, then $f_{\mathbf{x}}$ denotes the row vector of partial derivatives $[f_1 \cdots f_n]$;
$\mathbf{N}$	a (1 by K) *row* vector with projected numbers of events;
$\mathbf{n}$	a (1 by K) *row* vector with adjusted numbers of events.

The vector $\mathbf{n}$ should satisfy the consistency conditions (constraints):

$$\mathbf{n} \cdot \mathbf{A} = \mathbf{c}$$

with $\mathbf{c}$ a non-negative (1 by C) vector and $\mathbf{A}$ a (K by C) matrix with full rank. Of course, $C \leq K$. The full-rank condition boils down to requiring that no superfluous consistency conditions (i.e. dependent on other consistency conditions) are included in the matrix $\mathbf{A}$.

5.2 | Formulation of the consistency problem

A consistency algorithm finds a vector of adjusted numbers of events **n** satisfying the consistency conditions and being "optimal" according to some criterion yet to be specified. The projection model computes these numbers of events given values for the model parameters Θ. Consequently the vector **N** can be written as a function of these model parameters: $\mathbf{N} = G(\Theta)$. Similarly, the vector of adjusted numbers of events **n** is a function of the adjusted model parameters θ: $\mathbf{n} = G(\theta)$. Generally speaking, the *optimality criterion* corresponds to some measure of *closeness* of θ with respect to the original vector Θ.

Thus a consistency algorithm solves the following optimization problem:

$$\text{find } \theta \text{ to} \quad \text{minimize } F(\Theta,\theta) \quad \text{subject to} \quad \mathbf{n}(\theta)\cdot\mathbf{A} = \mathbf{c} \tag{5.1}$$

The Lagrangean for this constrained optimization problem is given by:

$$L(\theta,\lambda) = F(\Theta,\theta) + \{\mathbf{n}(\theta)\cdot\mathbf{A}\text{-}\mathbf{c}\}\cdot\lambda^{T} \tag{5.2}$$

where λ is a (1 by C) vector of Lagrange multipliers.
First order conditions are:

$$F_{\theta}(\Theta,\theta) + \lambda\cdot\mathbf{A}^{T}\cdot\mathbf{n}_{\theta} = \mathbf{0} \tag{5.3}$$

$$\mathbf{n}(\theta)\cdot\mathbf{A} - \mathbf{c} = \mathbf{0} \tag{5.4}$$

The solution vectors θ and λ can be deduced from (5.3) and (5.4). In general, the system of equations (5.3)-(5.4) is nonlinear, so that an iterative procedure is required.

5.3 | Solution to the consistency problem for a specific class of objective functions

5.3.1. A specific class of objective functions

Let us specify the objective function $F(\cdot)$ as follows:

$$F(\mathbf{N},\mathbf{n};p) = \text{Norm}^{2}\,[\,(\mathbf{n}\text{-}\mathbf{N})\cdot\dot{\mathbf{N}}^{-p}\,] = (\mathbf{n}\text{-}\mathbf{N})\cdot\dot{\mathbf{N}}^{-2p}\cdot(\mathbf{n}\text{-}\mathbf{N})^{T} \tag{5.5}$$

For this particular specification, the optimization problem becomes linear in the unknown parameters. This attractive property is achieved by combining two things: the choice of the adjusted events vector **n** as control variable; and the quadratic specification of $F(\cdot)$.

Of course, the solution vector **n** remains a function of the adjusted model parameters θ. If these model parameters are intensities or o-e rates, then this function gives an invertible correspondence between θ and **n**, so that one could also write: $\theta = G^{-1}(\mathbf{n})$. Thus once the adjusted numbers of events have been found, the underlying adjusted model parameters follow immediately. We will return to this issue in section 5.4.

It can be shown (Van Imhoff, 1992) that the solution to the problem of minimizing F(·) in (5.5) subject to (5.4) is given by:

$$\mathbf{n} = \mathbf{N}\cdot\{\ \mathbf{I} - \mathbf{A}\cdot(\mathbf{A}^{T}\dot{\mathbf{N}}^{2p}\mathbf{A})^{-1}\cdot\mathbf{A}^{T}\dot{\mathbf{N}}^{2p}\ \} + \mathbf{c}\cdot(\mathbf{A}^{T}\dot{\mathbf{N}}^{2p}\mathbf{A})^{-1}\cdot\mathbf{A}^{T}\dot{\mathbf{N}}^{2p} \qquad (5.6)$$

The first term on the right-hand side of (5.6) can be interpreted as an averaging term, reshuffling numbers of events in order to meet conditions of internal consistency. The second term involves a complete shift of the events vector, reflecting the pressure imposed by the conditions of external consistency.

Since we have assumed **A** to have full rank, the matrix $\mathbf{A}^{T}\dot{\mathbf{N}}^{2p}\mathbf{A}$ in (5.6) is invertible whenever either **N** does not contain too many zeros or p=0. For p≠0 this can be achieved by leaving any zero element of **N** out of the optimization, putting the corresponding element of **n** equal to zero as well.

5.3.2. Interpretation of the parameter p

Minimization of the objective function (5.5) is equivalent to weighted least squares optimization, where each element of the adjustment vector (**n**-**N**) is weighted by some inverse power of the corresponding element of the vector **N** of numbers of events from which the adjustment starts. For example, if p=0, F(·) reduces to the square of the Euclidian distance between the vectors of projected and of adjusted numbers of events, respectively.

Now minimizing (the square of) Euclidian distances is, at least in special cases, equivalent to taking arithmetic averages. That is, for p=0 one would expect our consistency algorithm to yield adjusted numbers of events that in some way correspond to arithmetic averages of the originally projected numbers of events. More generally, it can be shown that our class of objective functions (5.5) corresponds to a certain class of averages of the elements of the vector **N**, characterized by the parameter p. This correspondence can be illustrated by considering the case in which the matrix **A** is such that all elements of **n** are restricted to be equal, i.e. **n**=mι where m is some average of the elements of **N** and ι denotes a vector with all elements equal to one.

If we substitute mι for **n** and minimize F(**N**,**n**) as a function of the single variable m, we obtain the following general expression:

$$m = \sum_{i=1}^{K} N_i^{1-2p} \Big/ \sum_{i=1}^{K} N_i^{-2p} \qquad (5.7)$$

For p=0, (5.7) reduces to $m = \sum N_i / K$, which is the *arithmetic mean* of the elements of the vector **N**. For p=1, we obtain $m = \sum N_i^{-1} / \sum N_i^{-2}$, which corresponds to the minimization of the *relative* distance between **N** and mι, rather than the *absolute* distance under p=0. Finally, for p=½ we have $m = K / \sum N_i^{-1}$, which is the *harmonic mean*. The latter expression corresponds to the harmonic mean solution to the two-sex problem in nuptiality models (Keilman, 1985b).

5.3.3. Comparison with the unidimensional harmonic mean method

If the consistency matrix **A** is blockwise diagonal, then the consistency problem can be split up in independent subproblems. This is the case, for instance, if each n_i enters at most one consistency relation. Then for each of the constraints, the adjusted (consistent) number of events can be found independently of the other constraints.

However, the more detailed the classification of events, the larger the number of consistency relations, and also the higher the probability that numbers of events are restricted in multiple ways. For these multidimensional consistency problems a matrix formulation becomes unavoidable. In fact, the procedure adopted by Van Dam and Keilman (1987) in order to circumvent the problem of cells entering several consistency relations boils down to artificially putting some elements of **A** equal to zero, thus dividing the consistency problem into several independent unidimensional sub-problems. One of the innovations made possible by the present matrix formulation is that such rather arbitrary assumptions are no longer required.

5.3.4. Relationship between age-specific and aggregate adjustment factors

In multidimensional demography, it will generally be the case that the consistency conditions read in terms of events aggregated over all age groups only. This is so because these models typically trace the age of the individual only, not the ages of other persons with whom the individual under consideration interacts.

Now the question arises whether there exists a simple relationship between the adjustments of the age-specific numbers of events, on the one hand, and the adjustments of the aggregated numbers of events, on the other hand. If such a simple relationship is found, then the consistency problem could be greatly simplified by dropping the age dimension from the variables involved in the optimization problem.

It can be shown (Van Imhoff, 1992) that, for objective functions of type (5.5), the age-specific adjustments in numbers of events can be written in terms of the adjustments in aggregate numbers of events if and only if either p=0 or p=½. In other words, our simple relationship exists only for the (generalized) *arithmetic mean* and for the (generalized) *harmonic mean* specification of the consistency problem. This result gives strong reasons in favour of one of these specifications, as the solution to the consistency problem can be greatly simplified by taking the short-cut via consistent *aggregate* numbers of events. Indeed, the implementation of the consistency algorithm in LIPRO is such that only aggregate consistency relations can be imposed.

For the arithmetic (p=0) mean we have:

$$\mathbf{n}_x = \mathbf{N}_x + (\mathbf{n}_\Sigma - \mathbf{N}_\Sigma)/\mathrm{NAGE} \tag{5.8}$$

where the subscript x refers to events for age group x and the subscript Σ to events aggregated over all age groups. Thus, for the arithmetic mean, the age-specific adjustments are *equal in absolute terms*.
For the harmonic mean (p=½), we have:

$$\mathbf{n}_x = \{ \iota + (\mathbf{n}_\Sigma - \mathbf{N}_\Sigma) \cdot \dot{\mathbf{N}}_\Sigma^{-1} \} \cdot \dot{\mathbf{N}}_x \tag{5.9}$$

Thus, for the harmonic mean, the age-specific adjustments are *equal in relative terms*. This result justifies the proportional adjustment method of Van Dam and Keilman (1987).

5.4 | From adjusted events to adjusted rates

A multidimensional projection model specifies jump intensities (or occurrence-exposure rates for models based on the linear integration hypothesis) for all possible transitions. Once adjusted numbers of events have been found by the consistency algorithm, the corresponding adjusted rates can be computed. Adjustments in the numbers of events affect the numbers of person-years lived within each cell of the state vector. Therefore, *all* rates change, even although the numbers of only *some* of the events are adjusted.
This is of course theoretically unsatisfactory. The rates are to some extent *behavioural* parameters, reflecting an individual's tendency to experience a certain event (cf. Schoen, 1981). If consistency is required for aggregate behaviour, then one would like to adjust only those behavioural parameters which are directly related to the initial inconsistencies, leaving the other rates exactly as they were. On the other hand, if only some of the rates are adjusted, then the correspondence between adjusted numbers of events and adjusted rates is lost.
The previous discussion suggests an iterative approach which is capable of leaving the rates intact which are not directly related to the consistency relations, without losing the correspondence between rates and numbers of events. This iterative scheme is optional in the LIPRO program. The procedure consists of the following steps:

1. compute rates corresponding to adjusted numbers of events;

2. replace the unrelated rates by their initial values;
3. compute numbers of events for rates obtained under step 2;
4. replace the constrained numbers of events by their adjusted values as calculated by the constrained optimization procedure;
5. repeat steps 1-4 until convergence has been reached.
   In LIPRO, iterations stop when either the Euclidian norm of the change in the vector of person years becomes less than a user-supplied convergence criterion, *or* steps 1-4 have been repeated a certain maximum number of times. In the latter case, LIPRO will print a message if no convergence was achieved.

It should be pointed out that, for the *linear* version of the projection model, an alternative one-step computation scheme exists (Keilman, 1985a, pp. 1483-1484).

6. SOME ISSUES IN MULTIDIMENSIONAL LIFE TABLE ANALYSIS

The LIPRO program offers several options for the construction and analysis of multidimensional life tables. This chapter discusses several technical issues concerning the way in which these life tables have been implemented in LIPRO.

6.1 | Interpretation of life tables in LIPRO

As LIPRO is a program for demographic projection, its demographic data are of the *period-cohort* type. On the other hand, life table analysis in the strict sense involves data of the *age-cohort* (or simply cohort) type. That is, a life table analyses events experienced by an imaginary group of people born at a particular *instant*, while within the context of LIPRO, events are experienced by a group of people born within a particular *time span*. Therefore, the life tables produced by the program are not life tables in the strict sense of the word. Rather, they should be interpreted as a summary of the events experienced by an imaginary cohort over its life cycle.

Starting point for the life table analysis is a set of rates (either intensities for the exponential model, or occurrence-exposure rates for the linear model). In creating the life tables, LIPRO sets the rates for international migration equal to zero. That is, the population is assumed to be *closed*.

6.2 | Determining the radix of the life table

In single-dimensional life tables, the radix of the table is a single number (usually: 100,000) indicating the size of the group of people to which the life table refers. In multidimensional life tables, the radix of the table is a vector of numbers, each element corresponding to the number of people starting their life in a particular state. The sum of the elements of the vector equals the size of the imaginary cohort. In LIPRO, this sum equals 100,000.

As long as the state space is such that all individuals are born into the same state i, the radix is a vector consisting of the element 100,000 in cell i and zeros elsewhere. For example, in a marital status model, all individuals start their life in the "single" state. If the states are labelled "single", "married", "widowed", and "divorced", then the radix equals: [100,000 0 0 0].

However, it is not always the case that the radix is so easily determined. There are many specifications of the state space which lead to a situation in which children can be born into more than one state. In regional models, for example, children are born into the state occupied by their mother at the time of birth. And in the NIDI household model, the position of the child is dependent on the position of the mother: children of married women are born into the state "child with married parents", children of cohabiting women are born into the state "child with cohabiting parents", and so on.

We are therefore confronted with the problem how to determine the distribution of our imaginary cohort across states of birth. It is clear that each distribution leads to a different life table (except in the not very interesting case in which all rates are the same across states of origin, implying that the classification chosen is demographically irrelevant).

If we start from a given radix, with a particular distribution across states of birth, we can compute a corresponding life table. The female members of the imaginary cohort will bear children during the course of their life cycle. The distribution of these children across states of birth will in general differ from the distribution within the radix from which the life table for their mothers was calculated.

The only case in which the distribution of the children across states of births is exactly equal to the distribution of their mothers across the states into which they themselves were born, is the case of a *stable population*. A stable population is defined as a population that remains constant over time in all respects except size. In particular, in a stable population the distribution of newly-born children across states of birth remains constant.

The problem of determining the stable distribution of births across states can be solved as follows. Assume that there are K possible states into which children can be born. In regional models, K equals the number of regions. In the household model to be presented in chapter 7, K equals 4 (being the states CMAR, CUNM, C1PA, and OTHR; cf. section 7.2). The index i_k, $k=1 \cdots K$, gives the index of the state corresponding to the k-th state of birth; in the household model, we have $i_1=1$, $i_2=2$, $i_3=3$, $i_4=11$. For each of these states i_k, $k=1 \cdots K$, we construct a life table based on a unitary female radix $\mathbf{r}_k$ with 100,000 in position i_k and zeros elsewhere. From this life table, we can calculate the vector of female births $\mathbf{b}_k$. The vector $\mathbf{b}_k$ represents the number of girls, classified by the state into which they are born, born out of mothers who themselves were born into state i_k.

We now have K radices $\mathbf{r}_k$ and K corresponding birth vectors $\mathbf{b}_k$. The next problem is to determine the stable radix $\mathbf{s}$, such that the vector of female births

c generated by a female radix **s** is a multiple of **s**. The stable radix can be written as a weighted sum of the K unitary radices:

$$\mathbf{s} = \mathbf{w}\cdot\mathbf{R} = 100{,}000 \cdot \mathbf{w} \tag{6.1}$$

where **R** is a (K by K) matrix, the *rows* of which are given by the unitary radices $\mathbf{r}_k$, k=1···K, and **w** is a row vector of weights. The vector of births **c** generated by **s** is also a weighted sum of the K birth vectors:

$$\mathbf{c} = \mathbf{w}\cdot\mathbf{B} \tag{6.2}$$

where **B** is the (K by K) matrix, the *rows* of which are given by the birth vectors $\mathbf{b}_k$, k=1···K. We require **c** to be a multiple of **s**:

$$\mathbf{c} = f\cdot\mathbf{s} \tag{6.3}$$

with f a scalar. From (6.1)-(6.3) we obtain:

$$\mathbf{w}\cdot\mathbf{B} = f \cdot 100{,}000 \cdot \mathbf{w} = \lambda\cdot\mathbf{w} \tag{6.4}$$

From (6.4), we see that the unknown vector **w** is an eigenvector of the birth matrix **B** and λ its corresponding eigenvalue. From the mathematical theory of stable population, it follows that the appropriate eigenvector is the one corresponding to the *dominant eigenvalue*, since this is the distribution to which any initial population will eventually converge. The dominant eigenvalue λ^* is also known as the *net reproduction factor in the stable population*.

6.3 | Handling the highest age group

For the highest age group, which is open ended, the demographic rates determine the number of events that will be experienced during a period, the length of which equals the length of the projection interval (h). However, after such a time span, a number of the individuals present at the start of the interval will still be alive. For the calculation of the life table, these surviving individuals should be exposed to another interval of demographic risk. This process should be repeated until all members of the imaginary cohort have died.

For this reason, LIPRO lets h→∞ for the highest, open-ended age group. If for this age group the initial population is denoted by ℓ, the events matrix by **N**, the intensity matrix by **M** and the vector of person years by **L**, then:

$$\text{final population} = \mathbf{0} = \ell + \iota\cdot\mathbf{N} = \ell + \iota\cdot(\dot{\mathbf{L}}\cdot\mathbf{M}) = \ell + \mathbf{L}\cdot\mathbf{M}$$

from which

$$\mathbf{L} = - \ell \cdot \mathbf{M}^{-1}$$

6.4 | Calculating mean ages

For some of the calculations performed by LIPRO, the mean age at which a particular event is experienced has to be calculated. Within a particular age group, the mean age could in principle be different across events: in general, the higher the intensity of experiencing a particular event, the lower the mean age at which it occurs. The exact expressions for calculating these mean ages are given by Van Imhoff (1990b).

Since such sophisticated calculations would be very time-consuming (especially in the exponential model), LIPRO uses an alternative calculation as an approximation. The implicit assumption behind this formula is that for a particular age group, all events on average occur at the same mean age. The formula is given by:

$$a_e = a_0 + L / (P_0 + P_h)$$

where:

a_e = average age at time of event
a_0 = average age at start of interval (= midpoint of age group)
L = number of person years lived during interval
P_0 = number of survivors at start of interval
P_h = number of survivors at end of interval

6.5 | Fertility indicators

LIPRO optionally calculates six fertility indicators for each state as well as for the aggregate across states. These indicators are the following:

1. Total fertility rate = sum of fertility rates across age groups
2. Average number of children = average number of births per woman, taking inter-household changes and mortality into account
3. Gross reproduction rate = sum of female fertility rates across age groups
4. Net reproduction rate = total number of female births per woman
5. Average length of generation = average age of mother at birth of daughters
6. Annual growth rate = annual growth rate of female population in stable population = ln [net reproduction rate] / (average length of generation)

6.6 | Experience tables

In some applications, it is useful to analyse the occurrence of a particular demographic event, or group of events, over the lifetime of the average individual. Examples include the analysis of the proportion ever-married as a function of age, or the probability of experiencing at least one dissolution of a relationship.

For this type of life table analysis, LIPRO offers the opportunity to construct so-called *experience tables*. An experience table is a life table, restricted to those members of the life table population who have experienced at least one event of a particular type earlier in their life. Examples include "ever been married", "ever experienced the loss of a spouse", "ever lived in a one-parent family".

An experience table corresponds to a particular *events set*. The events set specifies the type of events, the experience of which changes the status of an individual from "never experienced" to "at least experienced once". An events set can include:

- internal events
- births into a particular state

The experience table is constructed like an ordinary life table: starting from an initial radix, the age-specific rates are applied to the surviving population. The steps in the construction of an experience table are the following:

- the state space is extended with a second external state, namely "at least experienced once". This state is comparable to the external state "dead" in that it is absorbing: an individual once in the state "at least experienced once" can never leave it.
- the rates for internal events are redirected in accordance with the specification of the events set: for each event in the set, the rate is added to the initially zero rate for exit into the state "at least experienced once", at the same time setting the rate for the original event equal to zero.
- an "inexperience table" is constructed starting from the initial radix. If the events set specifies births into one or more particular states, the corresponding element of the radix is set equal to zero. This "inexperience table" is a life table for the individuals with the status "never experienced".
- finally, the "inexperience table" is substracted from the original life table to yield the experience table.

PART III

APPLICATION

7. THE SPECIFICATION OF THE STATE SPACE IN THE HOUSEHOLD MODEL

7.1 General considerations

The general multidimensional projection model described in chapters 3 to 6 was applied to a study into the impact of population dynamics on future social security expenditures in the Netherlands. In this study, the term population dynamics is interpreted as changes in household structure (household formation and dissolution) and age structure of the population. Regarding social security, the emphasis is on those social security schemes that are particularly sensitive to the living arrangement and/or age of the recipient. The consequences of population dynamics for social security expenditure are traced by linking the results of macrosimulations produced by the LIPRO household projection model, to fixed user profiles for social security schemes. The technique of employing user profiles is dealt with in more detail in chapter 11. The current chapter and chapters 8 to 10 will focus on the demographic dimension of the problem.

A meaningful classification of individuals should be such that the resulting categories are relatively homogeneous, with respect to both demographic behaviour and the use of social security schemes.
Classification by age and sex is obviously necessary for demographic reasons: mortality, fertility, and household formation and dissolution (e.g. marriage, tendency to start one-person households, tendency to become head of one-parent family) are to a large extent determined by age and sex. *Formally*, the distinction between the sexes is of less importance for the use of social security, as social security legislation is approaching full equality of men and women in the Netherlands. *In practice*, however, the distinction is highly relevant. This is because the economic position, which is a major determinant of the eligibility for social security benefits, of men is generally very different from that of women. For instance, one-parent families with labour income less frequently apply for social welfare than one-parent families without labour income. Labour force participation rates for women are lower than for men (in the Netherlands

they are *much* lower). Consequently, we expect average social security benefits for female single parents to be higher than for male single parents.

The choice of a classification of living conditions is the most problematic. On the one hand, one would like a very detailed classification in order to make the categories as homogeneous as possible. In particular, household size should be included among the classification criteria (important for child allowance and social welfare). On the other hand, there are technical limitations to the number of categories that can be distinguished. These restrictions stem from the finite capacity of computers, but especially from the limited availability of the necessary input data.

Although the actual choice of classification may vary with the special characteristics of the social security system in the country under consideration, a minimal classification of household positions would be the following:

1. dependent child
2. one-person household
3. partner (either married or cohabiting)
4. head of one-parent family
5. other

The categories "one-person household" and "head of one-parent family" can be subdivided according to the event that caused the particular household position (exit from existing household, divorce, death of spouse). The type of event leading to the present living condition will determine the degree to which individuals apply for various social security schemes. For the *sum* of all social security schemes, such a sub-classification would be less important.

An important consideration in the choice of household positions is that the classification should facilitate the transformation of a projection of individuals into a projection of households. The more detailed the classification of individuals is, the more accurate the distribution of households can be. This is particularly relevant for the scoring of children into households of various types. Distinction of household positions "partner" and "head of one-parent family", according to the number of children present in the household, would be desirable; however, a complete breakdown would lead to insurmountable data and computing problems. As a first approximation, a distinction could be made between families with and without children.

Within the category "partner", a further distinction could be made between married couples and consensual unions. In the Netherlands, the distinction has by now almost completely disappeared from social security legislation. From a purely demographic point of view, the distinction is theoretically interesting. With respect to international comparability, the distinction can hardly be missed. For social security, an important argument in favour of the distinction is that the registration of consensual unions is much less complete than the registration of marriages, implying differences between the two categories in both the degree to which couples apply for social security allowances and the degree to which the executive authorities will honour these applications.

7.2 | The specification of household positions

After weighing all the arguments set out in the previous section, it was decided to use a classification which contains 11 household positions. We feel that this classification offers a reasonable compromise between the conflicting objectives of completeness and feasibility. An individual in a private household may occupy, at a certain point in time, one of the following household positions.

1.	CMAR	child in family with married parents
2.	CUNM	child in family with cohabiting parents
3.	C1PA	child in one-parent family
4.	SING	single (one-person household)
5.	MAR0	married, living with spouse, but without children
6.	MAR+	married, living with spouse and with one or more children
7.	UNM0	cohabiting, no children present
8.	UNM+	cohabiting with one or more children
9.	H1PA	head of one-parent family
10.	NFRA	non family-related adult (i.e. an adult living with family types 5 to 9)
11.	OTHR	other (multi-family households; multiple single adults living together)

These 11 household positions together define 7 household types:

1.	SING	a one-person household
2.	MAR0	a married couple without children, but possibly with other adults
3.	MAR+	a married couple with one or more children, and possibly with other adults
4.	UNM0	a couple living in a consensual union without children, but possibly with other adults
5.	UNM+	a couple living in a consensual union with one or more children, and possibly with other adults
6.	1PAF	a one-parent family, possibly with other adults (but no partner to the single parent!)
7.	OTHR	multi-family households, or multiple single adults living together without unions.

No upper age limit was used with respect to the definition of "child". In practice, a situation could be encountered in which an adult child, even at an advanced age, belongs to the same household as his or her parent(s). For instance, a household consisting of an elderly mother and her co-residing daughter aged 50 is labeled here as a "one-parent family", although in reality the mother might have joined her daughter to form one household (and thus the household would be "other"). The solution we chose was based on the data which were available for this project: the Housing Demand Survey of 1985/1986 (see chapter 8) contains information regarding the structure of the household of each respondent, but no clear guidelines were given to the interviewer as to how to define a child. Thus the notion of child used here is not always the same as that used in social security regulations. However, because the number of households containing "old children" is probably small, the bias is likely to be limited. (Moreover, in the empirical part of this study, intensities for jumps from CMAR, CUNM or C1PA to SING for age groups 50-54 and over were set at an arbitrarily high value, so as to avoid a large number of older "children", see section 8.4.2).

Numbers of households of various types may be easily inferred from numbers of persons in the 11 household positions. Thus a household projection in terms of individuals may be translated into one in terms of households:

1. the number of households of type SING equals the number of persons in household position SING;
2. the number of households of type MAR0 equals half the number of persons in household position MAR0;
3. the number of households of type MAR+ equals half the number of persons in household position MAR+;
4. the number of households of type UNM0 equals half the number of persons in household position UNM0;
5. the number of households of type UNM+ equals half the number of persons in household position UNM+;
6. the number of households of type 1PAF equals the number of persons in household position H1PA;
7. the number of households of type OTHR equals the number of persons in household position OTHR divided by the average number of persons in OTHR households. This average household size was 2.82 persons in 1985. It is assumed that the average size of OTHR households remains unchanged throughout the projection period.

7.3 | Household events

Given the classification of household positions (the definition of the state space), a matrix of *household events* can be identified. The events matrix given in Table 7.1 is based on the following assumptions:

1. spouses who divorce or separate no longer co-reside;
2. a return to one of the positions for a co-residing child (CMAR, CUNM, C1PA) is only possible from the position SING (or OTHR);
3. adults can only leave the household through the (intermediate) position of SING.

Given these assumptions, it is possible to identify the demographic event which causes the internal or external event. These events are listed below (impossible events are denoted with an asterisk). Items on the main diagonal in Table 7.1 need some clarification. Most of them are "non-events" and these are omitted.

Table 7.1. Events matrix of the household model

from: to:	1	2	3	4	5	6	7	8	9	10	11	dead	emigr
1. CMAR	*	*	·	·	·	·	·	·	*	·	·	·	·
2. CUNM	·	*	·	·	·	·	·	·	*	·	·	·	·
3. C1PA	·	·	*	·	·	·	·	·	*	·	·	·	·
4. SING	·	·	·	*	·	·	·	·	·	·	·	·	·
5. MAR0	*	*	*	·	*	·	*	*	*	*	·	·	·
6. MAR+	*	*	*	·	·	*	*	*	·	*	·	·	·
7. UNM0	*	*	*	·	·	*	*	·	*	*	·	·	·
8. UNM+	*	*	*	·	*	·	·	*	·	*	·	·	·
9. H1PA	*	*	*	·	*	·	*	·	*	*	·	·	·
10. NFRA	*	*	*	·	*	*	*	*	*	*	·	·	·
11. OTHR	·	·	·	·	·	·	·	·	·	·	*	·	·
birth by mother's state before birth:	child's position after birth:												
1. CMAR	*	*	*	*	*	*	*	*	*	*	·	*	*
2. CUNM	*	*	*	*	*	*	*	*	*	*	·	*	*
3. C1PA	*	*	*	*	*	*	*	*	*	*	·	*	*
4. SING	*	*	·	*	*	*	*	*	*	*	*	*	*
5. MAR0	·	*	*	*	*	*	*	*	*	*	*	*	*
6. MAR+	·	*	*	*	*	*	*	*	*	*	*	*	*
7. UNM0	*	·	*	*	*	*	*	*	*	*	*	*	*
8. UNM+	*	·	*	*	*	*	*	*	*	*	*	*	*
9. H1PA	*	*	·	*	*	*	*	*	*	*	*	*	*
10. NFRA	*	*	*	*	*	*	*	*	*	*	·	*	*
11. OTHR	*	*	*	*	*	*	*	*	*	*	·	*	*
immigration	·	·	·	·	·	·	·	·	·	·	·	*	*

* = impossible event.
· = possible event.

However, for some "aggregate" positions, such as UNM+ (consensual union with *1 or more* children), MAR+ (with marriage partner and *1 or more* children), or H1PA, the arrival of an additional child (due to birth or return to parental home), or the exit of a child (due to home-leaving, death or emigration - when sufficiently many children stay behind) causes the adults to remain in the same household position. On the other hand, not every person who remains in the position UNM+, MAR+, or H1PA, experiences the arrival or exit of a child. In fact, most of them will not. Thus for these "aggregate" positions the one-to-one correspondence between an event, on the one hand, and a pair of positions, on the other, does not hold. This bears some implications for the consistency between (numbers of) events of adults and those of children; see below.

From	**To**	**Demographic event**
CMAR	CMAR	* (no event)
CMAR	CUNM	* (assumption 1)
CMAR	C1PA	a) divorce or separation of parents b) death of parent
CMAR	SING	leaving the parental home to start one-person household
CMAR	MAR0	marriage
CMAR	MAR+	marriage with a lone parent
CMAR	UNM0	start of a consensual union
CMAR	UNM+	start of a consensual union with a lone parent
CMAR	H1PA	*
CMAR	NFRA	entrance into an existing family
CMAR	OTHR	a) entrance into or formation of OTHR household b) child, while living with both parents, gets own child c) second family moves in
CUNM	CMAR	marriage of cohabiting couple with child(ren)
CUNM	CUNM	*
CUNM	C1PA	a) divorce or separation of parents b) death of parent
CUNM	SING	leaving the parental home to start a one-person household
CUNM	MAR0	marriage
CUNM	MAR+	marriage with lone parent
CUNM	UNM0	start of a consensual union
CUNM	UNM+	start of a consensual union with a lone parent
CUNM	H1PA	*
CUNM	NFRA	entrance into an existing family
CUNM	OTHR	a) entrance into or formation of OTHR household b) child, while living with cohabiting adults, gets own child c) second family moves in
C1PA	CMAR	marriage of lone parent
C1PA	CUNM	lone parent starts consensual union

C1PA	C1PA	*
C1PA	SING	a) leaving the parental home to start a one-person household b) death of a lone parent with one co-residing child
C1PA	MAR0	marriage
C1PA	MAR+	marriage with lone parent
C1PA	UNM0	start of a consensual union
C1PA	UNM+	start of a consensual union with a lone parent
C1PA	H1PA	*
C1PA	NFRA	entrance into an existing family
C1PA	OTHR	a) entrance into or formation of OTHR household b) child, while living with one parent, gets own child c) second family moves in d) lone parent of two or more co-residing children dies
SING	CMAR	return to married parents
SING	CUNM	return to cohabiting parents
SING	C1PA	return to single parent
SING	SING	*
SING	MAR0	marriage
SING	MAR+	marriage with lone parent
SING	UNM0	start of a consensual union
SING	UNM+	start of a consensual union with a lone parent
SING	H1PA	a) return of child to lone parent b) birth
SING	NFRA	entrance into an existing family
SING	OTHR	entrance into or formation of non-family household
MAR0	CMAR	* (assumption 2)
MAR0	CUNM	* (assumption 2)
MAR0	C1PA	* (assumption 2)
MAR0	SING	a) divorce or separation b) death of partner
MAR0	MAR0	*
MAR0	MAR+	a) birth b) return of child to married parents
MAR0	UNM0	* (assumption 1)
MAR0	UNM+	* (assumption 3)
MAR0	H1PA	* (assumption 3)
MAR0	NFRA	* (assumption 3)
MAR0	OTHR	entrance into or formation of non-family household

MAR+	CMAR	* (assumption 2)
MAR+	CUNM	* (assumption 2)
MAR+	C1PA	* (assumption 2)
MAR+	SING	divorce or separation
MAR+	MAR0	last child leaves the parental household
MAR+	MAR+	*
MAR+	UNM0	* (assumption 3)
MAR+	UNM+	* (assumption 3)
MAR+	H1PA	a) divorce or separation b) death of partner
MAR+	NFRA	* (assumption 3)
MAR+	OTHR	a) entrance into or formation of non-family household b) co-residing daughter gets a child
UNM0	CMAR	* (assumption 2)
UNM0	CUNM	* (assumption 2)
UNM0	C1PA	* (assumption 2)
UNM0	SING	a) divorce or separation b) death of partner
UNM0	MAR0	marriage
UNM0	MAR+	* (assumption 3)
UNM0	UNM0	*
UNM0	UNM+	a) birth b) return of child to cohabiting parents
UNM0	H1PA	* (assumption 3)
UNM0	NFRA	* (assumption 3)
UNM0	OTHR	entrance into or formation of non-family household
UNM+	CMAR	* (assumption 2)
UNM+	CUNM	* (assumption 2)
UNM+	C1PA	* (assumption 2)
UNM+	SING	divorce or separation
UNM+	MAR0	* (assumption 3)
UNM+	MAR+	marriage
UNM+	UNM0	last child leaves parental household
UNM+	UNM+	*
UNM+	H1PA	a) divorce or separation b) death of partner
UNM+	NFRA	* (assumption 3)
UNM+	OTHR	a) entrance into or formation of non-family household b) co-residing daughter gets a child
H1PA	CMAR	* (assumption 2)
H1PA	CUNM	* (assumption 2)

H1PA	C1PA	* (assumption 2)
H1PA	SING	last child leaves parent
H1PA	MAR0	* (assumption 3)
H1PA	MAR+	marriage
H1PA	UNM0	* (assumption 3)
H1PA	UNM+	start of a consensual union
H1PA	H1PA	*
H1PA	NFRA	* (assumption 3)
H1PA	OTHR	a) entrance into or formation of non-family household b) co-residing daughter gets a child
NFRA	CMAR	* (assumption 2)
NFRA	CUNM	* (assumption 2)
NFRA	C1PA	* (assumption 2)
NFRA	SING	exit from family and start of one-person household
NFRA	MAR0	* (assumption 3)
NFRA	MAR+	* (assumption 3)
NFRA	UNM0	* (assumption 3)
NFRA	UNM+	* (assumption 3)
NFRA	H1PA	* (assumption 3)
NFRA	NFRA	*
NFRA	OTHR	a) second family moves in b) co-residing daughter gets a child
OTHR	CMAR	a) married parents leave multi-family household b) return to married parents from OTHR household
OTHR	CUNM	a) cohabiting parents leave multi-family household b) return to cohabiting parents from OTHR household
OTHR	C1PA	a) lone parent leaves multi-family household b) return to lone parent from OTHR household
OTHR	SING	exit from OTHR household and start of one-person household
OTHR	MAR0	a) marriage b) married couple without children leaves multi-family household
OTHR	MAR+	a) marriage with lone parent b) married couple with child(ren) leaves multi-family household
OTHR	UNM0	a) start of consensual union b) cohabiting couple without children leaves OTHR household c) two co-residing adults start a consensual union

OTHR	UNM+	a) start of consensual union with lone parent b) cohabiting couple with child(ren) leaves OTHR household c) two co-residing adults of whom at least one is a lone parent start a consensual union
OTHR	H1PA	one-parent family leaves multi-family household
OTHR	NFRA	family with co-residing adult leaves multi-family household
OTHR	OTHR	*

7.4 | Consistency relations

Consistency relations were formulated on the basis of the household events which were identified in the previous section. As discussed in chapter 5, consistency relations describe constraints which the projected numbers of events have to satisfy.

The events matrix for the LIPRO household model, depicted in Table 7.1, contains 69 internal events, 22 exits, and 22 entries. For two sexes, this amounts to a total of 226 events. Formulation of consistency relations between these 226 events led to 37 restrictions in terms of 127 variables. Four assumptions turned out to be necessary in addition to the three assumptions listed in section 7.3:

4. divorced partners do not continue to live together;
5. adoption can be disregarded for the entry of a first child into the household;
6. the formation and dissolution of homosexual consensual unions can be disregarded as far as the two-sex requirement for cohabitation is concerned;
7. only complete households can migrate.

The 37 consistency relations are listed below. All relations are in terms of numbers of events. Each type of event is described using the following notation:

T(S,ORIG,DEST)

in which:

T	stands for type of event. T may be:	
	I	internal event
	X	external event (exit)
	B	birth (endogenous entry)
	N	immigration (exogenous entry)
S	stands for the sex experiencing the event. S may be:	
	F	female
	M	male
	M+F	both sexes

ORIG	stands for the household position, or range of household positions, from which the event takes place. In the case of births, ORIG indicates the position of the mother prior to the moment of birth.
DEST	stands for the household position, or range of household positions, to which the event leads. In the case of births, DEST indicates the household position that the newly-born child occupies.

Constraints for households of type MAR0

household dissolution:
1) I(F,MAR0,SING) + X(F,MAR0,DEAD) = I(M,MAR0,SING) + X(M,MAR0,DEAD)
birth of child, or return of child to parents:
2) I(M,MAR0,MAR+) = I(F,MAR0,MAR+)
formation of OTHR households:
3) I(M,MAR0,OTHR) = I(F,MAR0,OTHR)
emigration:
4) X(M,MAR0,REST) = X(F,MAR0,REST)
immigration:
5) N(M,REST,MAR0) = N(F,REST,MAR0)

Constraints for households of type MAR+

marriage dissolution:
6) I(M,MAR+,SING) + I(M,MAR+,H1PA) + X(M,MAR+,DEAD) = I(F,MAR+,SING) + I(F,MAR+,H1PA) + X(F,MAR+,DEAD)
7) I(M,MAR+,SING) + I(M,MAR+,H1PA) + X(M,MAR+,DEAD) = I(M+F,CMAR,C1PA) / [Mean number of children per married couple]
exit of last child:
8) I(M,MAR+,MAR0) = I(F,MAR+,MAR0)
formation of OTHR households:
9) I(M,MAR+,OTHR) = I(F,MAR+,OTHR)
emigration:
10) X(M,MAR+,REST) = X(F,MAR+,REST)
11) X(M,MAR+,REST) = X(M+F,CMAR,REST) / [M.n.o.c.p.m.c.]
immigration:
12) N(M,REST,MAR+) = N(F,REST,MAR+)
13) N(M,REST,MAR+) = N(M+F,REST,CMAR) / [M.n.o.c.p.m.c.]

Constraints for households of type UNM0

marriage:
14) I(M,UNM0,MAR0) = I(F,UNM0,MAR0)

household dissolution:
15) I(F,UNM0,SING) + X(F,UNM0,DEAD) =
I(M,UNM0,SING) + X(M,UNM0,DEAD)
birth of child, or return of child to parents:
16) I(M,UNM0,UNM+) = I(F,UNM0,UNM+)
formation of OTHR households:
17) I(M,UNM0,OTHR) = I(F,UNM0,OTHR)
emigration:
18) X(M,UNM0,REST) = X(F,UNM0,REST)
immigration:
19) N(M,REST,UNM0) = N(F,REST,UNM0)

Constraints for households of type UNM+

marriage:
20) I(M,UNM+,MAR+) = I(F,UNM+,MAR+)
21) I(M,UNM+,MAR+) =
I(M+F,CUNM,CMAR) / [Mean number of children per cohabiting couple]
marriage dissolution:
22) I(M,UNM+,SING) + I(M,UNM+,H1PA) + X(M,UNM+,DEAD) =
I(F,UNM+,SING) + I(F,UNM+,H1PA) + X(F,UNM+,DEAD)
23) I(M,UNM+,SING) + I(M,UNM+,H1PA) + X(M,UNM+,DEAD) =
I(M+F,CUNM,C1PA) / [M.n.o.c.p.c.c.]
exit of last child:
24) I(M,UNM+,UNM0) = I(F,UNM+,UNM0)
formation of OTHR household:
25) I(M,UNM+,OTHR) = I(F,UNM+,OTHR)
emigration:
26) X(M,UNM+,REST) = X(F,UNM+,REST)
27) X(M,UNM+,REST) = X(M+F,CUNM,REST) / [M.n.o.c.p.c.c.]
immigration:
28) N(M,REST,UNM+) = N(F,REST,UNM+)
29) N(M,REST,UNM+) = N(M+F,REST,CUNM) / [M.n.o.c.p.c.c.]

Constraints for households of type H1PA

marriage:
30) I(M+F,H1PA,MAR+) =
I(M+F,C1PA,CMAR) / [Mean number of children per lone parent]
cohabitation:
31) I(M+F,H1PA,UNM+) = I(M+F,C1PA,CUNM) / [M.n.o.c.p.l.p.]
emigration:
32) X(M+F,H1PA,REST) = X(M+F,C1PA,REST) / [M.n.o.c.p.l.p.]

immigration:
33) N(M+F,REST,H1PA) = N(M+F,REST,C1PA) / [M.n.o.c.p.l.p.]

Constraints for the formation of marriages and consensual unions

formation of marriages of type MAR0:
34) I(M,CMAR..SING,MAR0) + I(M,UNM0,MAR0) +
I(M,OTHR,MAR0) = I(F,CMAR..SING,MAR0) +
I(F,UNM0,MAR0) + I(F,OTHR,MAR0)
formation of marriages of type MAR+:
35) I(M,CMAR..SING,MAR+) + I(M,UNM+..H1PA,MAR+) +
I(M,OTHR,MAR+) = I(F,CMAR..SING,MAR+) +
I(F,UNM+..H1PA,MAR+) + I(F,OTHR,MAR+)
formation of consensual unions of type UNM0:
36) I(M,CMAR..SING,UNM0) + I(M,OTHR,UNM0) =
I(F,CMAR..SING,UNM0) + I(F,OTHR,UNM0)
formation of consensual unions of type UNM+:
37) I(M,CMAR..SING,UNM+) + I(M,H1PA,UNM+) +
I(M,OTHR,UNM+) = I(F,CMAR..SING,UNM+) +
I(F,H1PA,UNM+) + I(F,OTHR,UNM+)

Note that a constraint for household type MAR+ similar to constraint number 2 for type MAR0 cannot be formulated because MAR+ is an aggregate position. Hence in the present LIPRO application there is no guarantee that the number of males who are originally in position MAR+, and who experience the arrival of an additional child in the household, equals the corresponding number of females. The same holds for males and females in aggregate positions UNM+, H1PA, and OTHR.

To illustrate the flexibility of the LIPRO computer program, it should be pointed out that the form in which the consistency relations are entered as input to the program is exactly the same as that of the expressions listed here (see chapter 16).

8. FROM DATA TO INPUT PARAMETERS

8.1 | Introduction

A projection of future household positions requires two types of input data:

1. an initial population at the start of the projection interval (in our case December 31st, 1985);
2. data on jump intensities, or, alternatively, data on jumps and exposed population from which jump intensities can be estimated.

Our main source of demographic data is the so-called "Woningbehoeften-onderzoek 1985/1986" ("Housing Demand Survey 1985/1986") or simply WBO 1985/1986. A short description of the data set is given in section 8.2. The next two sections describe how the initial population (8.3) and the jump intensities (8.4) were determined.

8.2 | The Housing Demand Survey of 1985/1986 (WBO 1985/1986)

The Housing Demand Surveys ("Woningbehoeftenonderzoeken" or WBO's) are conducted by the Netherlands Central Bureau of Statistics (NCBS) at four year intervals. The 1985/1986 edition started from a sample of 72,071 addresses. The field work took place during the last few months of 1985 and the first few months of 1986. Because of non-response, institutional households, and other factors, the WBO 1985/1986 contains detailed information on 46,730 households. The data include the household situation of the respondents at the time the survey was taken, and their household situation one year earlier. A slight drawback of the WBO 1985/1986 is that the questionnaire focuses on private households: only a few basic questions are included for persons living in institutions.

The WBO 1985/1986 gives us the household position of all individuals in the sampled private households at the survey date. This information was used to construct the initial population for the simulation, together with data on the distribution by age, sex, and marital status of the WBO respondents living in institutional households (see section 8.3). The WBO data were corrected so as to correspond to the observed population structure by age, sex, and marital status as per December 31, 1985.

Information on jumps between the 11 household positions can be obtained from variables indicating the household position of each person one year earlier, to be reconstructed from a small number of "retrospective" questions included in the questionnaire. Unfortunately, this "retrospective" information is incomplete, requiring the use of simplifying assumptions and approximation methods.

In all computations employing WBO 1985/1986 data, we used weight factors provided by the NCBS in order to achieve national representativeness.

8.3 | The initial population

The starting point of our projections is the situation as per December 31, 1985. From the WBO 1985/1986, the number of persons in each of the 11 household positions can be calculated, by age and sex. Since these WBO 1985/1986 figures are subject to sampling error, they have been adjusted to bring them in line with the official NCBS population statistics for December 31, 1985. These statistics give the population according to age, sex, and marital status.

First, the population statistics were adjusted to eliminate the population living in institutions, using estimated age, sex, and marital status specific numbers living in institutions as given by Faessen and Nollen-Dijcks (1989). Next, the age- and sex-specific numbers from the WBO 1985/1986 were adjusted proportionally over the 11 household positions, equalizing the sum of the numbers in positions MAR0 and MAR+ to the numbers in marital status "married", and equalizing the sum of the numbers in the other 9 household positions to the sum of the numbers in marital states "never married", "widowed" and "divorced". This procedure resulted in the population in private households as of December 31, 1985, according to age, sex, and household position. Table 8.1 summarizes this information.

8.4 | Estimation of jump intensities

8.4.1. Estimation of transition probabilities

Because the parameters of the household model are jump intensities, whereas the WBO 1985/1986 provides information on (most household) transitions, an algorithm was devised to construct intensities from transition data. The first step was the determination of transition probabilities. If, for each individual in the sample, his/her household position at some previous point in time were known, then transition probabilities could be calculated from the simple age- and

Table 8.1. The population in private households according to age, sex, and household position, the Netherlands, December 31, 1985

	Females				Males				House-holds
	0-19	20-64	65+	total	0-19	20-64	65+	total	
	in thousands								
cmar	1705	237	0	1942	1792	474	0	2266	-
cunm	29	2	0	31	36	6	0	42	-
c1pa	178	49	0	227	193	114	0	307	-
sing	13	456	411	880	8	502	98	609	1489
mar0	4	865	357	1226	0	778	445	1224	1225
mar+	3	2145	34	2182	0	2122	67	2189	2186
unm0	8	197	13	217	1	218	12	230	224
unm+	0	41	0	42	0	44	1	45	44
h1pa	1	235	29	265	0	39	7	46	311
nfra	0	13	18	31	1	18	10	29	-
othr	20	66	47	133	20	80	17	117	89
total	1963	4306	909	7177	2052	4395	656	7104	5567

Source: Data constructed on the basis of WBO 1985/1986.

sex-specific cross-tables of past versus present household positions. (It should be noted that transition probabilities thus computed are net of emigration and mortality.) Unfortunately, the variables in the WBO 1985/1986 do not allow an exact reconstruction of past household positions, at least not in terms of our 11-cell classification. Therefore, an approximation method was devised.
For each individual, the WBO 1985/1986 gives the following relevant variables on the household situation one year before the survey date:

- did the individual live in the same household?
- relation to head of household (RELTOHEAD) in which the individual lived at the time (whether or not this was the same household as the present one), coded as follows:
  1. head of one-person household
  2. head of multi-person household
  3. married spouse of head
  4. unmarried partner of head
  5. (step)child of head and/or partner
  6. other adult
  7. other child
  8. not yet born (i.e. born during last year)
  9. living abroad (i.e. immigrated during last year);
- marital status;
- the number of individuals who left the household during the past year.

The households in the sample fall into one of the following three categories.

1. Households without entries and without exits.
   For these households, reconstruction of the state of its members one year ago is unnecessary. The only point to bear in mind is the possibility of a transition from an unmarried to a married couple.
2. Households with entries.
   For the *non-entrants* (i.e. the members of the household who were already present one year earlier), the household position can be found by "subtracting" the entrants from the present household composition.
   For the *entrants*, the previous household position has been approximated by considering their previous value on the variable RELTOHEAD and assuming that the age- and sex-specific cross-tabulation of RELTOHEAD versus our 11-cell classification did not change between 1984 and 1985.
   Immigrants were not taken into account, as the WBO 1985/1986 data are not reliable in this respect.
   For those individuals *born during the year prior to the survey date*, we tried to reconstruct the household position of the mother at the moment of childbirth. If necessary, we used simplifying assumptions. Once the household position of the mother has been determined, the household position into which the child is born follows automatically. If this household position at birth is crossed with the household position at the survey date, the transition matrix for age group 0 can easily be calculated.
3. Households with exits.
   Here too, an approximation method had to be used since the household position of the person(s) who left, and consequently the household position of the remaining household members before the departure, is unknown.
   For the *stayers*, their previous values on the variables RELTOHEAD, marital status, and household size were considered, assuming an unchanging age- and sex-specific distribution across the 11 household positions within each combination of RELTOHEAD, marital status, and household size.
   The *departed persons* do not need separate treatment. If they moved into another household, they can be assumed to be included in the entrants discussed under item 2. If they left the population (through death or emigration), the corresponding jump intensity is estimated from different sources.

8.4.2. From transition probabilities to jump intensities

The computations thus far have yielded single-year transition matrices for internal events, for each age/sex group. What we need are intensities, being the fundamental parameters of the exponential multidimensional projection model (Van Imhoff, 1990a). The mathematical relationship between a transition matrix **T** and an intensity matrix **M** is given by:

$$\mathbf{T} = \exp[\mathbf{M}h] \qquad (8.1)$$

where h is the length of the observation interval (here 1 year, except for age group 0 where h is approximately equal to ½). Then

$$\mathbf{M} = \log[\mathbf{T}] / h \qquad (8.2)$$

where the log of a matrix is defined in terms of its Taylor power series. It may happen that the latter power series does not converge. In that case the empirical transition matrix **T** is said to be non-embeddable, i.e. inconsistent with the assumptions of the exponential model (Singer and Spilerman, 1976). In our application, only four out of 176 transition matrices turned out to be non-embeddable. By putting the probabilities for some very improbable transitions equal to zero, embeddability could be achieved for these four cases. Impossible transition intensities (i.e. those denoted by an asterisk in Table 7.1) were subsequently put equal to zero.

However, even for embeddable transition matrices, application of expression 8.2 leads to very unreliable estimates of the intensities. This is caused by the fact that the logarithm of a matrix is very sensitive to small changes in one of its elements. Since the empirical transition matrices **T** are subject to a high degree of sampling error, the resulting intensities exhibit a very irregular and unrealistic pattern when plotted as a function of age.

Therefore it was decided to follow a different approach. This approach rests on the assumption that an observed transition can be identified with an event. That is, it is assumed that each individual experiences one event at most during the observation period. Since the observation period is rather short (1 year), this assumption appears to be quite reasonable. The only exceptions were made for transitions that are impossible events according to the events matrix of Table 7.1. For example, if a woman was observed to be in position UNM0 one year before being observed to be in state MAR+, it has been assumed that she experienced two events, namely first the event from UNM0 to MAR0 and then the event from MAR0 to MAR+. A full list of these assumptions on multiple events in the case of "impossible transitions" is given in Table 8.2.

From the events matrices constructed in this way, intensity matrices can be estimated using the moment estimator developed by Gill (1986). The computer program for estimating intensities from events matrices of any rank is described by Van Imhoff (1989).

The intensity matrices obtained in this way refer to internal events only. In order to estimate household position-specific mortality and emigration intensities, we used marital status as an approximation. From the NCBS population statistics 1981-1985, marital status-specific exit intensities were estimated using the method of Gill and Keilman (1990). These intensities were subsequently transformed into intensities by household position, using the age-

Table 8.2. Assumptions on multiple events

Observed transition	Assumed events
cmar → cunm	cmar → c1pa → cunm
mar0 → cmar	mar0 → sing → cmar
mar0 → cunm	mar0 → sing → cunm
mar0 → c1pa	mar0 → sing → c1pa
mar0 → unm0	mar0 → sing → unm0
mar0 → unm+	mar0 → sing → unm+
mar0 → h1pa	mar0 → mar+ → h1pa
mar0 → nfra	mar0 → sing → nfra
mar+ → cmar	mar+ → sing → cmar
mar+ → cunm	mar+ → sing → cunm
mar+ → c1pa	mar+ → sing → c1pa
mar+ → unm0	mar+ → sing → unm0
mar+ → unm+	mar+ → h1pa → unm+
mar+ → nfra	mar+ → sing → nfra
unm0 → cmar	unm0 → sing → cmar
unm0 → cunm	unm0 → sing → cunm
unm0 → c1pa	unm0 → sing → c1pa
unm0 → mar+	unm0 → mar0 → mar+
unm0 → h1pa	unm0 → unm+ → h1pa
unm0 → nfra	unm0 → sing → nfra
unm+ → cmar	unm+ → sing → cmar
unm+ → cunm	unm+ → sing → cunm
unm+ → c1pa	unm+ → sing → c1pa
unm+ → mar0	unm+ → sing → mar0
unm+ → nfra	unm+ → sing → nfra
h1pa → cmar	h1pa → sing → cmar
h1pa → cunm	h1pa → sing → cunm
h1pa → c1pa	h1pa → sing → c1pa
h1pa → mar0	h1pa → sing → mar0
h1pa → unm0	h1pa → sing → unm0
h1pa → nfra	h1pa → sing → nfra
nfra → cmar	nfra → sing → cmar
nfra → cunm	nfra → sing → cunm
nfra → c1pa	nfra → sing → c1pa
nfra → mar0	nfra → sing → mar0
nfra → mar+	nfra → sing → mar+
nfra → unm0	nfra → sing → unm0
nfra → unm+	nfra → sing → unm+
nfra → h1pa	nfra → sing → h1pa

and sex-specific marital status distribution for each household position as weights. A similar approximation method was used to produce estimates of the immigrant population by household position from immigration statistics 1981-1985 by marital status.

Since the number of estimated intensities is very large compared with the number of observations, the resulting estimates are subject to large random variations. In order to reduce this variation, the one-year/single age group intensities were transformed into five-year/five-year age group intensities. A secondary advantage of this transformation is that it reduces the number of computations for a given projection by a factor of 25. The transformation involves a weighted average of the single-year intensities, using the average population (over the year) in each household position as weights, and taking into account the fact that a five-year age group over a period of five years involves 9 different one-year age groups. This procedure was applied to internal intensities, to the exit and fertility intensities, and to the numbers of immigrants, and resulted in 38 sets of intensity matrices (i.e. 2 sexes and 19 age groups, 18 ranging from 0-4 to 85+ and one for the age group born during the five-year period).

Finally, intensities for jumps from CMAR, CUNM or C1PA to SING for age groups 50-54 and over were made equal to one. No observations are available for these events (and thus intensities cannot be computed). The procedure sketched here guarantees that an ever-growing group of older "children" during the projections is avoided.

8.4.3. Adjusting the intensities to achieve internal and external consistency

The five-year intensities were used to make a household projection over a single projection interval, i.e. the five-year period 1986-1990. Not surprisingly, the projected numbers of events failed to satisfy the conditions for internal consistency. In addition, the results on vital events in several respects diverged from the official numbers of the NCBS, i.e. the sum of observed numbers for the years 1986-1987, and the corresponding numbers in the national population forecast for the years 1988-1990. Using the consistency algorithm, the numbers of events projected by LIPRO were adjusted to yield internal consistency, as well as external consistency with the official numbers on seven vital events:

- number of births;
- number of deaths;
- number of marriages;
- number of marriage dissolutions;
- number of male entries into widowhood;
- number of female entries into widowhood;
- net international migration.

The precise constraints for these events are listed in Table 8.3. From the internally and externally consistent numbers of events, the intensities were reconstructed using Gill's algorithm. It is this adjusted set of jump intensities that constitutes the basis of the projections to be discussed in chapter 10.

Table 8.3. Constraints for external consistency, 1986-1990

```
{1. Number of live births}
938200 = B(M+F,cmar..c1pa,othr) + B(M+F,sing,c1pa) +
         B(M+F,mar0..mar+,cmar) + B(M+F,unm0..unm+,cunm) +
         B(M+F,h1pa,c1pa) + B(M+F,nfra..othr,othr);
{2. Number of deaths}
610600 = X(M+F,cmar..othr,dead);
{3. Number of marriages}
446700 = I(M,cmar..sing,mar0..mar+) + I(M,unm0,mar0) +
         I(M,unm+,mar+) + I(M,h1pa,mar+) + I(M,othr,mar0..mar+);
{4. Number of marriage dissolutions}
427100 = I(M,mar0..mar+,sing) + X(M,mar0..mar+,dead) +
         I(M,mar+,h1pa);
{5. Number of new widows}
208500 = X(M,mar0..mar+,dead);
{6. Number of new widowers}
80000  = X(F,mar0..mar+,dead);
{7. Net immigration}
179100 = N(M+F,rest,cmar..othr) - X(M+F,cmar..othr,rest);
```

9. DEMOGRAPHIC SCENARIOS

9.1 On the term "scenario"

In daily life, a scenario gives a more or less detailed description of the way the future evolution of a process is perceived. A film scenario contains the details of what will result in a movie. A journalist who wants to reveal certain dubious aspects of a politician’s behaviour imagines how various parties will react to his reports, and his publication strategy is based upon these perceptions. Both the film director and the journalist construct a scenario.

A scientific scenario involves a coherent description of the way the researcher perceives the future. Thus a scenario is an instrument used in futures studies. A scenario may be of a quantitative or of a qualitative nature, depending on the process involved. Envisioning the geo-political constellation in the 21st century requires a qualitative scenario. Demographers who explore future population trends formulate quantitative scenarios.

The examples given here illustrate that a scenario differs from a forecast. A forecast is an unconditional statement of the most likely future trends, formulated on the basis of insights into current processes. A scenario is conditional: it develops the consequences of the assumptions that are made.

More specifically, the scenarios reported here are a quantification of assumed demographic patterns regarding household events and vital events, and they indicate how household structures will develop in the future if these assumptions are borne out. The scenarios consist of a set of values for jump intensities (and numbers of immigrants), being the basic parameters (exogenous variables) of the household projection model presented in chapter 7. These values are formulated for the entire projection period.

9.2 Jump intensities and the multidimensional life table

The value and the implications of a given set of age-specific jump intensities are difficult to assess, because time series for most of these intensities are lacking. Hence it is impossible to analyse these parameters for the past, and extrapolations cannot be made (except for such simple events as marriage, marital birth, and death).

Therefore, multidimensional life table analyses were used as an intermediate step in the construction of household scenarios. In a life table analysis, the life course is explored for a fictitious cohort by assuming that the members of this cohort follow a given set of age-specific jump intensities over their life span. The life table is a procedure for calculating a large number of summary indicators, such as life expectancy, the mean number of children, the average number of years spent in married life, etc.

The life table offers the opportunity to judge a given set of jump intensities on the basis of corresponding summary indicators which can be easily interpreted. For instance, assume that a scenario has to be designed with increased propensities (relative to some observed pattern) to start a consensual union, and at the same time with decreased marriage propensities. The problem then is *by how much* the consensual union propensities should be increased, given the fact that the scenario should result in reasonable values for all summary indicators. A 50 percent growth in consensual union propensities resulting in proportions ever married below 30 percent would clearly be unrealistic.

The following life table indicators were used to assess the various scenarios (values as of 1985 are given in parentheses):

1. Mortality
    life expectancy at birth, males (70.9)
    life expectancy at birth, females (78.1)
2. Fertility
    total fertility rate (1.39[1])
    proportion of births outside wedlock (8%)
3. Marriage
    proportion ever-married, males (72.2%)
    proportion ever-married, females (79.1%)

9.3 | Five demographic scenarios

Five demographic scenarios were explored. In this section they will be described verbally, whereas section 9.4 shows how they were quantified. Model parameters for which an explicit trend has been extrapolated until a certain year in the

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[1] This value has been calculated on the basis of WBO 1985/1986 information. Three factors explain why it differs slightly from the TFR calculated on the basis of vital statistics (1.51 in 1985, see NCBS, 1990, p. 21): the WBO estimate is subject to sampling error; it is obtained from surviving women only; and it has been calculated on the basis of 5-year age groups.

future (e.g. 2010 for mortality in four scenarios) are kept at a constant level from that year until the year 2050, the end of the projection period.

9.3.1. Constant Scenario

In the Constant Scenario, it is assumed that all intensities (and numbers of immigrants) are constant during the entire projection period, except for possible adjustments due to consistency relations. Thus the Constant Scenario illustrates how the population in private households in the Netherlands would evolve, if household dynamics as observed in the year 1985 would also apply to the future.

9.3.2. Realistic Scenario

The Realistic Scenario fits in, as much as possible, with the demographic expectations contained in the official population forecast of the Netherlands Central Bureau of Statistics (the medium variant of the 1989-based forecast, see Cruijsen, 1990). The Realistic Scenario does not include extreme trends, as demographic developments are extrapolated smoothly into the future. The following "reasonable" assumptions were made:

1. Mortality:
   A gradual further increase in life expectancy until the year 2010. The increase for males is somewhat stronger than that for females. Thus the difference in life expectancies between the sexes will diminish slightly.
2. Fertility:
   A moderate growth of period fertility rates until the year 2025, to a level which is still much lower than replacement level. At the same time a steep increase in the proportion of extra-marital births.
3. Household formation:
   A decrease in the proportion ever-married by about 8 percentage points (to the year 2025). The accompanying drop in first marriage intensities is completely compensated for by higher intensities to start a consensual union. Thus a modest substitution of formal marriages by consensual unions is anticipated, which is also expressed by a firm increase in the fertility of cohabiting couples. Moreover, remarriage propensities for lone parents are slightly raised.
4. Household dissolution:
   A rise until the year 2025 of divorce propensities (which are low compared to other countries), both for marriages and consensual unions.
5. International migration:
   A modest decline of immigration numbers and of emigration propensities by 10 percent until the year 2000.

9.3.3. Swedish Scenario

In the Swedish Scenario, the consequences for the Netherlands are traced of a household formation and dissolution pattern which tends towards the pattern observed in Sweden in 1985. When compared with the Realistic Scenario, the Swedish Scenario is characterized by:

- relatively little importance attached to formal marriage and, at the same time, much more emphasis on consensual unions;
- a rather high instability of affective relationships; and
- a relatively high fertility.

9.3.4. Fertility Scenario

The Fertility Scenario is identical to the Realistic Scenario, with the exception of fertility assumptions. In the Fertility Scenario, the Total Fertility Rate increases to replacement level (2.1 children per woman) over a period of 40 years. Given current fertility conditions in the Netherlands, this is a rather extreme assumption.

9.3.5. Mortality Scenario

The Mortality Scenario is an alternative to the Realistic Scenario as well. Compared with the latter scenario, an additional rise in life expectancy is assumed: 1 year extra for females, 3 years extra for males.

9.4 | Quantification of the scenarios

The upper panel of Table 9.1 presents the target values of various summary indicators in the scenarios.

In multidimensional models such as LIPRO, many variables show strong interrelations. For instance, a reduction in marriage propensities affects not only proportions married, but through resulting changes in the household structure of the population, also fertility (fertility intensities for married persons are higher than those for unmarried persons) and mortality (unmarried persons have lower survival probabilities than married persons). Therefore, it is impossible to determine unequivocally how intensities should be adjusted in order to obtain a given value of a certain summary indicator. This explains why a "trial-and-error" approach was followed when determining appropriate values for the intensities.

All intensities for a given event were adjusted proportionally, irrespective of age. This implies an unchanged age pattern for the event in question. The lower panel of Table 9.1 shows proportional adjustment factors which resulted in target values for summary indicators as presented in the upper part of the table. Note the strong adjustment for the fertility of cohabiting women without children. The reason is the low level of fertility for this group in the Netherlands in the mid-1980s. As formal marriages will gradually be substituted by consensual unions, cohabiting couples will tend to show a childbearing behaviour closer to married couples than at present. Even a modest degree of substitution requires rather strong adjustments in fertility intensities of cohabiting persons. The adjustment factors shown in Table 9.1 apply to the projection intervals from the year 2025 onwards, and in some cases even earlier. Adjustment factors for intervals between 1986-1990 and the target year develop according to a straight line, starting from 1 and ending at the values shown in the table.

Table 9.1. Key indicators in the five scenarios[1]

	Constant (1985)	Realistic	Swedish	Fertility	Mortality
Target values for the year 2025, life table indicators:					
Life expectancy at birth:					
males (in 2010)	70.9	75.0	75.4	R	78.0
females (in 2010)	78.1	81.5	81.7	R	82.5
Total fertility rate	1.39	1.65	1.90	2.10	R
Proportion births outside wedlock	8%	33%	50%	R	R
Proportion ever-married:					
males	72%	64%	67%	R	R
females	79%	70%	67%	R	R
Target values for the year 2025, intensities (relative to the 1985 value):					
Consensual unions		*	*	*	*
Remarriage of lone parents		+33%	+50%	R	R
Divorce of formal marriages		+50%	-	R	R
Divorce of married couples with children		-	+100%		
Separation of cohabiting partners		+50%	-	R	R
Emigration (in 2000)		-10%	R	R	R
Immigration (in 2000)		-10%	R	R	R
Adjustment factors for intensities:					
Mortality:					
males (in 2010)		-31%	-34%	R	-45%
females (in 2010)		-27%	-28%	R	-33%
Marriage:					
lone parents		+33%	+50%	R	R
other *		-36%	-40%	R	R
Divorce and separation:					
married couples without children		+50%	+10%	R	R
married couples with children		+50%	+100%	R	R
cohabiting partners		+50%	+10%	R	R
Fertility:					
married women		+20%	constant	+55%	R
single women		+80%	+300%	+133%	R
cohabiting women without children		+440%	+340%	+600%	R
cohabiting women with children		+80%	+300%	+133%	R
lone parents		+20%	+150%	+55%	R
other women		+20%	+100%	+55%	R
International migration:					
emigration (in 2000)		-10%	R	R	R
immigration (absolute numbers) (in 2000)		-10%	R	R	R

[1] R: Realistic Scenario value

* A reduction of marriage intensities is accompanied by a rise in corresponding intensities to form a consensual union, to the extent that the sum of these two intensities (i.e. the intensity to start a partner relation) remains unchanged.

10. HOUSEHOLD PROJECTIONS: RESULTS

10.1 The Realistic Scenario

Table 10.1 presents results of the Realistic Scenario. Multidimensional models produce thousands of numbers, when used for projections of the population according to age, sex, and additional characteristics for a number of years in the future. Thus, to avoid "hay-stacking" effects in the output, we selected only a few outcomes. The initial population is shown, as well as that for the years 2000, 2015 (when the youngest members of the post-World War II cohorts reach retirement age), 2035 (when aging is at its maximum), and 2050.
The development of the total population by household position is illustrated in Figure 10.1. Total population size reaches its maximum in 2025 (16.4 million), after which a gradual decline sets in. Developments of the population by household position are characterized by:

- a decrease in the number of children;
- a strong decline in the number of couples with children;
- an increase in the number of lone parents which is modest in the absolute sense, but much stronger in the relative sense;
- a diminishing average household size;
- an enormous growth in the number of individuals living in a one-person household.

The tremendous increase in the number of persons living alone is the most striking result of the application of the LIPRO model to household projections in the Netherlands, irrespective of the scenario chosen. Regarding this particular household trend we can speak of a forecast, since there is little uncertainty left: a variety of input scenario’s persistently resulted in an upward trend regarding persons living alone.

Table 10.1. Results of the Realistic Scenario

31 Dec. 1985	Females				Males				House-holds
	0-19	20-64	65+	total	0-19	20-64	65+	total	
	in thousands								
cmar	1705	237	0	1942	1792	474	0	2266	-
cunm	29	2	0	31	36	6	0	42	-
c1pa	178	49	0	227	193	114	0	307	-
sing	13	456	411	880	8	502	98	609	1489
mar0	4	865	357	1226	0	778	445	1224	1225
mar+	3	2145	34	2182	0	2122	67	2189	2186
unm0	8	197	13	217	1	218	12	230	224
unm+	0	41	0	42	0	44	1	45	44
h1pa	1	235	29	265	0	39	7	46	311
nfra	0	13	18	31	1	18	10	29	-
othr	20	66	47	133	20	80	17	117	89
total	1963	4306	909	7177	2052	4395	656	7104	5567

31 Dec. 2000	Females				Males				House-holds
	0-19	20-64	65+	total	0-19	20-64	65+	total	
	in thousands								
cmar	1522	312	0	1833	1578	579	0	2157	-
cunm	49	3	0	52	63	8	0	71	-
c1pa	222	140	0	361	227	292	0	520	-
sing	0	677	615	1292	0	777	190	967	2259
mar0	1	1010	480	1490	0	903	585	1488	1489
mar+	1	1948	45	1994	0	1951	50	2001	1997
unm0	0	178	5	183	0	187	9	196	190
unm+	0	60	2	61	0	62	2	64	63
h1pa	0	408	38	445	0	92	14	106	551
nfra	0	23	14	37	0	26	6	32	-
othr	22	78	32	132	25	90	9	124	91
total	1816	4836	1230	7882	1893	4967	867	7727	6641

31 Dec. 2015	Females				Males				House-holds
	0-19	20-64	65+	total	0-19	20-64	65+	total	
	in thousands								
cmar	1332	319	0	1650	1377	578	0	1955	-
cunm	82	4	0	86	97	9	0	106	-
c1pa	232	190	0	422	241	378	0	620	-
sing	0	927	841	1768	0	960	332	1293	3061
mar0	1	1039	649	1689	0	893	793	1686	1687
mar+	1	1610	58	1669	0	1607	69	1676	1672
unm0	0	195	6	202	0	197	17	214	208
unm+	0	97	4	101	0	98	5	104	102
h1pa	0	429	62	491	0	134	25	159	650
nfra	0	26	16	42	0	43	11	54	-
othr	23	80	35	138	27	101	12	140	98
total	1670	4916	1670	8257	1742	5000	1265	8007	7480

Table 10.1. Results of the Realistic Scenario (end)

	Females				Males				
31 Dec. 2035	0-19	20-64	65+	total	0-19	20-64	65+	total	House-holds
	in thousands								
cmar	1213	255	0	1468	1244	480	0	1724	-
cunm	155	5	0	160	173	10	0	183	-
c1pa	284	195	0	479	305	392	0	697	-
sing	0	974	1324	2298	0	1003	585	1588	3886
mar0	1	790	750	1541	0	638	900	1538	1539
mar+	1	1309	55	1365	0	1304	68	1372	1368
unm0	0	204	10	214	0	194	33	227	220
unm+	0	150	9	159	0	153	9	162	161
h1pa	0	408	71	479	0	142	35	178	657
nfra	0	27	26	53	0	46	25	71	-
othr	22	74	52	147	26	101	24	151	106
total	1675	4390	2297	8362	1748	4463	1680	7891	7938

	Females				Males				
31Dec. 2050	0-19	20-64	65+	total	0-19	20-64	65+	total	House-holds
	in thousands								
cmar	1145	253	0	1398	1171	465	0	1636	-
cunm	164	7	0	171	183	13	0	196	-
c1pa	288	204	0	492	311	414	0	725	-
sing	0	1000	1310	2311	0	992	569	1562	3872
mar0	1	739	615	1355	0	610	742	1353	1354
mar+	1	1224	42	1267	0	1221	53	1274	1271
unm0	0	211	9	220	0	195	38	233	226
unm+	0	151	11	162	0	156	9	164	163
h1pa	0	402	60	462	0	151	32	183	644
nfra	0	27	31	58	0	46	26	72	-
othr	21	72	51	144	25	100	24	148	104
total	1619	4289	2131	8039	1690	4364	1493	7546	7634

This trend is even stronger when the number of households is considered, instead of the number of persons by household position. Figure 10.2 shows the development in the number of households of various types for the Realistic Scenario. The increase in the proportion of one-person households is dramatic: from 27 percent in 1985 to no less than 51 percent in 2050.

The rise in the number of persons living alone goes hand in hand, to a large extent, with the general aging of the population. In 1985, 34 percent of the persons living alone was aged 65 or over; in 2035 and in 2050 the share is 49 percent. Also note the diminishing share of the traditional family in Figure 10.2, i.e. the married couple with one or more children. Changes in the age structure only partially explain this: elderly couples are more frequently in the "empty nest" phase than younger couples. However, changes in household formation patterns are more important: more couples remain childless, less persons marry, and more marriages are dissolved at a relatively early stage.

Figure 10.1. The population in private households by household position, the Netherlands, 1985-2050 (Realistic Scenario)

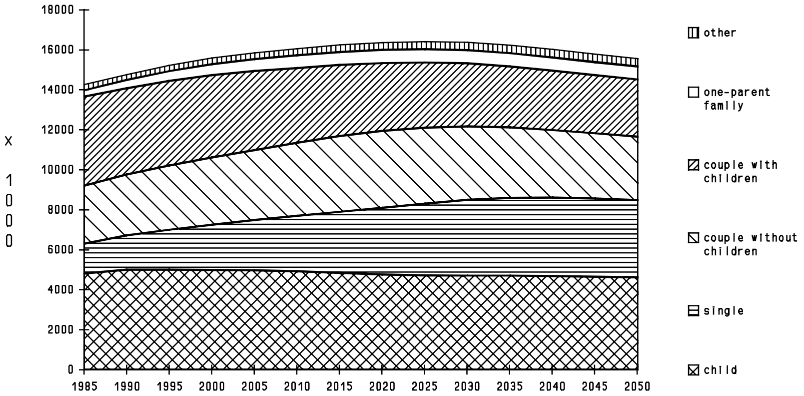


Figure 10.2. Private households by type, the Netherlands, 1985-2050 (Realistic Scenario)

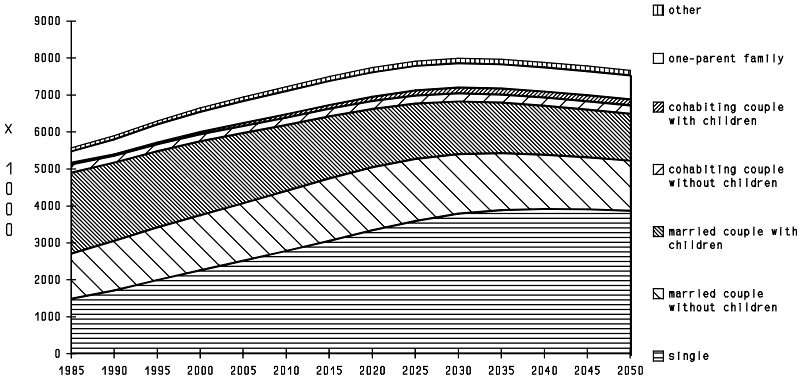


Figure 10.3. Age pyramid for some household positions, 1985

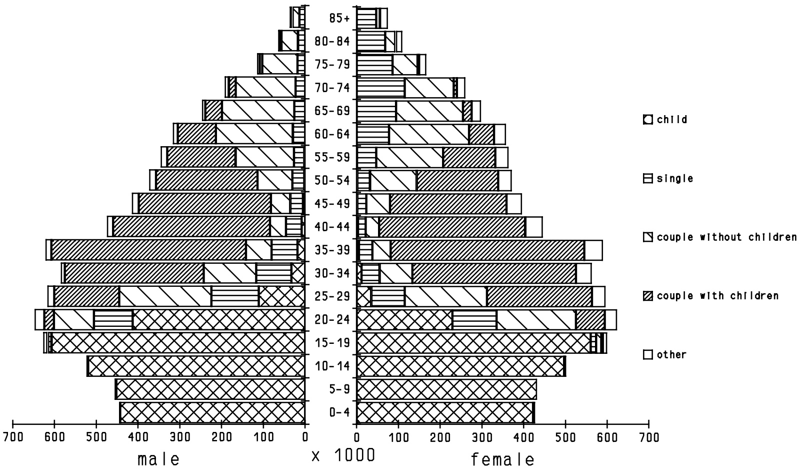
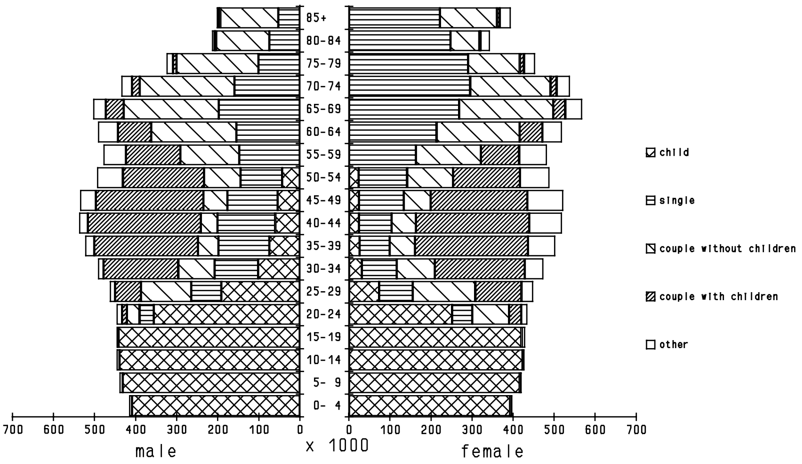


Figure 10.4. Age pyramid for some household positions, 2035 (Realistic Scenario)



The age pyramids in Figures 10.3 and 10.4 further illustrate the age-specific developments in household structure between 1985 and 2035. The strong growth of the number of elderly persons living alone comes out very clearly. Improved longevity is responsible for the rising numbers of elderly couples (both married and in consensual union) without children. Unmarried cohabitation will slowly become more popular among the elderly in the Realistic Scenario, but the numbers involved will remain low, as Table 10.1 indicates. Stated differently, the mean age of cohabiting persons will rise in the first half of the 21st century, especially among males.

10.2 | A comparison of the five scenarios

Main results of the five scenarios for the years 2035 and 2050 are presented in Table 10.2 and in Figures 10.5 to 10.8.

A comparison between the Realistic Scenario and the Constant Scenario reveals a large number of substantial differences. The size of the total population in private households, in particular, differs strongly between these two scenarios: in 2050, it is almost 2 million persons lower in the Constant Scenario. Also note the relatively high share, in the Realistic Scenario, of one-person households: in spite of the higher population size in this scenario, the share is 51 percent in 2050, as compared to 45 percent in the Constant scenario.

The remaining scenarios were designed as variants of the Realistic Scenario, and thus they will be compared with the latter scenario. The Constant Scenario, with its rather unrealistic assumption of constant demographic rates (note, in particular, the extremely low fertility as of 1985), is much less suitable for purposes of comparison, and hence will not be used as a benchmark.

Although the Swedish Scenario results in a somewhat larger share of one-parent families than the Realistic Scenario does, the differences between the two scenarios are surprisingly small, see for instance Figures 10.5 and 10.6. The limited impact for household structures in the Swedish Scenario of relatively high rates for starting a consensual union and the high share of births taking place outside wedlock is explained largely by the high marriage propensities of cohabiting couples with children (UNM+) in the Netherlands. In spite of the large influx into the UNM+ position, this position is rather unstable and a substantial part of the influx moves on quickly to the position MAR+. This makes the scenario less Swedish than it perhaps could have been.

Of course, the Fertility Scenario results in a larger total population; compare, for instance, Figure 10.7 and Figure 10.4. However, the consequences for household structures are very small indeed. The most important effect of increased fertility is a higher average household size for households with children; yet the share of such households in all households remains more or

Table 10.2. Results of the various scenarios, 2035 and 2050

Constant Scenario

31 Dec.	Females				Males				House-holds
2035	0-19	20-64	65+	total	0-19	20-64	65+	total	
	percentages								
cmar	83	6	0	10	83	11	0	24	-
cunm	3	0	0	1	3	0	0	1	-
c1pa	13	4	0	5	12	8	0	7	-
sing	0	19	59	25	0	18	31	17	45
mar0	0	24	31	21	0	19	58	22	23
mar+	0	34	2	19	0	33	4	21	21
unm0	0	4	1	2	0	4	2	3	3
unm+	0	1	0	1	0	1	1	1	1
h1pa	0	7	4	5	0	2	2	2	7
nfra	0	1	1	1	0	1	1	1	-
othr	1	2	2	2	1	1	1	2	1
	in thousands								
100%	1433	4317	1939	7689	1492	4346	1345	7183	7117

Constant Scenario

31 Dec.	Females				Males				House-holds
2050	0-19	20-64	65+	total	0-19	20-64	65+	total	
	percentages								
cmar	84	6	0	19	83	11	0	24	-
cunm	3	0	0	1	3	0	0	1	-
c1pa	12	4	0	4	12	8	0	7	-
sing	0	19	62	26	0	18	32	17	45
mar0	0	24	28	20	0	20	56	22	22
mar+	0	33	2	19	0	33	4	21	21
unm0	0	4	1	2	0	4	2	3	3
unm+	0	1	0	1	0	1	1	1	1
h1pa	0	7	3	5	0	2	2	2	7
nfra	0	1	1	1	0	1	1	1	-
othr	1	2	2	2	1	2	1	2	1
	in thousands								
100%	1319	4077	1746	7142	1373	4100	1170	6644	6612

Table 10.2. Results of the various scenarios, 2035 and 2050 (continued)

Realistic Scenario

	Females				Males				
31 Dec. 2035	0-19	20-64	65+	total	0-19	20-64	65+	total	House-holds
	percentages								
cmar	72	6	0	18	71	11	0	22	-
cunm	9	0	0	2	10	0	0	2	-
c1pa	17	4	0	6	17	9	0	9	-
sing	0	22	58	27	0	22	35	20	49
mar0	0	18	33	18	0	14	54	20	19
mar+	0	30	2	16	0	29	4	17	17
unm0	0	5	0	3	0	4	2	3	3
unm+	0	3	0	2	0	3	1	2	2
h1pa	0	9	3	6	0	3	2	2	8
nfra	0	1	1	1	0	1	1	1	-
othr	1	2	2	2	1	2	1	2	1
	in thousands								
100%	1675	4390	2297	8362	1748	4463	1680	7891	7938

Realistic Scenario

	Females				Males				
31 Dec. 2050	0-19	20-64	65+	total	0-19	20-64	65+	total	House-holds
	percentages								
cmar	70	6	0	17	69	11	0	22	-
cunm	10	0	0	2	11	0	0	3	-
c1pa	18	5	0	6	18	9	0	10	-
sing	0	23	62	29	0	23	38	21	51
mar0	0	17	29	17	0	14	50	18	18
mar+	0	29	2	16	0	28	4	17	17
unm0	0	5	0	3	0	4	3	3	3
unm+	0	4	1	2	0	4	1	2	2
h1pa	0	10	3	6	0	3	2	2	8
nfra	0	1	1	1	0	1	2	1	-
othr	1	2	2	2	1	2	2	2	1
	in thousands								
100%	1619	4289	2131	8039	1690	4364	1493	7546	7634

Table 10.2. Results of the various scenarios, 2035 and 2050 (continued)

Swedish Scenario

31 Dec. 2035	Females 0-19	20-64	65+	total	Males 0-19	20-64	65+	total	House-holds
	percentages								
cmar	61	5	0	15	59	10	0	19	-
cunm	15	0	0	3	15	0	0	4	-
c1pa	23	5	0	7	24	10	0	11	-
sing	0	20	57	25	0	23	36	20	48
mar0	0	19	33	19	0	15	53	20	20
mar+	0	27	2	15	0	27	3	15	16
unm0	0	6	1	3	0	5	3	3	3
unm+	0	4	1	2	0	4	1	2	2
h1pa	0	12	3	7	0	3	2	2	10
nfra	0	1	1	1	0	1	1	1	-
othr	2	2	2	2	2	2	1	2	1
	in thousands								
100%	1812	4402	2295	8509	1892	4484	1748	8124	8011

Swedish Scenario

31 Dec. 2050	Females 0-19	20-64	65+	total	Males 0-19	20-64	65+	total	House-holds
	percentages								
cmar	58	5	0	15	56	10	0	19	-
cunm	16	0	0	4	17	1	0	4	-
c1pa	24	5	0	8	25	11	0	12	-
sing	0	21	61	26	0	23	39	20	49
mar0	0	18	29	17	0	15	48	18	18
mar+	0	26	2	14	0	25	3	15	15
unm0	0	6	1	3	0	5	3	4	4
unm+	0	4	1	2	0	4	1	2	2
h1pa	0	12	3	7	0	3	2	2	10
nfra	0	1	1	1	0	1	2	1	-
othr	2	2	3	2	2	2	2	2	1
	in thousands								
100%	1842	4377	2128	8347	1923	4468	1565	7951	7772

Table 10.2. Results of the various scenarios, 2035 and 2050 (continued)

Fertility Scenario

31 Dec. 2035	Females 0-19	20-64	65+	total	Males 0-19	20-64	65+	total	House-holds
	percentages								
cmar	71	6	0	20	70	11	0	24	-
cunm	10	0	0	2	11	0	0	3	-
c1pa	17	5	0	7	18	9	0	10	-
sing	0	21	57	25	0	22	35	19	48
mar0	0	16	33	16	0	13	53	17	18
mar+	0	31	3	16	0	30	4	17	18
unm0	0	5	0	2	0	4	2	3	3
unm+	0	4	0	2	0	4	1	2	2
h1pa	0	10	3	6	0	3	2	2	9
nfra	0	1	1	1	0	1	1	1	-
othr	1	2	2	2	2	2	1	2	1
	in thousands								
100%	2148	4580	2298	9025	2242	4663	1675	8581	8087

Fertility Scenario

31 Dec. 2050	Females 0-19	20-64	65+	total	Males 0-19	20-64	65+	total	House-holds
	percentages								
cmar	69	7	0	21	68	12	0	25	-
cunm	11	0	0	3	12	0	0	3	-
c1pa	18	5	0	7	19	10	0	11	-
sing	0	22	61	26	0	22	38	19	49
mar0	0	15	29	14	0	12	59	15	16
mar+	0	30	2	16	0	29	4	17	18
unm0	0	5	0	3	0	4	3	3	3
unm+	0	4	1	2	0	4	1	2	3
h1pa	0	10	3	6	0	3	2	2	9
nfra	0	1	1	1	0	1	2	1	-
othr	1	2	2	2	1	2	2	2	1
	in thousands								
100%	2256	4763	2129	9148	2355	4862	1485	8702	8055

Table 10.2. Results of the various scenarios, 2035 and 2050 (end)

Mortality Scenario

31 Dec. 2035	Females 0-19	Females 20-64	Females 65+	Females total	Males 0-19	Males 20-64	Males 65+	Males total	House-holds
	percentages								
cmar	73	6	0	17	71	11	0	21	-
cunm	9	0	0	2	10	0	0	2	-
c1pa	17	4	0	6	17	9	0	8	-
sing	0	22	55	27	0	23	35	21	49
mar0	0	18	36	20	0	14	54	20	20
mar+	0	30	2	16	0	30	4	17	17
unm0	0	5	0	3	0	4	2	3	3
unm+	0	3	0	2	0	4	1	2	2
h1pa	0	9	3	6	0	3	2	2	8
nfra	0	1	1	1	0	1	1	1	-
othr	1	2	2	2	1	2	1	2	1
	in thousands								
100%	1682	4403	2399	8484	1757	4509	1917	8183	8173

Mortality Scenario

31 Dec. 2050	Females 0-19	Females 20-64	Females 65+	Females total	Males 0-19	Males 20-64	Males 65+	Males total	House-holds
	percentages								
cmar	71	6	0	17	69	11	0	21	-
cunm	10	0	0	2	10	0	0	3	-
c1pa	18	5	0	6	18	9	0	9	-
sing	0	23	58	28	0	23	38	21	50
mar0	0	18	32	18	0	14	49	19	19
mar+	0	29	2	16	0	28	3	16	16
unm0	0	5	0	3	0	4	3	3	3
unm+	0	4	1	2	0	4	1	2	2
h1pa	0	9	3	6	0	3	2	2	8
nfra	0	1	1	1	0	1	2	1	-
othr	1	2	2	2	1	2	2	2	1
	in thousands								
100%	1628	4303	2257	8188	1700	4415	1759	7874	7917

Figure 10.5. *Population by household position, 1985 and 2050, Realistic Scenario versus Swedish Scenario*

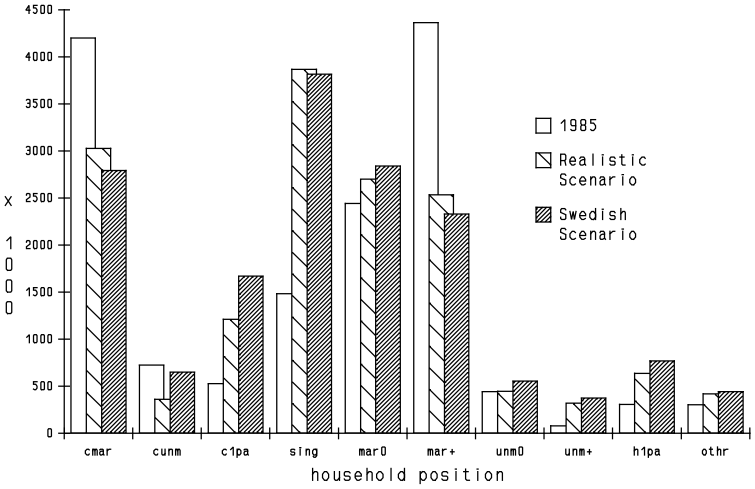


Figure 10.6. *Households by household type, 1985 and 2050, Realistic Scenario versus Swedish Scenario*

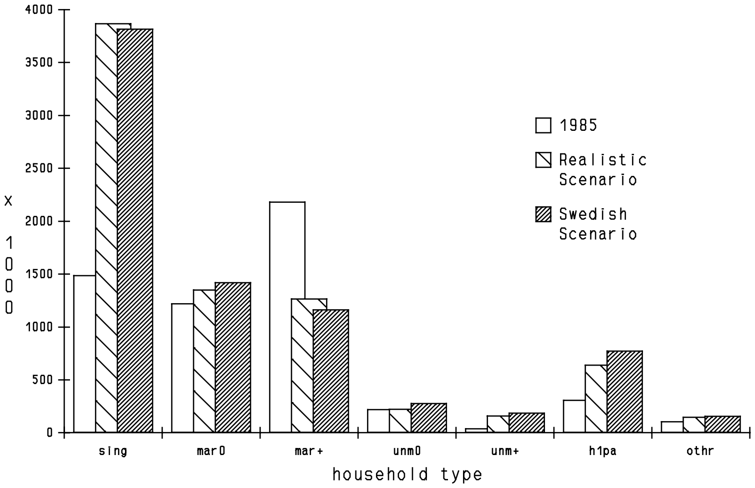


Figure 10.7. Age pyramid for some household positions, 2035 (Fertility Scenario)

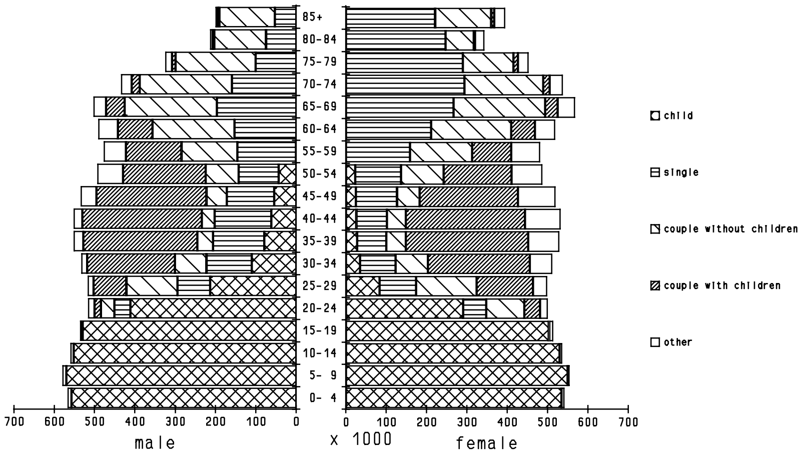
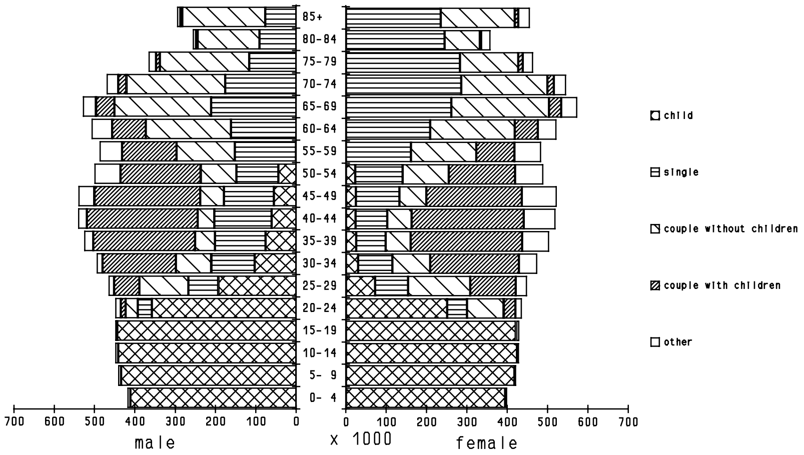


Figure 10.8. Age pyramid for some household positions, 2035 (Mortality Scenario)



less unchanged. The projection period is too short for the increased fertility to have any impact on the size and the composition of the elderly population. The share of this sub-group in the total population will diminish somewhat: for tha population aged 65 and over the figure is 20 percent in the Fertility Scenario in 2050, compared to 23 percent in the Realistic Scenario.

The Mortality Scenario results in even stronger aging effects than the Realistic Scenario. The elderly comprise 25 percent of the total population in 2050. Household structures are mainly affected for women: numbers of women living alone (mostly widows) are somewhat lower, and those for women living with their spouse a bit higher; compare Figure 10.8 with Figure 10.4.

10.3 | The effect of a particular model specification

The LIPRO model for the projection of households contains a number of innovations, compared to other demographic household projection models. Two important aspects of LIPRO are, firstly, its focus on household events for individuals, and secondly, the use of constant intensities (the exponential model) during the unit projection interval. As a consequence of the first aspect, it was necessary to formulate consistency relations for various household events to satisfy. Thus the occurrence of "impossible" numbers of household events was avoided as much as possible. The use of the exponential model is attractive from a theoretical perspective, but it requires much more computer time than the linear model.

We investigated the sensitivity of projection results for alternative model assumptions: consistency vs. no consistency, and the exponential vs. the linear model. Table 10.3 shows projection results for the Constant Scenario in the year 2035. When the consistency algorithm is switched off in the program, important differences arise for married persons and for children in one-parent families; compare columns 3-6. After 50 years, one observes a shortage of 50,000 married males without children, and a surplus of about the same amount among married males with children. Because birth rates and death rates differ by household position, total population size is also affected when consistency constraints are left out: it is 150,000 persons less in 2035.

The use of the linear model also leads to changes in the results, albeit smaller than in the previous case (compare columns 3 and 4 with columns 7 and 8). In particular, differences for single persons and for children can be observed, and hence also for the total population.

Table 10.3. Population by sex and household position, 1985 and 2035 (Constant Scenario), three model specifications

	1985		2035 Exponential, consistency		2035 Exponential, no consistency		2035 Linear, consistency	
	F	M	F	M	F	M	F	M
				in thousands				
cmar	1942	2266	1456	1723	1446	1709	1416	1691
cunm	31	42	40	54	35	51	39	53
c1pa	227	307	348	518	324	471	333	516
sing	880	609	1954	1218	1932	1189	2011	1287
mar0	1226	1224	1608	1606	1575	1626	1627	1625
mar+	2182	2189	1496	1504	1528	1477	1480	1489
unm0	217	230	186	198	161	221	188	200
unm+	42	45	46	49	45	52	46	49
h1pa	265	46	385	121	405	112	385	123
nfra	31	29	42	58	42	57	40	59
othr	133	117	129	133	135	127	130	131
total	7177	7104	7689	7183	7629	7091	7695	7223

10.4 | Comparison with the official NCBS population forecast

In constructing the Realistic Scenario, we have tried to adhere, as much as possible, to the demographic expectations contained in the official population forecast of the Netherlands Central Bureau of Statistics (1990). Although quite a number of differences exist between the LIPRO model and the NCBS projection model, both projections should produce at least roughly comparable results.

Table 10.4 compares the most important results of the NCBS projection (medium variant, projection 1990; see De Beer, 1990) with those of the Realistic Scenario. As far as the younger age groups are concerned, the results are reasonably close; there are some minor differences, notably for the age group 15-39, that could well be attributed to differences in the time path of the assumed demographic trends, and perhaps also to differences in the age pattern of international migration.

Table 10.4. Comparison of LIPRO projection with NCBS forecast (in thousands)

	NCBS forecast 1990, medium variant, population per January 1					
	1991	1995	2000	2005	2010	2020
0-14 years	2735	2834	2952	2958	2809	2504
15-39 years	6007	5906	5678	5402	5181	5148
40-64 years	4331	4638	5065	5556	5944	5801
65-79 years	1497	1559	1650	1694	1825	2397
80 years and over	438	484	515	582	618	666
total	15008	15420	15860	16192	16377	16517

	LIPRO, Realistic Scenario, population per December 31					
	1990	1995	2000	2005	2010	2020
0-14 years	2719	2763	2779	2691	2565	2471
15-39 years	5977	5811	5565	5315	5081	4942
40-64 years	4317	4712	5161	5611	5945	5715
65-79 years	1455	1549	1629	1700	1853	2466
80 years and over	307	387	456	563	639	790
total	14774	15223	15589	15880	16082	16385

For the older age groups, the differences between the two projections are significantly larger. The numbers in the LIPRO projection are initially below those of the NCBS forecast, which can be explained by the fact that the LIPRO calculations do not take into account the population in collective households. However, aging is more rapid in the LIPRO projections. The most probable explanation for these differences lies in the assumed mortality trends. Although the Realistic Scenario was set in such a way that the increase in life expectancy exactly follows the life expectancy in the NCBS forecast, the corresponding projected number of deaths is much smaller in the LIPRO projection as compared to the NCBS forecast.

This rather peculiar phenomenon can be explained from the fact that LIPRO and the NCBS have a different way of handling mortality differentials between household positions or marital states. Although the NCBS model recognizes mortality probabilities that differ across marital states, the model calculates both life expectancy and the projected number of deaths *without* taking the composition of the population by marital state into account; it is only in the second phase of the projection process that the projected aggregate number of deaths is subdivided into numbers of deaths by marital status. In the LIPRO model, on the other hand, deaths are immediately attributed to the relevant household positions. The result is that, with constant mortality rates, changes in the marital composition of the population do *not* affect the life expectancy in the NCBS model, while changes in household structue *do* affect the life expectancy in the LIPRO model.

Two groups of hypotheses for explaining differences in mortality rates across living arrangements (marital status or household position) can be distinguished (e.g., Beets and Prins, 1985, p. 53). The *protection hypothesis* states that the living arrangement explains mortality; single persons die earlier than married persons because the former have a less healthy life style. The *selection hypothesis* argues exactly the opposite: persons with a high mortality risk have a lower probability of marriage than persons with a normal mortality risk.

From the point of view of the selection hypothesis, changes in the household structure of the population should not be allowed to influence life expectancy, while it should be allowed to have an effect according to the protection hypothesis. Thus, one might conclude that in the NCBS model mortality is projected from the selection approach, while in the LIPRO model it is projected from the protection approach.

11. HOUSEHOLD PROJECTIONS AND SOCIAL SECURITY

Household projections such as those presented in the previous chapter may be used for several policy purposes, such as the planning of housing facilities, for tracing future consumption patterns, etc. In the present study, the projections served to assess *the impact of changes in age structure and household composition on social security expenditures* in the Netherlands. Hence the social security projections were not an end in itself, and therefore they are by and large of an illustrative nature.
It should be stressed that social security in the sense used here involves much more than just old age pensions. Welfare, survivor pensions, unemployment benefits, and other state subsidies to maintain a certain minimum income level are also included in the notion of social security. However, not all types of expenditures will be considered here. The focus will be on those expenditures that are particularly sensitive to household developments.

Section 11.1 presents a general discussion of the interrelations between social security and demography. Earlier studies applicable to the Netherlands are most relevant here, but a few international comparative studies are also reviewed briefly. Section 11.2 shows how LIPRO has been extended with a social security cost module. This module consists of a number of so-called *social security user profiles*, one for each type of benefit. These user profiles constitute a straightforward generalization of the age profiles which were employed earlier in studies into the impact of aging on social security expenditures (e.g. Holzmann, 1987; IMF, 1987). Section 11.3 contains the results of the illustrative social security projections.

11.1 | Demography and social security

11.1.1. General

Social security expenditures in the Netherlands amounted to 115 billion Dutch guilders in 1988; see Table 11.1. About 93 billion guilders were spent on social insurance. Within the latter group of regulations, the Ministry of Social Affairs and Employment of the Netherlands distinguishes the so-called *demographic regulations*, which constitute nearly one-third of all social security expenditures. These demographic regulations involve old age state pensions ("Algemene Ouderdomswet" or AOW), early retirement schemes ("Vervroegde Uittreding" or VUT), child allowance ("Algemene Kinderbijslagwet" or AKW), and survivor pensions ("Algemene Weduwen- en Wezenwet" or AWW). Section 11.2 presents a more extensive review of the Dutch social security system.

A certain social security scheme falls within the group of demographic regulations if its eligibility criterion is a demographic one. For instance, age (for old age state pension/AOW, and for child allowance/AKW), number and age of the children (AKW), age, marital status, and number of children under

Table 11.1. Social security expenditures in the Netherlands, 1975-1988

	1975	1980	1985	1988
		in DFl billion		
Total social security*	52.6	89.8	110.6	114.7
Including				
- social insurance	41.7	73.4	86.2	92.8
- social benefits	7.2	11.5	19.6	16.7
Share of total expenditures in net national income	26%	30%	29%	29%

* Excluding supplementary private pension insurance and regulations.

Source: Financiële Nota Sociale Zekerheid 1990, p. 152.

18 (for survivor pension/AWW) are relevant criteria for many of the demographic regulations. Non-demographic criteria, such as health and household income or individual income, are applied for eligibility assessment of the remaining regulations. The most important scheme in the latter group is welfare ("Algemene Bijstandswet" or ABW), which aims at ensuring a minimum income level.

In the present study, we selected three social security schemes: AOW, AWW, and ABW. The latter scheme was chosen because, in practice, a large part of the expenditures are supplied to lone mothers with insufficient income. On the other hand, we made projections for child allowance (AKW) but these will not be presented here, because the impact of the household structure of the population on AKW expenditures is very limited (Van Imhoff and Keilman, 1990a).

A number of authors have examined the link between demography and social security. Van den Bosch (1987) gives a systematic review, and he also discusses how these two issues are related to economic developments. Macro-demographic aspects such as population size and population structure are highly relevant here. However, micro-demographic aspects should also be considered: individual demographic behaviour, e.g. divorce, number of children, death, etc. Van den Bosch distinguishes two components with respect to social security:

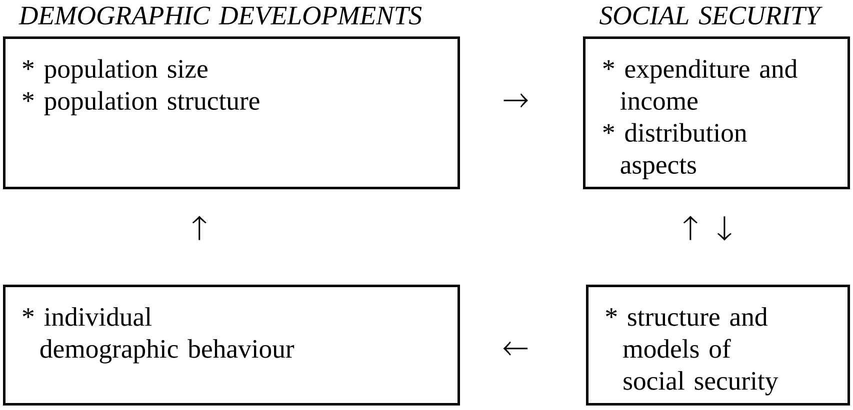
- expenditures, incomes, and distributional aspects;
- structure and models of social security.

Consequently, the relation between demography and social security may be studied at two levels, and in two directions; see Figure 11.1. The present study analyses the relationship denoted by the upper arrow: the impact of macro-demographic developments on social security expenditures.

11.1.2. Previous studies for the Netherlands

Table 11.2 shows the development of expenditures for the social security schemes of AOW, AWW, AKW, and ABW. The increase from DFl 21 billion in 1975 to the present level of DFl 38 billion is due to a number of factors: demographic factors (e.g. growth and aging of the population, changes in household structure), changes in eligibility criteria, variations in benefit levels, and inflation. Between 1975 and 1988, the population size rose from 13.6 million to nearly 14.7 million persons. The resulting average annual population growth rate of 0.6 percent is much lower than the average annual growth rate of 4.7 percent for expenditures of the four schemes presented in Table 11.2 for the same period. Hence demographic factors other than population size, as well as non-demographic factors have accounted for the larger share of the growth in expenditures.

Figure 11.1. Interrelations between demographic developments and social security



Based on: Van den Bosch (1987, p. 246).

Table 11.2. Expenditures for and number of recipients of demographic schemes, the Netherlands, 1975-1988 (see text for abbreviations)

	Expenditures (in DFl billion)			Recipients (* 1000)		
	1975	1980	1988	1975	1980	1988
AOW	11.7	19.4	24.9	1159	1280	1893
AWW	1.6	2.5	2.9	162	168	195
AKW	4.4	7.1	5.9	5186 1)	4865 1)	3585 1)
ABW 2)	3.1	4.5	4.0	229	162	216

1) Estimated on the basis of number of households by number of eligible children.
2) Senior citizens homes and "Rijksgroepsregeling Werkloze Werknemers/-RWW" excluded.

Source: Financiële Nota Sociale Zekerheid 1990, pp. 8-10, pp. 152-155.

International comparative studies, and studies pertaining to the Netherlands (both to be discussed below) have revealed that, generally speaking, the demographic component in the expenditures growth is less important than the non-demographic component. Increases in real benefits and inflation contribute much more than changes in demographic structure or population growth. These findings must be considered in conjunction with the rise of the welfare state in the industrialized world since the 1960s. A number of functions which has previously been performed by the family and other kin, were increasingly taken over by other institutions, in particular the state. Old age pensions and welfare are the most important examples here.

The approach which is generally taken to assess the impact of demographic and other components on social security expenditures is as follows. The population is divided into a number of relevant sub-groups, for instance according to age, or age and marital status. Two factors are determined for each sub-group: coverage, i.e. the proportion of persons relying on social security within the sub-group, and (average) level of benefits. Using standardization techniques, the contribution can be determined of the demographic component (size as well as demographic structure), the coverage component and the benefits level component (in nominal terms or in real terms) to overall expenditures.

Nelissen and Vossen (1984) analysed the impact of demographic factors on various social security expenditures in the Netherlands between World War II and 1982, and they considered the consequences of future population trends on these expenditures. The method used in the present project (see section 11.2) extends the approach employed by Nelissen and Vossen into two directions: the variety of future demographic trends is larger, and the household concept is used instead of marital status.

In chapters 9 and 10 we formulated a number of demographic scenario’s and computed their implication for the future age and household structure of the population. Nelissen and Vossen limited themselves to the population forecast of the Netherlands Central Bureau of Statistics (NCBS), which constitutes a probable (and hence relatively narrow, in terms of the span of possible futures) trajectory of the population.

In the population forecast, the NCBS categorizes the population by age, sex, and marital status. In the present project we go one step further: the individual’s household position is used instead of his or her marital status, because the former notion is more relevant regarding eligibility for many social security allowances than the latter notion is (see section 7.1). In their suggestions for further research, Nelissen and Vossen made this point as well (see also Van den Bosch, 1987, p. 251). However, the construction of an adequate household model was beyond the scope of their project.

The findings of Nelissen and Vossen for the period until 1982 can be summarized as follows. Expenditures for AOW, AWW, and AKW rose by 67 to 85 percent between 1975 and 1982. Non-demographic factors accounted for a growth of 60 to 63 percent, and inflation (43 percent) was much more important than real growth (12 to 16 percent). Demographic effects (growth in population size, changes in structure by age and marital status) resulted in a growth of 13 and 15 percent for AOW and AKW, respectively, and only 4 percent for AWW. For AOW and AWW expenditures, these demographic effects were almost entirely due to changes in population size (of the elderly and of widows, respectively). Changes in marital status structure of the population lead to a 5% decrease in AWW expenditures, whereas they had a negligible impact on AOW. These findings illustrate that for AOW, AWW, and AKW, demographic factors are much less important than non-demographic factors. Inflation was the major cause of the rise in expenditures between 1975 and 1982.

Because of a lack of data, Nelissen and Vossen could only analyse ABW benefits supplied to divorced women. The findings differ strongly from those for AOW, AWW, and AKW. The increase in the number of ABW benefits (81 percent in the period 1975-1982) was much sharper than that for the other three schemes. This is entirely due to demographic factors, in particular, growing numbers of divorced women. Other factors had a negative impact (minus 7 percent).

The relatively modest role of demographic factors in trends in social security developments was also assessed by Goudriaan *et al.* (1984). These authors investigated expenditures for AOW, AWW, ABW (supplied to divorcees), as well as a number of other schemes for the period 1970-1981. They found a rise in real expenditures for these schemes of 94 percent. On the basis of demographic factors alone (i.e. population growth, and changes in population structure according to age and marital status), the growth would have been only 16 percent.

Two important non-demographic causes for the growth in social security expenditures are:

1. more extensive coverage;
2. a real growth of benefit levels.

Goudriaan *et al.* concluded that the first cause was the major one behind the growth in expenditures for disability schemes. A real growth of benefit levels is related to economic growth, and leads to an increase in the spending power of households which solely rely on social security. In fact, a real benefit growth should be interpreted the same way as inflation.

On the basis of their analysis of observed trends, Nelissen and Vossen projected trends in future social security expenditures as far as they are related to demographic factors. Concerning non-demographic factors, these authors assumed no changes in the social security system - in particular this means that real benefit levels and coverage rates for each population sub-group are kept constant. Table 11.3 is due to Nelissen and Vossen (1984, pp. 145-146), who based their calculations on the NCBS population forecast of 1980. Most striking are the strong rise in AOW expenditures (in particular after 2010, when the post-World War II baby boom reaches retirement age) and ABW expenditures for divorced women (until approximately the year 2010).

These findings agree rather well with those from other studies. Van den Bosch (1987, p. 258) reviewed three projections for social security expenditures for the period 1985-2020. Although these studies apply to different sets of schemes (they represent between 48 and 56 percent of all social security expenditures), the results are basically the same: between 1985 and 2000 a rise in expenditures of 15-19 percent can be noted, and over the period 2000-2020 the growth is 10-15 percent. Finally, we mention the conclusions of a committee, installed by the Netherlands Ministry of Social Affairs and Employment, that reported in 1987 on financial issues related to future old age pensions ("Commissie Financiering Oudedagsvoorziening"). For social security (AOW, AWW, AKW, ABW for divorcees, and two disability schemes), the committee noted an increase in expenditures of 23-30 percent for the period 1985-2030, depending on future demographic developments. The rise would be particularly strong

Table 11.3. *Projected expenditures for AOW, AWW, and ABW, the Netherlands (see text for abbreviations)*

	AOW	AWW	ABW*
	in DFl billion		
1982	21.4	2.6	-
	index (1982 = 100)		
1985	104	105	120
1990	113	102	152
2010	139	117	196
2030	197	97	158

* Only for divorced women under 65.

Source: Nelissen and Vossen (1984, pp. 145-146).

between 1985 and 2010: 18-21 percent. For AOW alone, the growth in expenditures would be around 104 percent until 2030 (42 percent until the year 2010). Note how close the latter results are to those of Nelissen and Vossen (see Table 11.3).

11.1.3. International comparative studies

International comparative analyses into the impact of demographic factors on future social security expenditures were recently carried out by the OECD and the IMF; see for instance Holzmann (1987) and Heller *et al.* (1986). A major difference between these studies and the Dutch studies reviewed above is that in the former, demographic effects are restricted to shifts in the *age structure*, while in the latter studies the population was broken down by *age and marital status*.

Holzmann (1987) investigated public expenditures on pensions in the twenty OECD countries during the period 1960-1984. Table 11.4 contains a selection of his main findings. It includes three countries which take an extreme position with respect to demographic effects on expenditure growth: Ireland, Austria and Japan. The latter country's population is aging relatively quickly. Hence in both sub-periods it shows the strongest demographic effects on expenditure growth: about twice as much (4.8 and 3.4 percent per annum) as the average OECD growth (2.3 and 1.6 percent). Irish and, to a certain extent, also Austrian populations are aging much slower than the OECD countries as a whole. Thus for the periods 1960-1975 and 1975-1984, respectively, these countries have the weakest demographic component. In the Netherlands, the demographic effects are close to the OECD average (2.4 and 1.7 percent). Table 11.4 clearly shows that the modest contribution of purely demographic effects to public expenditures for pensions in the Netherlands in the past can also be found in other OECD countries. In the OECD as a whole, the contribution of demographic factors to real expenditures growth is roughly one-third (2.3/8.4 and 1.6/4.7). For the Netherlands, the ratio is 21 percent for the period 1960-1975, but for the subsequent period the demographic component constitutes almost half (47 percent) of the total real growth.

Regarding future trends in (real) public expenditures to old age pensions, Holzmann assumed that average life expectancies at birth in Member countries would increase by approximately two years until 2050. This led him to conclude that expenditures in the OECD would rise by 35 percent in the period 1985-2010, and by 87 percent during the years 1985-2030. These results agree rather well with those of Nelissen and Vossen for AOW in the Netherlands; see Table 11.3.

A strong future rise in public expenditures for old age pensions can also be noted from the study carried out by staff of the IMF. Table 11.5 summarizes the main findings for a number of industrialized countries. The calculations are made on the basis of a benchmark scenario, in which birth rates and mortality rates, as observed at the end of the 1970s, were kept constant.

Table 11.4. Average annual growth rate in public expenditure on pensions in OECD countries

	Nominal growth	Real growth			
		Total	Components		
			Demographic	Coverage	Expenditure per recipient
	percentage points				
Unweighted average for all OECD countries					
1960-1975[1)]	14.6	8.4	2.3	1.6	4.6
1975-1984	14.7	4.7	1.6	1.5	2.2
Selected OECD countries:					
1960-1975					
Netherlands	17.4	11.2	2.4	0.1	8.5
Ireland	16.6	8.4	0.8	1.3	6.2
Japan	21.4	13.0	4.8	4.4	2.6
1975-1984					
Netherlands	9.2	3.6	1.7	0.9	1.0
Austria	9.3	3.9	-0.5	2.3	2.1
Japan	12.6	11.1	3.4	2.2	5.1

1) Excluding Greece, Portugal, and Spain.

Source: Holzmann (1987, p. 420).

Table 11.5. Public expenditures for old age pensions in selected industrialized countries (index 1980=100)

	2000	2010	2025
Canada	154	189	317
France	175	230	325
Federal Republic of Germany	180	218	300
Italy	198	285	498
United Kingdom	159	199	290
United States	145	178	306

Source: Heller *et al.* (1986, p. 31).

The growth in expenditures in the six selected countries is stronger than that in the Netherlands: expenditures rise by between 80 (the US) and 185 (Italy) percent during the period 1980-2010, and by no less than 190 (the UK) to 400 (Italy) percent during 1980-2025. The relatively low growth rates for the Netherlands are caused by the rather high birth rates that could be observed in that country until the mid-1960s. Compared with the six other countries, this leads to a low proportion of the population aged 65 or over for the first few decades of the 21st century.

11.1.4. Conclusions

Three general conclusions become immanent on the basis of the existing literature.

1. The impact of demographic factors on most social security expenditures has been rather limited in the last few decades. At least as important (if not more important) were non-demographic factors such as inflation and the level of the benefits. For expenditures as a proportion of net national income, the impact of demographic factors is, of course, much stronger.
2. On the basis of demographic factors alone (and assuming no changes in the social security system), a sharp increase can be expected in public social security expenditures for the next few decades, in particular for old age pensions.
3. Concerning methodology, the approach taken in the current project is a further refinement of earlier approaches. A number of Dutch studies dealt with the impact of age, sex, and marital status on expenditures. In the

current project, this approach is extended to include household position of the individuals concerned, instead of marital status. Demographic characteristics other than age and sex are rarely used in international studies.

11.2 | Method[1]

If one is prepared to make certain assumptions about the way in which social security expenditures are distributed across the population, then demographic projections can be used to yield projections of social security outlays. Such assumptions would concern participation rates and average benefit levels for each cell in the demographic cross-classification table. For both variables we use the term *user profile*.

An example may clarify this approach. Let us assume that the number of female heads of a one-parent family in the age group 40-44 in the Netherlands will increase from 30,000 now to 50,000 in 1995. A user profile indicates that 80 percent of these women are on welfare at an average level of 15,000 Dutch guilders per year. The increase in welfare allowances induced by the change in household composition would then be from 0.80 * 30,000 = 24,000 now to 0.80 * 50,000 = 40,000 in 1995. The corresponding increase in welfare expenditure would be from Dfl 36 million now to Dfl 60 million in 1995, which amounts to additional welfare outlays of Dfl 24 million.

A complete user profile comprises *all* categories distinguished in the demographic projection model, defined by the relevant combinations of sex, age, and household position. If desired, user profiles can be constructed for different types of social security allowances, e.g. old age state pensions, disability allowances, welfare, etc.

Although for the purpose of the present project we have assumed that user profiles are invariant over time, there is no compelling reason for doing so. On the basis of expected or presumed changes in economic conditions, social security policy, and/or behavioural patterns, future trends in user profiles can be postulated and their effects on social security expenditures calculated. Just like the demographic model allows one to formulate various scenarios for demographic behaviour, the social security module also allows one to specify scenarios for social security behaviour.

Official data on numbers and average levels of social security allowances are very scarce. A complete breakdown by age, sex, and household position is not

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[1] The description of the social security system in this section applies to the situation in the Netherlands in the base year of the projection, i.e. 1985. Changes in the system that have taken place after that year have not been taken into account in the present study.

generally available for most arrangements. We therefore decided to rely on the WBO 1985/1986 to yield the necessary social security user profiles, although it is widely acknowledged that self-reported income data suffer from high selective non-response, and are otherwise notoriously unreliable. However, the results of the exercise turned out to be reasonably consistent with aggregate data from other sources.

The WBO 1985/1986 contains data on non-labour net income from 14 different sources for the persons who answered the questionnaire for the household in question, and for his/her partner, if present. Of these 14 sources, we investigated three: old age pensions (AOW), widow's and orphan's benefits (AWW), and social welfare (ABW).

AOW benefits depend directly on the household situation of the elderly. Each of the two spouses of a married couple (living in the same household) receives 70 percent of the social minimum level, while a person who lives alone gets 100 percent. For AWW, the household situation is not immediately relevant, but many widows who receive this form of social security will be a lone mother (H1PA) or a single person (SING). The household situation also plays an indirect role for ABW: this social security scheme is intended to maintain the economic position at the social minimum level. In practice, much of the ABW goes to divorced mothers and single persons with insufficient income.

The levels of the three benefits mentioned above are net levels, after deduction of income tax and social security premiums. Since most of these benefits are at or close to the social minimum level, the difference between net and gross benefits is relatively small because of the progressive Dutch tax scale. Respondents who reported they were on social security, without providing information about the level of the benefit, were assumed to receive the average benefit of those respondents in the same category who did give the benefit level.

For each of the three social security arrangements, 11 household positions, and two sexes, this procedure yielded two age-user profiles: one for the fraction of the population on social security, and one for the average net benefit per individual.

In order to check the reliability of these user-profiles, the data were compared to statistics from the NCBS Personal Income Distribution 1985. Some aggregation across household positions and social security schemes was necessary to make such a comparison possible. The results of the calculations are summarized in Table 11.6.

As can be seen from Table 11.6, the various data sources are reasonably consistent, with a possible exception for the social provisions. There the difference can mainly be attributed to the fact that Unemployment Benefits (RWW) to children living with their parents are not observed in the WBO 1985/1986.

Table 11.6. Comparing social security data from different sources

	Total	Share of household types (%) 5)				
	=100%	SING	MAR0	MAR+	1PAF	OTHER
Old age state pensions (AOW)						
Number of recipients 1):						
PID 1985 2)	1,554.7	31	49	7	3	10
WBO 1985/1986 3)	1,414.7	34	50	6	2	7
Aggregate outlays 4):						
PID 1985	19,085.0	35	44	7	4	10
WBO 1985/1986	17,168.0	36	48	7	2	7
Widow's and orphan's benefits (AWW)						
Number of recipients:						
PID 1985	143.8	46	0	0	36	17
WBO 1985/1986	141.0	47	1	1	42	9
Aggregate outlays:						
PID 1985	2,041.3	44	0	0	39	17
WBO 1985/1986	1,877.0	45	1	1	45	9
Social provisions (ABW+RWW) 6)						
Number of recipients:						
PID 1985	688.8	27	5	31	20	17
WBO 1985/1986	367.5	35	5	15	31	14
Aggregate outlays:						
PID 1985	8,074.6	26	6	26	27	15
WBO 1985/1986	4,825.0	31	6	18	34	11

1) In thousands.
2) NCBS Personal Income Distribution 1985.
3) Own calculations, based on NCBS Housing Demand Survey 1985/1986.
4) Net outlays, in Dfl million.
5) SING = one-person households.
MAR0 = married couples without children.
MAR+ = married couples with children.
1PAF = one-parent families.
6) RWW = Unemployment Benefits.

In the calculations to be presented in section 11.3, we will limit ourselves to *relative* changes in social security outlays. This further reduces the number of objections against using self-reported income statistics.

As stated above, constant user profiles were applied in the illustrative social security projections. Hence, in following this procedure, we assumed that for each combination of age, sex, and household position, the use of the various social security schemes remains unchanged. Because the primary aim of this study is to assess the impact of household changes on social security expenditures, and *not* to make a forecast of these expenditures, the assumption is less restrictive than it might seem at first sight.

However, the assumption of constant user profiles poses a problem for survivor pensions (AWW) and welfare (ABW). The problem is caused by the fact that the household positions "Single" (SING) and "Head of one-parent family" (H1PA) are not broken down by marital status, i.e. the type of event which led to the household position. With respect to the positions SING and H1PA, AWW pensions are wholly paid to widowed persons, whereas the greater part of ABW is supplied to divorcees. The assumption of constant user profiles implicitly presupposes that for AWW and ABW, the composition according to marital status remains the same for the positions SING and H1PA for each combination of age and sex. This assumption is rather unlikely, given the results of the demographic scenarios.

Two strategies may be adopted to deal with this problem. First, the state space may be extended by breaking the positions SING and H1PA further down according to marital status. This approach, leading to 19 household positions, was followed in experimental calculations in this project. Results will not be reported here - the interested reader is referred to Van Imhoff and Keilman (1990a). A second approach, followed in the present text, is to combine results for AWW and ABW. There are valid reasons to do so: both schemes are primarily aimed at women and their dependent children after marriage dissolution. The level of both allowances is largely independent of the marital status of the recipient.

11.3 | Illustrative social security projections

In the presentation of social security results, the following symbols are used for summary variables:

1. N: Projected number of recipients.
2. U: Projected total amount of expenditures in Dutch Guilders.
   The projected amounts are in constant guilders. Thus an increase in spending power is not accounted for. This poses no problems insofar as the spending power develops in parallel to average real wages, because it is implicitly

assumed that recipients benefit from economic growth, *casu quo* that they are protected against negative consequences of inflation.

Trends in numbers of recipients or expenditures have to be related to population variables, in order to indicate the relative burden for society. Much of social security costs are paid for by the working population. Ideally, one should relate social security projections to the labour force, and take wage levels into account. Such calculations are beyond the scope of the present study. As a first approximation, the following variables were used:

3. U/P: The average level of benefits per head of the population.
4. U/L: The average level of benefits per head of the potential labour force. (L). The potential labour force is defined as the population between 20 and 64 years of age.

The presentation of the results for these four summary variables will emphasize relative trends, using index figures with 1985 as the base year.

11.3.1. Old age pensions

Table 11.7 illustrates the development over time of summary variables related to old age state pensions in the Realistic Scenario. From 1985 to 2035, total outlays rise steadily to more than twice the expenditures in 1985. Next, a modest decline sets in. When aging is at its maximum, total expenditures amount to 2.7 times Dfl 22.9 billion, or 61.8 billion guilders. This corresponds to 16 percent of the net national income in 2035 (assuming that the net national incomes grows at the same rate as the population aged 20-64)! In 1985 the share is only 6 percent.

Changes in the household structure of the elderly cause expenditures to rise more sharply than total outlays (270 versus 254 in 2035). In particular, this can be attributed to the rising share of elderly single persons (and the diminishing proportion of those living with a spouse), because two single persons together receive 40 percent more AOW than a couple does (see section 11.2).

The last column of Table 11.7 indicates that during the first few decades of the projection period the potential labour force (population aged 20-64) grows more quickly than the number of elderly. After 2010, the large birth cohorts born immediately after World War II reach retirement age, and a reverse effect sets in, implying an increasing burden to the economically active population. (It should be emphasized, however, that total AOW expenditures relative to the *actual* labour force are likely to rise less strongly than those relative to the *potential* labour force because of the upward trend in female labour force participation in the Netherlands.)

Next we turn to a comparison of the five demographic scenarios. The corresponding time paths of AOW expenditures are presented in Table 11.8.

Table 11.7. Projections for old age state pensions (AOW) - Realistic Scenario

	Number of outlays N	Total expenditures U	Expenditures per capita U/P	Expenditures per capita aged 20-64 U/L
1985	1.57 mln = 100	22.9 bln = 100	DFl 1603 = 100	DFl 2632 = 100
1990	113	114	110	107
1995	124	126	118	114
2000	134	136	125	121
2005	145	148	133	129
2010	159	163	145	141
2015	188	192	169	169
2020	208	215	187	191
2025	227	237	206	216
2030	244	257	224	244
2035	254	270	237	265
2040	252	269	239	269
2045	242	260	235	260
2050	232	250	229	251

Differences between the scenarios turn out to be quite small, with the exception of the rather improbable Constant Scenario. The relatively favourable life chances under the Mortality Scenario lead to additional expenditures of 4.5 billion guilders in 2035. The Fertility Scenario clearly implies lower expenditures per capita of the potential labour force (U/L) from the time the additional children appear on the labour market (around 2015), but the effect of increased fertility is relatively modest: the rise in U/L until 2050 (125 percent) is only 25 percentage points lower than the increase under the Realistic Scenario.

Finally, the projections imply a sharper rise in old age state pension expenditures than those in the studies mentioned in section 11.1.2. Both Nelissen and Vossen (1984) and the "Commissie Financiering Oudedagsvoorziening" project expenditures in 2030 that are approximately twice as high as those in 1985, whereas our results imply a factor of about 2.5. The difference can be attributed to two circumstances. Firstly, our projections are based on lower mortality and higher immigration than the other two studies. Secondly, the introduction of household position has led to relatively many elderly who live alone.

Table 11.8. AOW expenditures under various scenarios

	Constant	Realistic	Swedish	Fertility	Mortality
Total AOW expenditures, index 1985=100 (DFl 22.9 bln)					
1985	100	100	100	100	100
1990	114	114	114	114	114
1995	125	126	126	126	127
2000	132	136	137	136	138
2005	139	148	148	148	151
2010	149	163	164	163	168
2015	170	192	194	192	201
2020	186	215	217	215	226
2025	201	237	239	237	251
2030	215	257	260	257	274
2035	222	270	274	269	290
2040	219	269	273	269	291
2045	209	260	264	259	284
2050	199	250	254	249	274

	Constant	Realistic	Swedish	Fertility	Mortality
Expenditures per capita of potential labour force, index 1985=100 (DFl 2632)					
1985	100	100	100	100	100
1990	107	107	107	107	107
1995	113	114	114	114	115
2000	117	121	121	121	122
2005	122	129	130	129	132
2010	129	141	142	141	145
2015	150	169	170	168	175
2020	167	191	193	189	200
2025	186	216	219	212	228
2030	207	244	247	237	259
2035	223	265	268	254	283
2040	225	269	271	253	289
2045	218	260	262	240	282
2050	212	251	250	225	273

The small effect on expenditures resulting from a rise in fertility may be compared with a similar effect of increasing migration. Elsewhere (Van Imhoff and Keilman, 1990b) we assumed a rise of the numbers of immigrants by 50 percent over the period 1986-2000, and a constant level after 2000. Emigration rates were kept at their 1985 level, while other parameters were the same as those in the Realistic Scenario. This high immigration scenario resulted in a growth in the index (1985=100) for the old age state pension expenditures per potential worker to 220 in 2040, and a subsequent decline to a level of 207 in 2050. These index numbers are within the range defined by the scenarios in Table 11.8 - in fact they are very close to those of the Constant Scenario. This illustrates the point that neither an increase (within reasonable bounds) in fertility nor an increase in immigration results in a substantial reduction of the social security burden which may be expected for the future.

11.3.2. Survivor pensions and social welfare

This sub-section discusses results for widow's and orphan's pensions (AWW) and social welfare (ABW). In the presentations, we have aggregated AWW and ABW for reasons discussed in section 11.2.

Table 11.9 demonstrates that total outlays increase considerably, in particular during the first two decades of the projection period. From the year 2010 onwards, the growth is somewhat stronger than that in total outlays per capita of the potential labour force. This reflects a modest shift from one-parent families to single persons within the group of recipients.

The various scenarios (see Table 11.10) only demonstrate minor differences. The rise in expenditures until 2050 in the Swedish Scenario is about 30 percentage points higher than that in the Realistic Scenario. This is due to a more rapid growth in the number of one-parent families caused by higher divorce levels. The additional expenditures in the Fertility Scenario may be traced back to the fact that relatively many children are confronted with their parents' divorce.

11.3.3. The usefulness of including household structures in social security projections

As stated in section 11.1, the novelty of the approach presented here lies in the fact that the present model breaks the population down according to household position, whereas earlier studies did not. An obvious question is, to what extent our projection results would be altered if household structures would *not* have been taken into account. To investigate this, the demographic projections in the Realistic Scenario were combined with social security projections according to four different user profiles:

1. the full profile, implying a breakdown of the population according to age, sex, and household position;
2. a profile with a breakdown by age and sex;

Table 11.9. Projections for the sum of survivor pensions (AWW) and welfare (ABW) - Realistic Scenario

	Number of outlays N	Total expenditures U	Expenditures per capita U/P	Expenditures per capita aged 20-64 U/L
1985	0.29 mln = 100	6.3 bln = 100	DFl 441 = 100	DFl 724 = 100
1990	117	118	114	111
1995	136	137	128	124
2000	156	156	143	139
2005	177	176	159	154
2010	195	191	173	165
2015	203	199	179	174
2020	213	207	186	185
2025	218	212	190	194
2030	217	211	189	200
2035	211	205	185	202
2040	209	204	186	203
2045	211	206	191	206
2050	213	207	195	208

3. a profile with a breakdown by sex and household position;
4. a profile with a distinction by sex only.

Results for AOW and AWW+ABW are given in Table 11.11.
The conclusion is that old age state pensions are not very sensitive to changes in household composition. A model that does not include household position performs almost as well as the LIPRO household model, as far as old age pensions are concerned - compare the first and the second column in the upper panel. The age effect is by far the dominant factor.
The opposite holds true for widow's and orphan's benefits; see the lower panel of Table 11.11. Here the use of user profiles without a distinction according to household position (column 2) leads to estimates of total outlays that are way off the mark. The inclusion of household position as an extra dimension in the state space (in addition to age) results in much more accurate social security projections.

Table 11.10. AWW+ABW expenditures under various scenarios

Total AWW+ABW expenditures, index 1985=100 (DFl 6.3 bln)

	Constant	Realistic	Swedish	Fertility	Mortality
1985	100	100	100	100	100
1990	118	118	118	118	118
1995	135	137	139	137	136
2000	151	156	162	157	156
2005	166	176	185	177	174
2010	177	191	204	194	189
2015	179	199	215	203	196
2020	181	207	227	213	205
2025	180	212	235	220	210
2030	172	211	236	221	208
2035	163	205	232	218	203
2040	158	204	231	219	202
2045	157	206	234	224	204
2050	155	207	236	229	205

AWW+ABW expenditures per capita of potential labour force, index 1985=100 (DFl 724)

	Constant	Realistic	Swedish	Fertility	Mortality
1985	100	100	100	100	100
1990	111	111	111	111	111
1995	122	124	126	124	124
2000	134	139	144	140	138
2005	146	154	162	155	152
2010	154	165	176	168	163
2015	158	174	188	177	171
2020	163	185	202	188	181
2025	166	194	215	198	191
2030	166	200	224	204	196
2035	163	202	227	205	198
2040	163	203	229	206	200
2045	164	206	231	207	203
2050	165	208	232	207	204

Table 11.11. Four methods to project social security expenditures, Realistic Scenario

	Full user profile[1]	Household position excluded	Age excluded	Age and hh-position excluded
AOW expenditures, index 1985=100 (DFl 22.9 bln)				
1985	100	100	100	100
1990	114	113	110	104
1995	126	125	121	107
2000	136	135	131	109
2005	148	146	141	111
2010	163	161	152	113
2015	192	189	162	114
2020	215	210	171	115
2025	237	229	177	116
2030	257	247	181	115
2035	270	258	181	115
2040	269	257	180	113
2045	260	248	178	111
2050	250	238	175	110
AWW+ABW expenditures, index 1985=100 (DFl 6.3 bln)				
1985	100	100	100	100
1990	118	102	119	104
1995	137	106	138	107
2000	156	110	153	110
2005	175	116	165	112
2010	191	120	174	113
2015	198	119	181	115
2020	207	118	188	116
2025	212	116	194	117
2030	211	112	198	117
2035	205	107	199	116
2040	203	105	199	115
2045	205	105	198	113
2050	206	104	196	111

1) User profile includes sex and household position.

It should be noted that the results for AOW expenditures indirectly illustrate the strong relation between age and living arrangement. Adding household position to a profile with a breakdown according to age only, does not yield any substantial improvement. However, a profile in which age is *replaced* by household position projects nearly half the total rise in expenditures (cf. the first and the third column of the upper panel of Table 11.11). This may be explained by the fact that most of the single persons are aged 65 and over.

12. SUMMARY AND CONCLUDING REMARKS

This book reports the findings of the research project "The impact of changing household structures on future social security expenditures in the Netherlands", which was carried out at the Netherlands Interdisciplinary Demographic Institute (NIDI) with financial support from the Netherlands Ministry of Social Affairs and Employment. The aim of this project was to construct a dynamic household projection model, to formulate various scenarios for possible demographic futures of the Netherlands' population, to carry out a projection of the future population of the Netherlands broken down by age, sex, and household position, and, finally, to trace the consequences of these future demographic developments, in particular, changes of household structures, for some social security expenditures.

The model constructed during the project is called LIPRO ("LIfestyle PROjections"). It is a very general and flexible multidimensional projection model, including a number of methodological innovations. In particular, these innovations involve the exponential specification of the projection model and the so-called consistency algorithm. A solution has been found which extends existing constant intensities models to include entries (for instance, due to immigration or childbearing). Moreover, LIPRO contains a very general algorithm to effectively deal with problems that arise because the behaviours of various individuals belonging to the same household are interrelated. In traditional demography this is known as the two-sex problem: the number of males who marry in a certain period should equal the number of marrying females. In LIPRO the problem has been reformulated in a much more general manner as a so-called consistency problem. The solution we propose can handle the relation between two or more adults, and that between children and parents, under processes of household formation and household dissolution.
The projection model is available as a computer program, called LIPRO 2.0. The user's guide to the program, and the program itself are included in this book.

For the present application, one of the dimensions of the projection model was chosen such that it describes the population in private households broken down by 11 household positions. A specification of households by type can be derived in a straightforward manner from the population broken down by the individual household positions. The 11 individual household positions define seven household types: one-person household, married couple without children, married couple with children, cohabiting couple without children, cohabiting couple with children, one-parent family, and other household. We identified the 113 different types of household events which individuals may experience as they jump from one of the 11 individual household positions to another, as well as those due to birth, death, immigration, and emigration. Moreover, consistency considerations gave rise to 37 different constraints on various household events. Input parameters of the model ("occurrence-exposure rates") and the initial population for the projection were estimated for males and females in 5-year age groups. The larger part of the input rates was derived from the Housing Demand Survey carried out by the Netherlands Central Bureau of Statistics, which contains information on current and past household status of the members of 47,000 private households in 1985 in the Netherlands.

Five scenarios were formulated for the demographic projection:

- the *Constant Scenario* illustrates how the population in private households in the Netherlands would evolve if household dynamics as observed in the year 1985 would also apply to the future;
- the *Realistic Scenario* fits in, as much as possible, with the demographic expectations contained in the official population forecast of the Netherlands Central Bureau of Statistics. It does not include extreme trends, as demographic developments are extrapolated smoothly into the future;
- in the *Swedish Scenario* we trace the consequences for the Netherlands of household formation and dissolution patterns which tend towards the patterns observed in Sweden in 1985;
- the *Fertility Scenario* is identical to the Realistic Scenario, with the exception of fertility assumptions. In the Fertility Scenario the Total Fertility Rate increases, over a period of 40 years, to replacement level (2.1 children per woman). Given current fertility conditions in the Netherlands, this is a rather extreme assumption;
- the *Mortality Scenario* is also an alternative to the Realistic Scenario. Compared with the latter scenario, an additional rise in life expectancy is assumed.

In the Realistic Scenario, the population reaches its maximum in 2025 (16.4 million), and it decreases slowly in the years thereafter. The main results of the Realistic Scenario for the period 1985-2050 can be summarized as follows:

- a decrease in the number of children;
- a strong decline in the number of couples with children;
- an increase in the number of lone parents which is modest in the absolute sense, but much stronger in the relative sense;
- a diminishing average household size;
- an enormous growth in the number of individuals living in a one-person household.

The tremendous increase in the number of persons living alone is the most striking result of the present application of the LIPRO-model to household projections in the Netherlands, irrespective of the scenario chosen. This particular household trend can be considered as a forecast, since there is little uncertainty left: a variety of input scenarios persistently resulted in a steep upward trend of the number of persons living alone.

This trend is even stronger when the number of households is considered, instead of the number of persons by household position. In 1985, only 27 percent of the households consisted of one person - according to the Realistic Scenario this share will increase to no less than 51 percent in 2050. To a large extent the growth in the number of persons living alone develops in parallel with the aging of the population. In 1985, 34 percent of all persons living alone was aged 65 or over; in 2035 and in 2050 the figure will be 49 percent.

The results also indicate a strong decrease in the share of married couples with children within all private households. Part of this development is explained by the general aging of the population: elderly couples have fewer children in their household compared to younger couples, simply because these children have left the parental home. But behavioural changes are important here as well: more couples remain voluntarily childless, fewer persons marry, and more marriages end in divorce.

A comparison between the Realistic Scenario and the Constant Scenario reveals a number of substantial differences. The size of the total population in private households differs strongly between these two scenarios: in 2050, it is almost 2 million persons less in the Constant Scenario. Also noteworthy is the relatively high share of one-person households in the Realistic Scenario, (51 percent in 2050, compared to 45 percent in the Constant Scenario in that year). Hence minor changes in demographic parameters may have major consequences.

Although the Swedish Scenario gives a somewhat larger share of one-parent families than the Realistic Scenario, the differences between the two scenarios are surprisingly few. The limited impact on household structures in the Swedish Scenario of relatively high rates for starting a consensual union and a high share of births taking place outside wedlock is mainly explained by the high marriage propensities of cohabiting couples with children in the Netherlands.

Obviously, the Fertility Scenario results in a larger total population. However, the consequences for household structures are very small indeed. The most important effect of increased fertility is a higher average household size for households with children; yet the share of such households in all households remains more or less unchanged. The projection period is too short for the increased fertility to have any impact on the size and composition of the elderly population. The share of this sub-group in the total population will diminish somewhat: for the population aged 65 and over the figure is 20 percent in the Fertility Scenario in 2050, as compared to 23 percent in the Realistic Scenario.

The Mortality Scenario results in even stronger aging effects than the Realistic Scenario. The elderly comprise 25 percent of the total population in 2050. Household structures are mainly affected for women: numbers of women living alone (mostly widows) are somewhat lower, and those for women living with their spouse a bit higher.

Estimates for future social security expenditures were computed by linking the demographic projections to so-called user profiles. For each combination of sex, age, and household position, such a user profile contains the share of the population relying on social security, and the average level of benefits. Three types of social security were described here: old age state pensions, survivor pensions, and social welfare. Sensitivity to changes in the demographic structure of the population, in particular its household composition, were an important argument for the choice of these three schemes from a variety of social security schemes in the Netherlands. User profiles were kept constant at their 1985 values for the entire projection period. Although the method allows for user profiles that vary over time, the use of constant profiles can be justified by referring to the problem formulation of this project. Insight should be gained into the impact of demographic changes for future social security expenditures, not into these expenditures per se.

Demographic developments have far-reaching consequences for public old age pension expenditures (AOW or "Algemene Ouderdomswet"). The aging of the population leads to an increase in the number of AOW benefits which is particularly strong in the years 2010-2015. In the Realistic Scenario the maximum is reached in 2035, when 2.54 as many benefits have to be supplied as in 1985. Expenditures follow a trajectory which largely runs parallel to that of the number of benefits. However, due to changes in the household composition of the population, expenditures increase more sharply than benefits. Two persons, each of them living alone, together receive more AOW than a married couple. Thus much of the overall rise in AOW expenditures can be explained, directly or indirectly, by changes in household structure, in particular, by the growing numbers of one-person households. Experiments with AOW user profiles including only age and sex, or only household position and sex, revealed

that a profile in which age is *replaced* by household position projects nearly half the rise in expenditures resulting from the full profile.
The AOW projections show little difference between the scenarios, except for the Constant Scenario with its relatively low life expectancy. The Mortality Scenario results in an even stronger growth: the index is 290 in 2035, compared to 270 in the Realistic Scenario (1985 = 100). The Fertility Scenario projects AOW expenditures per capita of the potential labour force for 2050 that are "only" 2.25 as high as those in 1985 - the corresponding figure for the Realistic Scenario is 2.51.

For survivor pensions (AWW) and welfare (ABW), the assumption of constant user profiles poses a problem. The household positions "Single" and "Head of one-parent family" are not broken down by marital status, i.e. the type of event which led to the household position. With respect to these two household positions, AWW pensions are wholly paid to widowed persons, whereas the greater part of ABW is supplied to divorcees. The assumption of constant user profiles implicitly presupposes that for AWW and ABW, the composition according to marital status remains the same for the positions "Single" and "Head of one-parent family" for each combination of age and sex. This assumption is rather unlikely, given the results of the demographic scenarios. Therefore, results for AWW and ABW were combined into one user profile. There are valid reasons to do so: both schemes are primarily aimed at women and their dependent children after marriage dissolution. The level of both allowances is largely independent of the marital status of the recipient.
The projection results indicate that total outlays for ABW and AWW increase considerably, in particular, during the first two decades of the projection period. From the year 2010 onwards, the growth is somewhat stronger than that in total outlays per capita of the potential labour force. This reflects a modest shift from one-parent families to single persons within the group of recipients.
The various scenarios only demonstrate minor differences. The rise in expenditures until 2050 in the Swedish Scenario is about 30 percentage points higher than that in the Realistic Scenario. This is due to a more rapid growth in the number of one-parent families caused by higher divorce levels.
Age explains very little in the projections for ABW and AWW. A projection with a user profile including only sex and household position closely follows the trajectory resulting from the full profile. On the other hand, the use of user profiles without a distinction according to household position leads to estimates of total outlays that are way off the mark.
As far as public expenditures for old age pensions are concerned, a general conclusion arising from this study is that demographic solutions to the pension problem caused by the aging of the population are hardly effective within the next 60 years or so. An increase in birth rates and/or immigration levels will hardly alleviate the burden for the working age population. The reason is that such solutions will not decrease the large share of the elderly in the future

population, unless unreasonably high levels of fertility and immigration are considered. Rather, the effects of non-demographic measures should be investigated, such as an increasing labour force participation, and a rise in the age at retirement.

A number of issues is open to further research.
Collective households (senior citizens homes, nursing homes, etc.) should be included in the analyses. There are two possibilities: collective households can be defined as exogenous to the system, similar to the states of "dead" and "rest of the world", or they could be defined as an additional 12th household position. The first approach seems easiest to handle, but at the same time it would produce less relevant information for policy makers, as compared to the second approach. Information regarding entries into and exits from collective households has to be gathered, irrespective of the approach chosen. These data are very scarce in the Netherlands, and this explains why collective households were omitted in the present project. Special research efforts have to be undertaken to solve this unsatisfactory situation.
The amount of information produced by the LIPRO household model is much larger than that presented in this book. Much more can be said about the mechanisms behind the demographic developments. A more intensive analysis of the underlying data will be one of the topics on the research agenda for the near future.
The intensities obtained by the method discussed in chapter 8 should be examined more critically than has been done so far. By plotting the age pattern of each intensity, possible implausibilities can be discovered. Next, remaining irregularities (for instance, due to sampling variability) in these patterns have to be removed by fitting smooth age-intensity profiles, giving the intensity of the events as a function of age (e.g., Van Imhoff, 1991). Smoothing out irregularities is one advantage of the use of parametrized functions. The second advantage is that it greatly facilitates the construction of demographic scenarios. But most important, a further investigation of the intensities may shed more light on the plausibility of the behavioural assumptions which were implicitly used in the various scenarios. A substantive analysis, complemented (if possible) by a time-series analysis and international comparative data, would be of great value in this respect. Such a behavioural analysis should at least address the issue of possible behavioural consequences of changes in the social security system. The impact of the social security system on demographic behaviour can only be indirectly included in the present approach, by the formulation of the demographic scenarios. A more formal sub-model, in which the demographic intensities are endogenized, could lead to different conclusions than those in the present study, as a consequence of possible feedback mechanisms.

PART IV

LIPRO
USER’S GUIDE

13. INTRODUCTION AND OVERVIEW

13.1 | Introduction

In the preceding chapters, the LIPRO projection program was described from a theoretical and an empirical point of view. The following chapters constitute a complete user's guide to the LIPRO computer program which is enclosed with this book in the form of a computer diskette.

The various features of the LIPRO program are discussed in their most logical order, i.e. the order in which they will be used during a typical sequence of calculations. The organization of the various chapters is as follows:

14. Getting started
    Introduces LIPRO's main menu, and the commands for defining a particular model specification.
15. Preparing data
    Discusses how demographic input data (intensities, initial population) are entered into the program.
16. Implementation of the consistency algorithm
    Clarifies how consistency requirements can be imposed, in line with the consistency algorithm presented in chapter 5.
17. Setting scenarios
    Discusses how hypotheses concerning future trends in demographic behaviour can be operationalized by demographic scenarios.
18. Projection
19. Analysis
    Discusses features for presenting projection results (tables), analysis of multi-state life tables, and exporting data for use by other programs.
20. Miscellaneous program features
21. Linking user profiles
    Presents a program by which the results of the population projection can be linked to user profiles to yield projections of, for example, social security expenditure.

The various program features will be discussed using examples from the application of LIPRO presented in part III of this book.

The remainder of this introductory chapter will discuss a number of general program features. These include program installation, the use of menus, issuing commands, the LIPRO editor, and the various types of program output.

Whenever this user's guide refers to variable by names, the variable name follows the FORTRAN convention: names starting with A-H or O-Z stand for real numbers (double precision); names starting with I,J,K,M,N stand for integer numbers; and names starting with L stand for character strings.

13.2 | Hardware requirements

The LIPRO computer programs, written in Borland's Turbo Pascal version 5.0, have been developed for MS/DOS Personal Computers or compatibles. A hard-disk and a memory of 640 Kb are required. In addition, the enclosed standard version of LIPRO requires the presence of a *mathematical co-processor*.
The standard version of the set of LIPRO programs has been compiled with the Turbo Pascal compiler switches N+ and E-. This means that the programs use the 8087 floating point data types provided by Turbo Pascal (N+), and that the routines for emulating 8087 floating point operations in case the mathematical co-processor is not present are *not* included in the source code (E-). For this reason, the standard versions can only be run on machines equipped with a mathematical co-processor. The standard version uses data type "double" for floating point variables. Each floating point number occupies 8 bytes, with 15 or 16 significant digits, and decimal powers ranging from -324 to +308.
Alternative versions of the LIPRO programs are the following:

1. programs compiled with N+ and E+. These programs keep the 8087 data type "double", but perform floating point operations by special routines using the normal 8086-type processor. This results in slower execution and a larger program code;
2. programs compiled with N-. These programs use the standard Turbo Pascal data type "real". Each floating point number occupies 6 bytes, with 11 or 12 significant digits, and decimal powers ranging from -39 to +38. This results in fast execution, less memory and disk space requirements, but a slight loss in precision.

If a co-processor is available, the standard version is by far preferable because of its rapid execution; this is especially true if one uses the exponential model specification. If no co-processor is available, version 2 is probably the best alternative. Alternative versions, for which handling and mailing costs will be charged, can be obtained directly from the NIDI.

13.3 | Installation

The distribution disk contains the following files:

LIPRO.EXE	the main program
LIPRO.FIG	configuration file
PROJECT.EXE	the projection program
EDIT79.EXE	general editor for simple ASCII files
BROWSE.EXE	program for scrolling through ASCII files
TABLE.EXE	program for printing tables
CONVERT.EXE	program for creating binary files from data in ASCII file and vice versa
MKRATE.EXE	program for estimating rates from initial population and observed events
MODRAT.EXE	program for setting scenarios
STABLE.EXE	program for multi-state life-table analysis
EDITDATA.EXE	program for editing data in binary files
AGGPOP.EXE	program for printing population tables aggregated over age groups
PRTRANS.EXE	program for printing transition probabilities
BIN68.EXE	program for converting binary files from 6-byte format to 8-byte format and vice versa
SOCPROF.EXE	program for creating, editing, and applying user profiles for social security

Before running LIPRO, all these files should be copied onto a hard-disk (assumed to be drive C:) in the same directory. This directory will be referred to as the *program directory*. Throughout this manual, the program directory is assumed to be C:\LIPRO.
In addition, the MS/DOS programs COMMAND.COM and PRINT.COM should be placed in the root directory of drive C:. If they are not in the root directory, the configuration file LIPRO.FIG will have to be modified (see chapter 20, the UTILITIES command).
Finally, it is advisable to create a separate sub-directory for each application of LIPRO. This sub-directory will be referred to as the *data directory*, which can be changed with the *ChDir* command (see section 13.7). In the examples throughout this manual, the data directory is assumed to be C:\LIPRO\DATA.

The program can be run by making the program directory the current directory and entering the command:

LIPRO

After an introductory screen, the main menu, to be discussed in chapter 14, will appear.

In general, any running program, if not in edit mode or menu mode, can be aborted by pressing the Ctrl-Break key.

13.4 | Menus

LIPRO is completely menu-driven. A menu consists of a list of commands, each command being preceded by a character displayed in high video. On entering a menu, a block cursor is placed behind the first command.
The highlighted bar on the third line of the screen gives the name of the current menu.
A particular command listed on the screen can be executed in two different ways:

1. by pressing the highlighted character preceding the command on the screen; or
2. by moving the block cursor using the arrow keys, and pressing RETURN once the block cursor is behind the desired command.

A menu can be left at all times by pressing Q (Quit) or ESC.

13.5 | Command bars

Some commands display a highlighted bar on the last line of the screen. This so-called *command bar* lists a number of alternative actions, each one preceded by a character.
A particular action listed in the command bar can be executed by pressing the character preceding the command name in the command bar.
A command bar can be left at all times by pressing Q (Quit) or ESC.

13.6 | Edit screens

An edit screen is a screen which displays information that may be modified by the user. An edit screen is indicated by a message in the highlighted bar on the bottom line of the screen:

Edit screen **F10/ESC to quit**

The edit screen contains one or more fields where the user may type new text. Fields, insofar as they are not filled with text, are shown by underline symbols ('_'). The current field and current position within the field are indicated by the position of the cursor. The following special keys are recognized in the edit mode:

Arrow left	move cursor one position to the left
Arrow up	move cursor to previous field
Arrow right	move cursor one position to the right
Arrow down	move cursor to next field
TAB	move cursor to first character of next field
Shift-TAB	move cursor to first character of previous field
RETURN	same as TAB if more than one field; leave edit screen if one field
Del	remove character under the cursor
Backspace	remove character left of the cursor
Ins	switch between insert mode and overwrite mode
End	move cursor to first empty position in current field
Ctrl-End	remove field from cursor to end
ESC	leave edit screen
F10	leave edit screen

If the contents of fields are checked by LIPRO, then this checking is done at the moment of exit from the edit mode.

13.7 | Directory screens

When LIPRO asks for an existing file, a so-called *directory screen* is displayed. It contains all files in the current directory whose file name satisfies a particular match string, e.g. *.INP (all files with extension .INP) or *.* (all files).
The fourth line of the screen displays the name of the current directory, the match string of the files on the screen, and the number of files.
The main screen contains the names of the available files. If no matching file names were found, one single string consisting of twelve dots is displayed, indicating an empty file.
The first file name on the screen shows a block cursor. Using the arrow keys, the block cursor can be moved around the screen. If RETURN or the space bar is pressed, the file under the block cursor is selected and control is returned to the calling menu or command.
The directory screen can also be used to perform certain operations on files. The possible commands are listed in the highlighted command bar on the bottom of the screen:

<CR>=Select   Commands: Edit Browse Print Delete Mask ChDir Quit

Each command can be chosen by pressing the key corresponding to the first letter of the command's name:

Edit
invokes the built-in editor EDIT79 to edit the file under the block cursor (see section 13.9).

Browse
allows one to scroll through the indicated file using the built-in BROWSE program (see section 13.8).

Print
invokes the MS/DOS command PRINT.COM to print the indicated file.

Delete
erases the file from the current directory. The user is asked to confirm the delete command. If a file is deleted, its name on the screen is replaced by '............', indicating an empty file.

Mask
is used to change the match string. When selecting a file, care should be taken in selecting a file name that does not meet the prescribed file name extension.

ChDir
can be used to change the current directory. When exiting from LIPRO, the current directory is saved in the configuration file LIPRO.FIG and automatically reset at a subsequent call to LIPRO.
It should be pointed out that the use of *ChDir* is restricted to the main menu's DEFINITIONS and FILES commands. The reason for this restriction is that LIPRO requires that all input and output files corresponding to one particular model specification are in the same data directory.

Quit
leaves the directory screen without actually selecting a file. This command is equivalent to ESCAPE, F10, or pressing RETURN while the block cursor is on an empty file.

13.8 | Browse

BROWSE is a program for rapid scrolling through ASCII files. It has a maximum capacity of 9999 lines, with 255 characters per line.
The following keys can be used within BROWSE:

PgDown	move to next page (23 lines)
PgUp	move to previous page
Arrow up	scroll one line up
Arrow down	scroll one line down
Arrow left	scroll one column left
Arrow right	scroll one column right
End	move to last page of file
Home	move to first page of file
TAB	scroll 10 columns right
Shift-TAB	scroll 10 columns left
Ctrl-right	scroll 79 columns right
Ctrl-left	scroll 79 columns left
ESCAPE	leave BROWSE
RETURN	leave BROWSE

From outside LIPRO, the program BROWSE.EXE can also be invoked by entering the MS/DOS command:

```
browse <file name>
```

where <file name> is the name of the file to be browsed.

13.9 | Editing ASCII files

EDIT79 is a program for the simple editing of ASCII files. It has a maximum capacity of 9999 lines, with 79 characters per line.
The following special keys can be used within EDIT79:

PgDown	move cursor to next page (23 lines)
PgUp	move cursor to previous page
Arrow up	move cursor one line up
Arrow down	move cursor one line down
Arrow left	move cursor one column left
Arrow right	move cursor one column right
End	move cursor after last character of current line
Ctrl-End	remove line from cursor to end
Ins	switch between insert mode and overwrite mode

Del	delete character under cursor
Backspace	delete character left of cursor
RETURN	insert mode: split current line at cursor; overwrite mode: move cursor to first character of next line
ESC	exit from EDIT79 without saving file. If the file has been changed since the last save, the user is asked to confirm this command.
F1	help
Ctrl-A	(ASCII) asks for the ASCII code of desired character (for typing characters not on the keyboard)
Ctrl-B	(Bottom) move cursor to bottom of file
Ctrl-D	(Delete) delete current line. The deleted line is added to an internal buffer and can be reloaded by pressing Ctrl-I (insert). This is the way to move or copy lines of text. The buffer, with a capacity of 100 lines, is emptied after entering a printable character from the keyboard.
Ctrl-E	(Exit) save the current file and exit from EDIT79
Ctrl-F	(Find) asks for a string and finds its first occurrence in the file starting at the current cursor position
Ctrl-G	(Get) finds the next occurrence of the string entered at the last Find command
Ctrl-H	same as Backspace
Ctrl-I	(Insert) inserts the lines in the internal buffer above the current line
Ctrl-J	(Join) joins the next line to the current line, but only if cursor is after last character of current line.
Ctrl-M	same as RETURN
Ctrl-Q	(Quit) exit from EDIT79 without saving file. If the file has been changed since the last save, the user is asked to confirm the Quit command.
Ctrl-R	(Read) asks for a file name and inserts the contents of the file above the current line
Ctrl-S	(Save) saves the current file without leaving EDIT79
Ctrl-T	(Top) moves cursor to first character of first line of file
Ctrl-Home	same as Ctrl-T

Any other key, as long as its scan code is not extended, will be treated as normal input from the keyboard.
From outside LIPRO, the program EDIT79.EXE can also be invoked by entering the MS/DOS command:

```
edit79 <file name>
```

where <file name> is the name of the file to be edited.

13.10 | Output files

LIPRO recognizes three types of output files:

- text files;
- the terminal (console);
- the printer.

Output *text files* have extension .OUT and are saved on disk. They may be inspected by invoking the program BROWSE, and printed by giving the PRINT command from the directory screen.
The *console* is the default output file. Its filename is CON. When the program prompts for the name of an output file, the console may be specified by entering either ’CON’ or an empty string (immediate RETURN).
The *printer* has file name LPT1. It can be chosen by entering ’LPT1’, ’PRN’, or ’LST’.
Whenever the user gives the command *Output file*, the program produces a directory screen with all text files having extension .OUT. An existing text file can be selected from the directory; it will be overwritten. Alternatively, one can press ESC or F10 to leave the directory screen, without selecting an existing output file. The program then asks whether a new output file has to be created. If the answer ’yes’ is given, the program prompts for a file name. The empty string and ’CON’ can be entered to specify the console. ’LPT1’, ’LST’, and ’PRN’ can be entered to specify the printer. Any other string is interpreted as the file name of a text file (do not include the extension !).

13.11 | Turbo Pascal error codes

Under normal conditions, LIPRO gives clear messages whenever an error occurs during the calculations. However, in some cases errors might occur which are not spotted by the program itself but rather by Turbo Pascal, the compiler used to create the LIPRO program. These errors result in an error code being displayed on the screen and in abortion of the program. A full list of Turbo Pascal error codes follows below:

2	File not found
3	Path not found
4	Too many open files
5	File access denied
6	Invalid file handle
12	Invalid file access code
15	Invalid drive number
16	Cannot remove current directory

17	Cannot rename across drives
100	Disk read error
101	Disk write error
102	File not assigned
103	File not open
104	File not open for input
105	File not open for output
106	Invalid numerical format
150	Disk is write-protected
151	Unknown unit
152	Drive not ready
153	Unknown command
154	CRT error in data
155	Bad drive request structure length
156	Disk seek error
157	Unknown media type
158	Sector not found
159	Printer out of paper
160	Device write fault
161	Device read fault
162	Hardware failure
200	Division by zero
201	Range check error
202	Stack overflow error
203	Heap overflow error
204	Invalid pointer operation
205	Floating point overflow
206	Floating point underflow
207	Invalid floating point operation
208	Overlay manager not installed
209	Overlay file read error

14. GETTING STARTED

14.1 | The MAIN menu

After the LIPRO programs have been installed (section 13.3), LIPRO can be run by making the program directory the current directory and entering the command:

```
LIPRO
```

After an introductory screen, the main menu will appear. The main menu is displayed in figure 14.1.

Figure 14.1. The MAIN menu

The MAIN menu offers the following commands:

Definitions
enters the DEFINITIONS menu. This menu defines, creates, and/or modifies the definition file and the parameter file (sections 14.2 and further).

Projection
invokes the program PROJECT for carrying out a multidimensional demographic projection (chapter 18).

Files
produces a list of all files in the current directory. By using the arrow keys to move the block cursor and by pressing the keys listed in the menu bar on the bottom of the screen, certain operations can be performed on the file under the block cursor (chapter 20).

Analysis
produces tables from data in the various r/a files (chapter 19).

Convert
produces r/a files from ASCII files prepared by external programs, e.g. LOTUS .PRN-files, or vice versa (chapter 15).

Rates
estimates rates from given data on initial population and observed events (chapter 15).

Scenarios
modifies the rates according to specifications in a user-prepared command file (chapter 17).

Edit data
allows one to directly edit the data in any of the LIPRO r/a files, without having to convert them first to ASCII format (chapter 15).

Utilities
allows one to change the different background and foreground colors in which the LIPRO main program displays text on the screen, as well as several other default settings (chapter 20).

Execute a program
is a utility for running programs without actually leaving LIPRO (chapter 20).

MS/DOS internal command
is a utility for executing DOS commands (like dir, rename, erase) without actually leaving LIPRO (chapter 20).

Quit
updates the configuration file and leaves the LIPRO program.

All these commands will be discussed more extensively in subsequent chapters.

14.2 | Basic input files

There are two sets of fundamental variables that need to be specified before any calculations can be made. These are:

1. specification of the state space. This specification is stored in a so-called *definition file*;
2. specification of names of r/a files, length of projection period, and other parameters affecting the calculations. These parameters are stored in a so-called *parameter file*.

Note: after issuing a *ChDir* command from a directory screen, both the definition file and the parameter file become undefined.

14.2.1. The definition file

The state space is characterized by two types of parameters (cf. chapter 3):

1. the number of categories in each dimension of the cross-classification table:
   a. (NAGE) the number of age groups
      (NWAGE) the width of the age groups
   b. (NSEX) the number of sexes
   c. (NPOS) the number of states
   d. (NOUT) the number of destinations for exits
   e. (NIN) the number of origins for exogenous entries
2. the names (labels) of each category:
   a. (LAGE) age groups
   b. (LSEX) sexes
   c. (LPOS) states
   d. (LOUT) destinations
   e. (LIN) exogenous origins

   The labels under c), d), and e) are used intensively throughout the program, as will be clarified in section 14.6.

These parameters are stored in the so-called definition file. Its file name extension is .DEF.
The first line of the computer screen displays the name of the current .DEF file and its key dimensions. *I* stands for the number of states (internal positions), *X* for the number of external states, *N* for the number of origins for exogenous entries, *S* for the number of sexes, and *A* for the number of age groups.
The name of the last .DEF file read before leaving LIPRO is saved in the configuration file LIPRO.FIG. At a subsequent call to LIPRO, the same .DEF file will be automatically read at the start of the program.
A .DEF file can be created or modified in the STATE SPACE menu, to be discussed in section 14.4.

14.2.2. The parameter file

The parameter file contains a number of parameters that control the interdependencies between the various r/a files used by the programs, and the way in which these r/a files are processed. Its file name extension is .PAR.
The LIPRO programs use six binary random access (r/a) files to store and read the main demographic data. These files contain:

- population by sex, age, state, and year;
- person years by sex, age, state, and year;
- rates and numbers of immigrants (unadjusted) by sex, age, type of event, and year;
- events (unadjusted) by sex, age, type of event, and year;
- events (adjusted after consistency step) by sex, age, type of event, and year;
- rates and numbers of immigrants (adjusted after consistency step) by sex, age, type of event, and year.

Each record contains data for a particular age group, sex, and year. Records are stored by order of year, within year by age, and within age by sex.

The parameters stored in the parameter file are the following:

1. Names of the r/a files:

a.	(LPOPUL)	population data
b.	(LPYEAR)	person years
c.	(LRATES)	rates and numbers of immigrants
d.	(LEVENT)	events
e.	(LRATEC)	consistent rates
f.	(LEVENC)	consistent events

2. Projection parameters:

   a. (SMALL) assumed zero. If during the computations a real number is encoutered that is smaller than SMALL in absolute value, then this number is considered zero. In particular, SMALL is used in detecting possible singularity of matrices (see section 4.5).

   b. (IRATES) a parameter indicating which set of rates should be used as the point of departure for each projection step:
      - 1 = same rates for each projection step (i.e. year 1 in LRATES, "constant scenario")
      - 2 = different rates for each projection step (i.e. year t in LRATES, "variable scenario")
      - 3 = consistent rates from previous projection step (i.e. year t-1 in LRATEC, "consistent scenario")

      This parameter is discussed more fully in chapter 18 on the PROJECTION command.

   c. (IMODEL) model type:
      - 1 = linear model
      - 2 = exponential model

   d. (DECRIT) convergence criterion for the computation of the exponent of the intensity matrix exp[Mh] (see section 4.5). Ignored if IMODEL=1.

   e. (H) length of the projection interval. It should be equal to the width of the age groups NWAGE.

   f. (ITIME1) the first year of the projection

   g. (ITIMEZ) the last year of the projection

3. Parameters concerning the consistency algorithm:

   a. (ICONS) a parameter indicating whether consistency of the numbers of events is required:
      - 1 = yes
      - 0 = no

   The remaining parameters are ignored if ICONS=0.

   b. (P) the parameter p in the consistency algorithm. P may be either 0 (arithmetic mean) or 0.5 (harmonic mean).

   c. (LCONSI) the name of the file with consistency relations, to be discussed in chapter 16.

d.	(ISTEP2)	a parameter indicating whether consistent rates are required (see section 5.4): 1 = yes 0 = no Usually ISTEP2 is set equal to 1, except when either the consistency algorithm produces "impossible" numbers of events (the program breaks down if it does), or the number of variables entering the consistency relations is so large that the usefulness of a second projection step is small. It is *necessary* to set ISTEP2=1 if the parameter IRATES has been set equal to 3 ("consistent scenario"), or if the consistent rates are found to be of interest in their own right.

The remaining parameters are ignored if ISTEP2=0.

e.	(ISTART)	starting values for person years: 1 = linear model based on consistent events 2 = exponential model based on inconsistent rates
f.	(DLCRIT)	convergence criterion for the computation of consistent rates, given consistent events. DLCRIT should be sufficiently small compared to the numbers of person years.
g.	(MAXITL)	maximum number of iterations allowed for the computation of consistent rates, given consistent events.

The first line of the computer screen displays the name of the current .PAR file. The name of the last .PAR file read before leaving LIPRO is saved in the configuration file LIPRO.FIG. At a subsequent call to LIPRO, the same .PAR file will be automatically read at the start of the program.
A .PAR file can be created or modified in the PARAMETERS menu, to be discussed in section 14.5.

14.3 | The DEFINITIONS menu

The DEFINITIONS menu gives access to two sub-menus, each dealing with one of the two fundamental files: the definition file and the parameter file. It is reached by choosing:

D. Definitions from the MAIN menu

The DEFINITIONS menu contains the following commands:

State space
moves the user to the STATE SPACE menu (section 14.4), dealing with LIPRO's definition file.

Parameters
moves the user to the PARAMETERS menu (section 14.5), dealing with LIPRO's parameter file.

Quit
returns to the MAIN menu.

14.4 | The STATE SPACE menu

The STATE SPACE menu defines, creates, and/or modifies a LIPRO definition file. It is reached by choosing:

D. Definitions	from the MAIN menu
S. State space	from the DEFINITIONS menu

The STATE SPACE menu contains the commands displayed in figure 14.2.

Figure 14.2. The STATE SPACE menu

Read
lets the user pick an existing .DEF-file from the current directory.

Create
asks for a valid file name to be created. If the file <file name>.DEF already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the dimensions have to be entered and the labels are assigned their default values.
In the example, we assume that the name "REAL" (for "Realistic Scenario") has been entered.

Dimensions
lets the user change the dimensions of the state space, i.e. the number of categories in each dimension of the cross-classification. In order to facilitate interpretation, the screen displays the lower limit of the highest age group, rather than the number of age groups. Figure 14.3 provides an example.

Figure 14.3. The DIMENSIONS command

The commands listed under *labels* let the user edit the names of the various categories. Figure 14.4 provides an example. The labels should be chosen with care, for reasons to be clarified in section 14.6.

Figure 14.4. The INTERNAL POSITIONS command

Quit returns the user to the DEFINITIONS menu.

14.4.1. Ranges and default values

The ranges and default values of the *dimensions* of the state space are as follows (cf. section 14.2.1):

Parameter	*Minimum*	*Maximum*	*Default*
NAGE	1	100	19
NWAGE	1	100	5
NSEX	1	2	2
NPOS	1	60	1
NOUT	1	2	1
NIN	0	1	0

For the *labels*, the default values are:

Parameter	*Default*
LAGE(1)	'BIRTHS'
LAGE(2..NAGE-1)	'a-b' if NWAGE>1 'a' if NWAGE=1
LAGE(NAGE)	'a+'
LSEX(1)	'TOTAL' if NSEX=1 'FEMALE' if NSEX=2
LSEX(2)	'MALE' if NSEX=2
LPOS(1..NPOS)	'STATE i'
LOUT(1)	'DEAD'
LOUT(2)	'REST'
LIN(1)	'REST'

14.4.2. Example

For the household model, the dimensions of the state space should be specified as given in figure 14.3. Note that a lower limit of the highest age group of 85 years implies that the number of age groups (NAGE) equals 19, given a width per age group of 5 years, and taking into account the fact that age group 1 refers to the individuals born during the projection interval.
The labels of the various categories are all equal to the default, with the exception of those for the internal positions, displayed in figure 14.4.

14.5 | The PARAMETERS menu

A .PAR file can be created or modified in the PARAMETERS menu. This menu is reached by choosing:

D. Definitions	from the MAIN menu
P. Parameters	from the DEFINITIONS menu

The PARAMETERS menu contains the following commands:

Read
lets the user choose an existing .PAR-file from the current directory.

Create
asks for a valid file name to be created. If the file <file name>.PAR already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the parameters have to be entered.

In the example, we assume that the name "REAL" (for "Realistic Scenario") has been entered.

Edit
lets the user change the parameters. Figure 14.5 gives an example of the corresponding edit screen.

Quit
returns the user to the DEFINITIONS menu.

14.5.1. Ranges and default values

The ranges and default values of the parameters in the parameter file are as follows (cf. section 14.2.2):

Parameter	*Minimum*	*Maximum*	*Default*
LPOPUL	-	-	’’
LPYEAR	-	-	’’
LRATES	-	-	’’
LEVENT	-	-	’’
LRATEC	-	-	’’
LEVENC	-	-	’BIRTHS’
SMALL	-	-	1E-10
IRATES	1	3	1
IMODEL	1	2	1
DECRIT	-	-	1E-10
H	1	100	NWAGE
ITIME1	0	9999	1
ITIMEZ	0	9999	NWAGE
ICONS	0	1	0
P	0.0	0.5	0.5
LCONSI	-	-	’’
ISTEP2	0	1	1
ISTART	1	2	1
DLCRIT	-	-	1E-10
MAXITL	-	-	10

14.5.2. Example

For the household model, the parameters should be specified as in figure 14.5. The scenario type in the example is specified as "variable". This means that for each projection period a separate set of demographic rates (jump intensities) will have to be created. The "scenario type" parameter will be discussed more fully in chapter 18, while the creation of the various sets of rates using the SCENARIOS command will be treated in chapter 17.

Figure 14.5. The edit screen of the PARAMETERS menu

The model type is specified as being exponential. Consistency is required with parameter p set equal to ½ (i.e. the generalized harmonic mean). The consistency relations will have to be specified in file REALCON.INP, which will be discussed in chapter 16. Consistent rates are *not* required, i.e. the rates corresponding to consistent events will not be computed. The reason for this choice lies in the tradeoff between computation time and increased accuracy.

14.6 | State labels and variable indicators

The state labels defined with the STATE SPACE command play a central role in many features of the LIPRO program. Their function is twofold. First, they are used to identify rows or columns in output tables. Second, and much more important, is their function as identifiers in *variable indicators*. Variable indicators are used on various occasions in the LIPRO program, including data conversion (chapter 15), definition of consistency relations (chapter 16), and scenario setting (chapter 17).

Because of this dual function of the state labels, they should be chosen with care. As labels in output tables, they should be as descriptive as possible. On the other hand, as identifiers in variable indicators, they have to be typed quite often and they should therefore be as short as possible. Thus, the state labels should be chosen such that they are descriptive and short at the same time.

Variable indicators are used thoughout the program to identify a particular type of event, or a particular cell in a table of population. For events or their corresponding rates, the general form of a variable indicator is as follows:

T(S,ORIG,DEST)

where

T	stands for type of event. T may be:	
	I	internal event
	X	external event (exit)
	B	birth
	N	entry (immigration)
S	stands for the sex experiencing the event. S may be:	
	F	female
	M	male
	M+F	both
	T	both (same as M+F)
ORIG	stands for state, or range of states, of origin. The label(s) should correspond to a valid label as defined in the .DEF file. In the case of births, ORIG indicates the state of the mother at the moment of birth. A range of states is indicated by two labels, separated by two periods.	
DEST	stands for state, or range of states, of destination. The label(s) should correspond to a valid label as defined in the .DEF file. In the case of births, DEST indicates the state into which the child is born. A range of states is indicated by two labels, separated by two periods.	

A few examples of variable indicators follow:

I(F,MAR+,H1PA)
The event bringing a woman from the state "married with child(ren)" to the state "head of one-parent family" (as a result of divorce or death of husband). Since this is an internal event, the event type is indicated by I.

X(M+F,CMAR..OTHR,DEAD)
All deaths, irrespective of sex and state.

B(M,MAR0..MAR+,CMAR)
All male legitimate births.

N(M,REST,SING)
Male immigration into state "one-person household".

A variable indicator for population tables contains only one state label, being the present state. Its general form is:

P(S,POS)

where S denotes sex as above, and POS denotes a valid internal state. For person years, the P is replaced by an L. For example:

P(F,UNM0)
The number of females living in a consensual union without children.

L(M,C1PA)
The number of person years lived by males in the state "child in one-parent family".

15. PREPARING DATA

Once the state space and the model parameters have been defined, the demographic input data have to be entered. For the moment, we will assume that the analysis is restricted to one single projection interval.
A projection requires two types of demographic input data:

a. the population at the start of the projection interval, classified by sex, age groups, and state (internal position);
b. jump intensities for all types of internal events and exits, fertility rates and numbers of immigrants, classified by sex and age group.

In terms of the symbols introduced in chapter 4, these input data refer to the following arrays:

a. initial population: $\ell(s,x,t_0)$ $s=1,NSEX$ $x=2\cdots NAGE$
   Remember that age group x=1 refers to individuals born during the projection interval, so that this age group is not included in the initial population.
b. rates and numbers of immigrants. For the *exponential model* the arrays are:
   rates for internal events: $\mathbf{M}_i(s,x,t_0)$ $s=1,NSEX$ $x=1\cdots NAGE$
   rates for exits: $\mathbf{M}_e(s,x,t_0)$ $s=1,NSEX$ $x=1\cdots NAGE$
   rates for births: $\mathbf{M}_b(s,x,t_0)$ $s=1,NSEX$ $x=1\cdots NAGE$
   numbers of immigrants: $\mathbf{O}(s,x,t_0;h)$ $s=1,NSEX$ $x=1\cdots NAGE$
   In the case of the *linear model*:
   rates for internal events: $\mathbf{M}_i(s,x,t_0;h)$ $s=1,NSEX$ $x=1\cdots NAGE$
   rates for exits: $\mathbf{M}_e(s,x,t_0;h)$ $s=1,NSEX$ $x=1\cdots NAGE$
   rates for births: $\mathbf{M}_b(s,x,t_0;h)$ $s=1,NSEX$ $x=1\cdots NAGE$
   numbers of immigrants: $\mathbf{O}(s,x,t_0;h)$ $s=1,NSEX$ $x=1\cdots NAGE$

Entering these input data is equivalent to creating the two random access files LPOPUL and LRATES (see section 14.2), and filling the records for the first year, which are located at the beginning of the r/a file, with numbers. Basically, there are two methods for creating these files:

1. typing the data one by one from the keyboard. This can be done with the EDIT DATA command, to be discussed in section 15.1;
2. preparing the data with an external program (e.g. a worksheet file) and converting them to LIPRO format using the CONVERT command, to be discussed in section 15.2.

As an alternative to entering the rates, LIPRO offers the powerful option of entering data on events (using either method), and having the rates estimated from observed events and initial population, using an estimation procedure developed by Gill and Keilman (1990). This option, implemented in the RATES command, will be discussed in section 15.3.

15.1 | The EDIT DATA menu

The EDIT DATA command invokes the program EDITDATA. EDITDATA reads all records corresponding to an observation or projection interval from a LIPRO r/a file and allows the user to edit these numbers individually. It is particularly useful for correcting minor errors or setting simple scenarios, without having to invoke the much more complicated SCENARIOS command. Of course, the command can also be used to enter data for the first time, but for models with a large state space this may not be the most efficient method.

Since EDITDATA may require huge amounts of memory, it is not possible to call other programs from EDITDATA. Therefore, even though the program's directory screen looks the same as those of the calling LIPRO program, it should not be used to browse, edit, or print files. Any attempt to call these programs will result in a (non-fatal) error message.

The EDIT DATA program is activated by choosing:

E. Edit data from the MAIN menu

The EDIT DATA menu is displayed in figure 15.1.

Type of data
toggles between the three possible data types: events, population, and rates. If data have been read and edited since the last save, the user is prompted to verify that the data may be discarded. Changing the data type sets the name of the r/a file to its default value.

Random access file
lets the user choose an existing r/a file (with extension .BIN) from the current directory. If no data have been read, they will be read from this file at a later *Read data* command. If data do have been read, they will be written to this file at a later *Save data* command; in the latter case it is also possible to specify the name of a non-existing r/a file. By default, the r/a file is LPOPUL for population data, LEVENT for events data, and LRATES for rates data.

Year
lets the user enter the year (first year of projection or observation period) to which the data refer. If no data have been read, they will be read at this position in the r/a file at a later *Read data* command. If data have been read, they will be written to this position in the r/a file at a later *Save data* command. The default is ITIME1.

Width of output field
lets the user enter the width of the field in which the numbers are to be edited. The minimum is 8, the maximum is 24, and the default is 10.

Number of decimal digits
lets the user specify the number of decimal digits for each number. A negative number indicates exponential notation.

Figure 15.1. The EDIT DATA menu

Initialize data to zero
sets all data in memory equal to zero. This option is useful if one wants to enter new data for a projection period or observation year.

Read data
reads the data from the r/a file at the position corresponding to *Year*.

Edit data
enters the edit mode, to be discussed below.

Save data
writes the data (if modified since the previous save) to the r/a file at the position corresponding to *Year*.

Quit
returns to the MAIN menu.

15.1.1. Edit mode

In the edit mode, the screen is divided into three windows (see figure 15.2 for an example):

Figure 15.2. The edit mode of the EDIT DATA menu

- the upper window contains information on the current file name (r/a file), year, and variable. The variable is indicated by a *variable indicator*, discussed in section 14.6;
- the middle window contains the data for the current variable, ordered by age group;
- the lower window is a command bar, containing the following commands:

Edit ; Age Sex Type Orig Dest (Ctrl=back) Quit

From the command bar, the following keys are defined:

E	Enter the edit screen. ESC or F10 returns to the command bar.
A	Next page of current variable. This will have no effect if all age groups fit on one screen, e.g. as in figure 15.2.
Ctrl-A	Previous page of current variable. This will have no effect if all age groups fit on one screen.
S	Other sex. In figure 15.2, this would result in a switch to variable I(M,SING,UNM0).
Ctrl-S	Other sex
T	Next variable type. This will only effect events or rates data. The variable types are: I (internal events), X (exits), B (births), and N (exogenous entries). In figure 15.2, this would result in a switch to variable X(F,SING,REST).
Ctrl-T	Previous variable type. In figure 15.2: N(F,REST,CMAR).
O	Next state of origin. This will only effect events or rates data. For births, origin refers to the state of the mother. In figure 15.2: I(F,MAR0,UNM0).
Ctrl-O	Previous state of origin. In figure 15.2: I(F,C1PA,UNM0).
D	Next state of destination. For population data, destination refers to the *current* state. For births, destination refers to the state into which the child enters. In figure 15.2: I(F,SING,UNM+).
Ctrl-D	Previous state of destination. In figure 15.2: I(F,SING,MAR+).
Q	Leave the edit mode.

15.2 | The CONVERT menu

The command CONVERT produces r/a files in LIPRO format from ASCII data files, created by an editor (like EDIT79), Lotus .PRN files, or another external program, or vice versa.
Typically, CONVERT is used in three cases:

1. to convert files with data on rates and population into a form that can serve as input to the projection program;

2. to convert files with data on events and population into a form that can serve as input to the estimation program (command RATES, section 15.3);
3. to convert LIPRO r/a files to ASCII format for subsequent processing by other programs.

The conversion program uses two different input files:

1. a *data file*, containing the data in ASCII format;
2. an *input file*, containing a description of the variables in the data file.

The data file contains a data matrix with numbers in free format (i.e. separated by blanks or end-of-line markers). Four different types of data are possible:

1. events: numbers of events by sex, type, and age;
2. rates: rates by sex, type of corresponding event, and age;
3. population data: numbers of individuals by sex, age, and state;
4. person years: numbers of person years by sex, age, and state.

The numbers in the data file may be arranged either by variable (sex and type of event, or state), or by observation (age group).

The input file is an ordinary text file. Its file name should have extension .INP. Its lines contain variable indicators, corresponding to the order of the variables in the data file. The general form of a variable indicator is discussed in section 14.6. *Each line should be terminated with a semicolon !*
If not all variables implicitly defined by the .DEF file are in the data matrix, then the corresponding data are set equal to zero when converting from ASCII to r/a.

Conversion can be started by choosing:

C. Convert from the MAIN menu

The CONVERT menu offers the commands displayed in figure 15.3.

Type of data
toggles between the four types of data one wants to convert. Type 1 (events) is the default. If the type of data is changed, the input file and the ASCII file become undefined, and the r/a file gets its default value.

Mode
toggles between the two modes of conversion: from ASCII to r/a; and from r/a to ASCII. From ASCII to r/a is the default.

Figure 15.3. The CONVERT menu

Input file
lets the user choose an existing input file (with extension .INP) from the current directory. If no file is chosen (by pressing ESC or F10), one may create a new input file by answering Yes to the corresponding question. If the file name of the input file to be created already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the input file has to be edited.

Edit input file
lets the user edit the variable names in the input file, using the EDIT79 program.

ASCII file
lets the user choose an existing ASCII file (with default extension .DTA) from the current directory. If the data file does not have the extension .DTA, the file can only be chosen after the match string has been changed with the directory screen's *Mask* command (see section 13.7).

Browse ASCII file
lets the user inspect the ASCII file, using the BROWSE program.

Random access (r/a) file
lets the user choose an existing r/a file (with extension .BIN) from the current directory. The default files are: LEVENT for data type 1, LRATES for data type 2, LPOPUL for data type 3, and LPYEAR for data type 4.

Sorting method
switches between the two alternative sorting methods *observation* (i.e. age group) and *variable*. Sorting by observation is the default.

Year
lets the user enter the year (first year of projection interval) for which data are to be converted. It determines the position of the records in the r/a file to be read or written. Default is ITIME1.

Width of output field
lets the user enter the number of characters for each number to be written to the ASCII file. It is ignored if conversion is from ASCII to r/a. Its default value is 10.

Number of decimal digits
lets the user specify the number of decimal digits for each number to be written to the ASCII file. It is ignored if conversion is from ASCII to r/a. Its default value is 0.

Line length (maximum)
lets the user specify the maximum length of each line to be written to the ASCII file. Whatever its value, each new age group (for sorting method OBS) or variable (for sorting method VAR) will start on a new line.

Convert
invokes the program for converting the data according to the type and input file specified.

Quit
returns the user to the MAIN menu.

15.2.1. Example

The population data for the household model, referring to the situation per 31 December 1985, were prepared by an external program. The data are arranged in a data matrix stored as file REALPOP.DTA, with each row corresponding to a particular combination of sex and household position. In other words, the sorting method is *observation*. If, starting from the screen displayed in figure 15.3, the command *Browse ASCII file* is given, the screen displayed in figure 15.4 appears.

Figure 15.4. Example of the BROWSE command

The input file, REALPOP.INP, contains the variable indicators for the variables in the data file, in exactly the same order in which the rows appear in the data file. Each variable indicator should start on a new line, and each line should be terminated with a semicolon. If, starting from the screen displayed in figure 15.3, the command *Edit input file* is given, the screen displayed in figure 15.5 appears.

After issuing the *CONVERT* command, conversion starts. If conversion is successfully terminated, the following message appears on the screen:

```
File REALPOP.BIN created, 36 records
```

15.3 | The RATES menu

The command RATES invokes the program MKRATE for estimating rates (intensities) from events and initial population. If estimation is based on the exponential model, then the moment estimator proposed by Gill and Keilman (1990) is used. An outline of the estimation procedure has been given in section 4.4.

Figure 15.5. Example of the EDIT INPUT FILE command

The data on events and initial population should be present in the form of LIPRO r/a files. Such files can be created by one of the methods described in sections 1 and 2 of this chapter. For more information on the data requirements, the reader is referred to section 4.4.
The parameters controlling the estimation procedure are read from the parameter file, discussed extensively in section 14.5. The following parameters are especially relevant:

H	the length of the observation interval.
SMALL	a small number, used in checking for singularity of a square matrix.
IMODEL	the model specification. 1=linear, 2=exponential.

DECRIT	convergence criterion for the computation of the exponent of the intensity matrix exp[Mh]. Ignored if IMODEL=1.
MAXITL	maximum number of iterations allowed for the computation of rates, given events.
DLCRIT	convergence criterion for the vector of person years. DLCRIT should be sufficiently small compared to the number of person years.

Estimation of rates can be started by choosing:

R. Rates from the MAIN menu

The RATES menu offers the following commands:

File of events
lets the user choose an existing r/a file of events (with extension .BIN) from the current directory. LEVENT is the default, as specified in the parameter file.
File of population
lets the user choose an existing r/a file of initial population (with extension .BIN) from the current directory. LPOPUL is the default, as specified in the parameter file.

File of rates
lets the user choose an r/a file of rates to be created (with extension .BIN) from the current directory. If no file is chosen, a new file can be created by answering ’Yes’ to the corresponding question. LRATES is the default, as specified in the parameter file.

File of person years
lets the user choose an r/a file of person years (with extension .BIN) from the current directory. If no file is chosen, a new file can be created by answering ’Yes’ to the corresponding question. LPYEAR is the default, as specified in the parameter file.

Create rates
invokes the estimation program MKRATE.

Quit
returns the user to the MAIN menu.

16. IMPLEMENTATION OF THE CONSISTENCY ALGORITHM

LIPRO's consistency algorithm, discussed extensively in chapter 5, enables one to make population projections subject to constraints on the projected numbers of events. If a projection *without* consistency is desired, the situation is very straightforward: simply set the parameter ICONS in LIPRO's parameter file equal to zero (see section 14.5) and skip the remainder of this chapter.

The consistency algorithm handles linear constraints (consistency requirements) that can be written as follows:

$$\mathbf{n} \cdot \mathbf{A} = \mathbf{c} \tag{16.1}$$

where **n** is a row vector with aggregate numbers of events (classified by sex, type, state of origin, and state of destination), **A** is a matrix with coefficients, and **c** is a vector of coefficients.
The specification of the elements in the events vector **n** is known once the state space has been determined. The total number of possible elements in vector **n** can be calculated as follows:

types of internal events:	NPOS*NPOS
types of exits:	NPOS*NOUT
types of births:	NPOS*NPOS
types of entries:	NPOS*NIN

These numbers of different types of events have to be added and then multiplied by the number of sexes, so that the dimension of **n** equals:

NSEX*NPOS*(2*NPOS+NOUT+NIN)

In the case of the household model:

2*11*(2*11+2+1) = 550

Of course, in evaluating the various formulas given in chapter 5, the computer program does not work with the full set of all possible types of events. The vector **n** is condensed in such a way that only those types of events that actually enter one or more of the consistency requirements are included in the vector; **A** and **c** are condensed accordingly.

In short, as far as the consistency algorithm is concerned, the following input is required:

a. a list of types of events (or *variables*, for short) entering the vector **n**;
b. the dimensions of the consistency problem (number of restrictions and number of variables involved);
c. the coefficients of the matrix **A**;
d. the coefficients of the vector **c**.

It would be a quite complicated and indeed very time-consuming business if these various inputs were to be entered one by one. Instead, LIPRO has been programmed in such a way that all inputs are jointly deduced by the program from a list of *consistency requirements in the form of formulas*. This method of input has many advantages:

- it saves a lot of time;
- the input is easy to read and possible errors are easy to check;
- it is very simple to make changes in the consistency requirements, e.g. adding or deleting one or more constraints;
- if the definition of the state space is slightly altered, the necessary adaptations in the consistency input may nevertheless be modest.

The consistency requirements in formula form are read by LIPRO from an ordinary text file. The form of this text file is discussed in the next sections. Besides specifying the arrays **n**, **A**, and **c** of the consistency problem (16.1), the subroutine handling this text file offers a number of additional features not discussed in chapter 5.

16.1 | The input file for the consistency algorithm

If the parameter ICONS is set equal to 1, the projection program reads the specification of the consistency relations from an ordinary text file. The name of this text file is defined in the parameter file as parameter LCONS (see chapter 14). It can be created or modified by using the built-in LIPRO editor

EDIT79 (section 13.9). Editing the input file can be achieved by the following commands:

P. Projection from the MAIN menu
E. Edit input file for consistency algorithm
from the PROJECTION menu

The lines of file LCONS contain formulas. These formulas should each start on a new line and end with a semicolon; they may extend over more than one line.
Whether LCONS contains text in lowercase or uppercase is irrelevant.

16.2 | Formulas for consistency relations

A formula is a linear combination of variables. The general form of a variable indicator is discussed in section 14.6.
Each formula corresponds to one consistency requirement. A formula should contain exactly one equality sign (=). On both sides of the equality sign the formula consists of variable indicators, preceded by a sign (+ or -) and optionally by a multiplicative constant, joined to the variable indicator by an asterisk (*); the sign may be omitted for the first term on both sides of the equality sign. In addition, each formula may optionally contain one signed constant that is *not* followed by a variable indicator.
These various elements in a consistency formula correspond to the elements of expression (16.1):

- the variable indicators correspond to the elements of the vector **n**: they identify the type of events entering the consistency relation;
- the signed multiplicative constants (a sign not followed by a constant implies a constant equal to 1) correspond to the elements of the matrix **A**;
- the constants *not* followed by a variable indicator correspond to the elements of the vector **c** (absence of such a constant implies a value of 0).

As an example, consider a marital status model with 4 internal states:

- NEVR	never married
- MARR	married
- DIVO	divorced
- WIDO	widowed

The corresponding input file LCONS could then read:

```
I(M,NEVR..WIDO,MARR) = I(F,NEVR..WIDO,MARR);
```

```
I(F,MARR,DIVO) = I(M,MARR,DIVO);
I(F,MARR,WIDO) = X(M,MARR,DEAD);
I(M,MARR,WIDO) = X(F,MARR,DEAD);
```

These formulas stand for the following consistency relations:

1. number of marrying males = number of marrying females (the range NEVR..DIVO includes all possible states of origin; the fact that this range includes state MARR does not present any problem, as long as the rates for I(*,MARR,MARR), by definition not being an event, are identically equal to zero)
2. number of divorcing males = number of divorcing females
3. number of females widowed = number of dead married males
4. number of males widowed = number of dead married females

16.3 | "Passive" consistency relations

As explained in chapter 5, the consistency algorithm adjusts each number of events in such a way that the adjusted number equals a generalized mean of all numbers entering a particular consistency relation. For example, referring to relation 4 in the example of the previous section, if the initially projected number of males entering widowhood equals 1,000 and the initially projected number of dead married females equals 1,200, then both numbers are adjusted to equal 1,091 (if the harmonic mean has been specified; 1,100 for the arithmetic mean).

However, one could argue that mortality should not be affected by the consistency step and that entries into widowhood should completely follow the projected number of deaths. Such a situation is sometimes referred to as "mortality-dominant widowhood consistency".

In order to allow for this type of dominant consistency relations, LIPRO offers the possibility of defining consistency relations in the following general layout:

```
PASSIVE {passive events} = {dominant events};
```

"PASSIVE" is a keyword that distinguishes this type of consistency relations from ordinary restrictions. Between "PASSIVE" and the equality sign, a linear combination of so-called passive events should be placed, and between the equality sign and the semicolon, a linear combination of dominant events. The effect is that LIPRO adjusts the numbers of passive events in such a way that the restriction is satisfied, without affecting the dominant events. This type of adjustment is done *after* imposing the ordinary (or "active") consistency relations. That is, if a dominant event enters one or more active restrictions, then

the passive restriction uses the consistent number of events for the dominant event in question.
Due to this strict order with which active and passive consistency relations must comply, all passive consistency relations should be placed at the end of the input file.

With mortality-dominant widowhood consistency, the file LCONS for the marital status model of the previous section could read:

```
I(M,NEVR..WIDO,MARR) = I(F,NEVR..WIDO,MARR);
I(F,MARR,DIVO) = I(M,MARR,DIVO);
PASSIVE I(F,MARR,WIDO) = X(M,MARR,DEAD);
PASSIVE I(M,MARR,WIDO) = X(F,MARR,DEAD);
```

16.4 | Formulas for endogenous constants

In some applications, e.g. the household model, some coefficients in the consistency relations may be endogenous. For example, if a lone parent remarries (experiences the event from H1PA to MAR+), then all her/his children experience the event from C1PA to CMAR. The corresponding consistency relation is as follows:

```
I(M+F,C1PA,CMAR) = m * I(M+F,H1PA,MAR+);
```

where m should equal the average number of children living in a one-parent family. In fact, m is an *endogenous constant*, dependent on demographic variables that are determined prior to the consistency step of the projection.

In order to allow for such endogenous constants, LIPRO offers the possibility of computing constants during the processing of the file LCONS. Such computations are indicated by inserted *assignment formulas* for endogenous constants in the input file. Endogenous constants are numbered from 1 to 200. If they are defined, they are indicated by a letter D, followed by their index number. If they are referred to, they are indicated by a letter C, followed by their index number. An assignment formula has the following general form:

Dn = variable_1 { operator variable_2 };

where *n* is the index number of the constant in question; it can be any integer in the range 1-200. $\mathit{variable}_1$ and $\mathit{variable}_2$ can take any of the following four forms:

1.	T(S,ORIG,DEST)	a (not consistent) number of events
2.	P(S,ORIG)	the number of individuals of sex S in state ORIG at the beginning of the projection interval
3.	x	a real number
4.	Cm	an endogenous constant

operator can be:

+	addition
-	subtraction
*	multiplication
/	division
>	linear interpolation This operator requires that both variables are constant real numbers, i.e. form 3 above. The endogenous constant defined with this operator will be assigned the value x_1 for the first projection interval, the value x_2 for the last projection interval, and values between x_1 and x_2 for intermediate intervals, computed by linear interpolation.

Now the example given above can be dealt with in the following way:

```
D1 = P(M+F,C1PA) / P(M+F,H1PA);
I(M+F,C1PA,CMAR) = C1 * I(M+F,H1PA,MAR+);
```

In fact, if one takes the position that the children of lone parents are just passive followers if their mother or father remarries, then we have in fact another example of a passive consistency relation. The preceding expressions should then be replaced by:

```
D1 = P(M+F,C1PA) / P(M+F,H1PA);
PASSIVE I(M+F,C1PA,CMAR) = C1 * I(M+F,H1PA,MAR+);
```

16.5 | Endogenous constants varying over time

Finally, LIPRO allows one to define constants which vary across projection intervals. This is achieved by letting the assignment formula be preceded by a so-called *year indicator*. A year indicator has the following general form:

$Y(\mathrm{year}_1\{..\mathrm{year}_2\})$

where $year_1$ and $year_2$ denote the index numbers of the first and last projection interval for which the assignment is to be executed.

Time-dependent constants are particularly useful in the context of *external consistency*, e.g. when one would like projected regional numbers of deaths to add up to the number of deaths in the national population projection. For example, if the endogenous constant #1 is to be 100,000 for the first projection interval and 125,000 for the second and third, then one should enter the following commands:

```
Y(1) D1 = 100000;
Y(2..3) D1 = 125000;
```

16.6 | Comments in the input file

The input file may also contain comments. This feature can be very useful, because consistency relations tend to become rather complicated.
Comments are placed between curled brackets and should not precede non-comment input on the same line. For example:

```
{This comment takes a complete line}
I(M,MARR,DIVO) = I(F,MARR.DIVO);
I(M,MARR,WIDO) = X(F,MARR,DEAD); {comment terminates the line}
```

16.7 | A complete example

Most of the features of LIPRO's input for the consistency algorithm are illustrated by the input file used for the household model. The consistency relations themselves, as well as the main assumptions underlying these consistency relations, have been presented in chapter 7. The corresponding input file for the consistency algorithm is reproduced below. Note the close similarity between the input file and the notation used in chapter 7.

```
{two-sex requirement for marriage}
I(M,cmar..sing,mar0) + I(M,unm0,mar0) + I(M,othr,mar0) =
   I(F,cmar..sing,mar0) + I(F,unm0,mar0) + I(F,othr,mar0);
I(M,cmar..sing,mar+) + I(M,unm+..h1pa,mar+) + I(M,othr,mar+) =
   I(F,cmar..sing,mar+) + I(F,unm+..h1pa,mar+) + I(F,othr,mar+);

{events for household type MAR0}
I(M,mar0,sing) + X(M,mar0,dead) = I(F,mar0,sing) + X(F,mar0,dead);
I(M,mar0,mar+) = I(F,mar0,mar+);
I(M,mar0,othr) = I(F,mar0,othr);
X(M,mar0,rest) = X(F,mar0,rest);
N(M,rest,mar0) = N(F,rest,mar0);
```

```
{events for household type MAR+}
I(M,mar+,sing) + I(M,mar+,h1pa) + X(M,mar+,dead) =
   I(F,mar+,sing) + I(F,mar+,h1pa) + X(F,mar+,dead);
I(M,mar+,mar0) = I(F,mar+,mar0);
I(M,mar+,othr) = I(F,mar+,othr);
X(M,mar+,rest) = X(F,mar+,rest);
N(M,rest,mar+) = N(F,rest,mar+);

{two-sex requirement for cohabitation}
I(M,cmar..sing,unm0) + I(M,othr,unm0) =
   I(F,cmar..sing,unm0) + I(F,othr,unm0);
I(M,cmar..sing,unm+) + I(M,h1pa,unm+) + I(M,othr,unm+) =
   I(F,cmar..sing,unm+) + I(F,h1pa,unm+) + I(F,othr,unm+);

{events for household type UNM0}
I(M,unm0,mar0) = I(F,unm0,mar0);
I(M,unm0,sing) + X(M,unm0,dead) = I(F,unm0,sing) + X(F,unm0,dead);
I(M,unm0,unm+) = I(F,unm0,unm+);
I(M,unm0,othr) = I(F,unm0,othr);
X(M,unm0,rest) = X(F,unm0,rest);
N(M,rest,unm0) = N(F,rest,unm0);

{events for household type UNM+}
I(M,unm+,mar+) = I(F,unm+,mar+);
I(M,unm+,sing) + I(M,unm+,h1pa) + X(M,unm+,dead) =
   I(F,unm+,sing) + I(F,unm+,h1pa) + X(F,unm+,dead);
I(M,unm+,unm0) = I(F,unm+,unm0);
I(M,unm+,othr) = I(F,unm+,othr);
X(M,unm+,rest) = X(F,unm+,rest);
N(M,rest,unm+) = N(F,rest,unm+);

{passive events - define constants}
D1 = P(M+F,mar+) / P(M+F,cmar);
D2 = P(M+F,unm+) / P(M+F,cunm);
D3 = P(M+F,h1pa) / P(M+F,c1pa);

{immigration of parents and children}
passive C1*N(M+F,rest,cmar) = N(M+F,rest,mar+);
passive C2*N(M+F,rest,cunm) = N(M+F,rest,unm+);
passive C3*N(M+F,rest,c1pa) = N(M+F,rest,h1pa);

{emigration of parents and children}
passive C1*X(M+F,cmar,rest) = X(M+F,mar+,rest);
passive C2*X(M+F,cunm,rest) = X(M+F,unm+,rest);
```

```
passive C3*X(M+F,c1pa,rest) = X(M+F,h1pa,rest);

{children from MAR+ as result of dissolution of marriage}
passive C1*I(M+F,cmar,c1pa) =
   I(M+F,mar+,sing) + I(M+F,mar+,h1pa) + X(M+F,mar+,dead);

{children from UNM+ as result of marriage}
passive C2*I(M+F,cunm,cmar) = I(M+F,unm+,mar+);
{children from UNM+ as result of dissolution of consensual union}
passive C2*I(M+F,cunm,c1pa) =
   I(M+F,unm+,sing) + I(M+F,unm+,h1pa) + X(M+F,unm+,dead);

{children from 1PAF as result of marriage or cohabitation}
passive C3*I(M+F,c1pa,cmar) = I(M+F,h1pa,mar+);
passive C3*I(M+F,c1pa,cunm) = I(M+F,h1pa,unm+);
```

17. SETTING SCENARIOS

The calculations underlying the projection over a single projection interval are based on two types of demographic input data:

a. population at the start of the projection interval;
b. rates (jump intensities and fertility rates) and numbers of immigrants for all types of events implicitly defined by the specification of the state space.

In most applications, the projection period extends over several consecutive projection intervals. For each projection interval (with the exception of the first one), the initial population is obtained from the final population at the end of the previous projection interval.
For the rates, however, the situation is not so simple. There is no unambiguous answer to the question which rates are to be used for the projection intervals following the first one. LIPRO offers three possibilities in this respect:

1. each projection interval uses the same set of rates. That is, rates are needed for one projection interval only, even though the projection period extends over more than one interval. This approach is denoted by the term *constant scenario*. It is chosen by setting the parameter IRATES in the parameter file (see section 14.2.2) equal to 1;
2. each projection interval uses a different set of rates. The r/a file with rates should contain data for each projection interval in the projection period. This approach is denoted by the term *variable scenario*. It is chosen by setting the parameter IRATES in the parameter file equal to 2. It is for this situation that the SCENARIO command, to be discussed in this chapter, was devised;
3. each projection interval, with the exception of the first one, uses the adjusted rates as initial rates (i.e. after imposing the consistency relations) calculated for the previous interval. That is, only one set of initial rates is needed. This approach, denoted by the term *consistent scenario*, can only be chosen in combination with ICONS=1 (i.e. consistency is required) and ISTEP2=1 (i.e. consistent rates are required). The choice is effectuated by setting the parameter IRATES in the parameter file equal to 3.

This chapter defines a scenario as a set of rates underlying a particular demographic projection. Since rates are stored in an r/a file, the setting of scenarios boils down to the creation of different r/a files of demographic rates.

If a *variable scenario* has been specified in the parameter file, the r/a file of rates should contain data for each projection interval in the projection period. There are three methods for creating such an "extended" file of rates:

a. entering all rates for all intervals one by one, using the EDIT DATA command of section 15.1. It is clear that this method will hardly ever be used in practice;
b. creating ASCII files of rates for each projection interval, and converting these one by one into the r/a format required by LIPRO, using the CONVERT command of section 15.2;
c. creating an extended rates file from a single set of rates according to certain transformation rules, using the SCENARIOS command.

Method c will be the subject of the remainder of this chapter.

17.1 | Overview of the SCENARIOS command

The SCENARIOS command invokes the program MODRAT for transforming or modifying the rates serving as input for the projection program, according to specifications supplied in an input file. Typically, MODRAT is used to prepare projections under different demographic scenarios which are variants of an underlying benchmark scenario. In other words, MODRAT creates a new r/a file of rates on the basis of an existing r/a file of rates; the newly created set of rates is a modification of the existing set of rates.
Optionally, the setting of scenarios may involve coefficients that are dependent on external data on observed events and/or population. Such coefficients are comparable to the "endogenous constants" discussed in the context of the consistency algorithm (section 16.4).

The MODRAT program invoked by the SCENARIOS command reads from four different files:

1. the *input file*, containing a specification of the way in which the rates in the benchmark scenario should be modified;
2. the *rates file*, containing the rates of the benchmark scenario;
3. (optional) the *population file*, containing data on population to be used in the computation of endogenous constants;
4. (optional) the *events file*, containing data on events to be used in the computation of endogenous constants.

MODRAT produces two files:

1. the *new rates file*, being the r/a file of rates to be created;[1]
2. the *output file*, containing messages.

Two additional parameters are passed to MODRAT:

1. (NINTRV) the *number of projection intervals* for which scenarios are to be set. This parameter determines the size of the output file;
2. (ITYPE) the *type of modification*:
   1 = *fixed*: for each projection interval, the rates in the new rates file are modifications of the rates for the first projection interval in the rates file;
   2 = *variable*: for each projection interval, the rates in the new rates file are modifications of the rates for the corresponding projection interval in the rates file;
   3 = *recursive*: for the first projection interval, the rates in the new rates file are modifications of the rates for the first projection interval in the rates file; for each subsequent projection interval, the rates in the new rates file are modifications of the rates set for the previous projection interval.

These three types of scenario setting are schematically illustrated in Figure 17.1. It should be noted that there is a close similarity between the function of the parameter ITYPE for MODRAT, on the one hand, and the function of the parameter IRATES for the projection program, on the other hand. However, the two should not be confused. MODRAT is *always* used for preparing a projection with a variable scenario. Also, the type of modification (ITYPE) is more or less independent of the type of scenario (IRATES) defined in the *currently active* parameter file.

17.2 | The input file for the SCENARIOS command

The input file is an ordinary text file. Its filename should have the extension .INP. Its lines contain formulas, controlling the setting of scenarios. In general, the *output file* will contain rates that are equal to their counterparts in the rates file, except for those rates for which modification formulas are given in the input file.

---

[1] After the new rates file has been created, its file name should be entered into the parameter file before it can serve as input for the demographic projection.

Figure 17.1. Three types of scenario setting

These formulas should each start on a new line and end with a semicolon; they may extend over more than one line. Comments in the input file are allowed, as described in section 16.6. The syntax rules are in many respects equal to those applying to the input file for the consistency algorithm (see chapter 16) and will therefore not be discussed in great length.

Two types of formulas are recognized:

1. assignments for rates;
2. assignments for endogenous constants.

17.2.1. Assignment formulas for rates

Rate modifications are entered by means of assignment formulas with the following general form:

{year indicator} {age indicator} variable = linear combination of variables;

The general form of a variable indicator is given in section 14.6. The syntax for specifying a linear combination of variables has been given in section 16.2 and will not be discussed here. It should be pointed out, though, that there is one important difference between formulas for consistency input and formulas for scenario input: the former are in terms of numbers of events, while the latter are in terms of rates. Therefore, *the variable indicators in a scenario input file are not allowed to refer to compound events: ranges of states are not allowed, and neither are the sex indicators 'T' and 'M+F'.*

The variable indicator on the left-hand side (LHS) of the equality sign in the assignment formula refers to the modified rate. Its value is set equal to the result of the evaluation of the linear combination on the RHS which reads in terms of original rates. However, if the RHS is negative, the modified rate is set equal to zero.

By default, the RHS is evaluated in terms of the original rates. For example, the variable X(M,SING,DEAD) refers to the level of the mortality rate of single males as set in the *rates file* (input file). In some cases, one would like to evaluate a variable in terms of its *current value*, i.e. its value after a modification defined by a previous expression has been applied. This can be achieved by marking the variable with the keyword "NEW". For example:

```
X(M,SING,DEAD)  =  0.90 * X(M,SING,DEAD);
X(F,SING,DEAD)  =  0.80 * newX(M,SING,DEAD);
```

The first command sets male mortality for singles to 90% of its level in the benchmark. The second command sets female mortality for singles to 80% of the *current* male mortality rate.

The assignment is executed for each age group. If a particular assignment should be limited to a subset of age groups, the assignment expression should be preceded by a so-called *age indicator*, the general form being

A(age_1{..age_2})

where age_1 and age_2 denote the index numbers of the first and last age group for which the assignment is to be executed. It should be recalled that index number 1 refers to the age group born during the projection interval.

The assignment is executed for each projection interval (1···NINTRV), unless a *year indicator* precedes the assignment formula. A year indicator has the following general form:

Y(year_1{..year_2})

where $year_1$ and $year_2$ denote the index numbers of the first and last projection interval for which the assignment is to be executed.

17.2.2. Assignment formulas for endogenous constants

Endogenous constants are defined in exactly the same way as discussed in sections 16.4 and 16.5. They are computed in terms of numbers of events (read from the events file) and population numbers (read from the population file), corresponding to the projection interval at hand.

17.3 | Example

As an example, consider the marital status model of section 16.2. Assume that, starting from a "constant scenario" (i.e. IRATES=1), we want to set a mortality scenario that reduces the mortality rates for ages 40 and over by 5 percentage points per year, starting from the second year. In doing so, we should take into account that a change in mortality of married males (females) implies a corresponding change in the rate at which married females (males) experience the jump into widowhood. Although not exact (because of age differences between male and female spouses), a reasonable approximation would be to reduce the rate of entry into widowhood by the same amount, assuming that married males are, on average, 5 years older than married females.
The corresponding input file could then read as follows:

```
Y(1..3) D1 = 1.00 > 0.80;
Y(2..5) A(10..19) X(M,NEVR,DEAD)      =C1 * X(M,NEVR,DEAD);
Y(2..5) A(10..19) X(M,MARR,DEAD)      =C1 * X(M,MARR,DEAD);
Y(2..5) A( 9..19) I(F,MARR,WIDO)      =C1 * I(F,MARR,WIDO);
Y(2..5) A(10..19) X(M,WIDO,DEAD)      =C1 * X(M,WIDO,DEAD);
Y(2..5) A(10..19) X(M,DIVO,DEAD)      =C1 * X(M,DIVO,DEAD);
Y(2..5) A(10..19) X(F,NEVR,DEAD)      =C1 * X(F,NEVR,DEAD);
Y(2..5) A(10..19) X(F,MARR,DEAD)      =C1 * X(F,MARR,DEAD);
Y(2..5) A(11..19) I(M,MARR,WIDO)      =C1 * I(M,MARR,WIDO);
Y(2..5) A(10..19) X(F,WIDO,DEAD)      =C1 * X(F,WIDO,DEAD);
Y(2..5) A(10..19) X(F,DIVO,DEAD)      =C1 * X(F,DIVO,DEAD);
```

Note 1: The first statement illustrates the use of the operator for linear interpolation (section 16.4). Constant number 1 will be assigned the values 1.00, 0.90, 0.80, 0.80, and 0.80 for the years 1, 2, 3, 4, and 5, respectively.

Note 2: The index number for age group 40-44 is 10, as index number 1 is used to denote the cohort born during the projection interval.

The second example refers to the household model. Assume that we want to reduce the mortality of married males by 5%. This also affects the following rates:

- female jumps from state MAR0 to SING;
- female jumps from state MAR+ to H1PA;
- male and female jumps from state CMAR to C1PA.

The complication is caused by the fact that the jumps MAR0 → SING, MAR+ → H1PA and CMAR → C1PA can be the result of two different events:

- death of spouse;
- divorce.

The problem is to modify the rates in such a way that the underlying divorce rates remain unaffected. In doing so, we have to make several simplifying assumptions:

1. married spouses are in the same age group;
2. the relative importance of divorce and death of parent as cause of the event CMAR → C1PA is independent of the age of the children.

From assumption 1, the rate at which a married woman becomes head of a one-parent family because of divorce can be written as:

I(F,MAR+,H1PA,divorce) = I(F,MAR+,H1PA) - X(M,MAR+,DEAD)

The modified rate of entry into state H1PA equals the sum of the (unchanged) rate of divorce and the (modified) rate of widowhood, i.e.

I_{new}(F,MAR+,H1PA) = I_{old}(F,MAR+,H1PA) - X_{old}(M,MAR+,DEAD) + X_{new}(M,MAR+,DEAD)

From assumption 2, the share of male mortality in explaining the number of jumps from state CMAR to C1PA can be calculated as

$$\alpha = \frac{\text{total number of male deaths from state MAR+}}{\text{total number of female (or male) exits from state MAR+}}$$

Since we reduce male mortality by 5%, the modified rate for entry into state C1PA should be set equal to:

I_{new}(CMAR,C1PA) = $(1-\alpha)$ * I_{old}(CMAR,C1PA) + 0.95 α * I_{old}(CMAR,C1PA)

The corresponding input file could then read as follows:

```
X(M,MAR0,DEAD) = 0.95 * X(M,MAR0,DEAD);
I(F,MAR0,SING) =   I(F,MAR0,DEAD) - X(M,MAR0,DEAD) +
                   newX(M,MAR0,DEAD);
X(M,MAR+,DEAD) = 0.95 * X(M,MAR+,DEAD);
I(F,MAR+,H1PA) =    I(F,MAR+,H1PA) - X(M,MAR+,DEAD) +
                    newX(M,MAR+,DEAD);
D1 = X(M,MAR+,DEAD) ; { numerator in expression for α }
D2 = I(F,MAR+,SING) + I(F,MAR+,H1PA);
D2 = C2 + X(F,MAR+,DEAD); { denominator in expression for α }
D2 = C1 / C2; { α }
D3 = 1 - C2; { 1 - α }
D4 = 0.95 * C2; { 0.95 α }
D5 = C3 + C4; { (1-α) + 0.95 α }
I(M,CMAR,C1PA) = C5 * I(M,CMAR,C1PA);
I(F,CMAR,C1PA) = C5 * I(F,CMAR,C1PA);
```

17.4 | The SCENARIOS menu

The setting of scenarios can be started by choosing:

S. Scenarios from the MAIN menu

The screen of the SCENARIOS menu is displayed in figure 17.2.

Figure 17.2. The SCENARIOS menu

Input file
lets the user choose an existing input file (with extension .INP) from the current directory. If no file is chosen (by pressing ESC or F10), one may create a new input file by answering Yes to the corresponding question. If the file name of the input file to be created already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the input file has to be edited.

Edit input file
lets the user edit the input file using the EDIT79 program.

Rates file
lets the user choose an existing r/a file of rates (with extension .BIN) from the current directory. LRATES is the default, as specified in the .PAR file.

New rates file
lets the user choose an r/a file of rates to be created (with extension .BIN) from the current directory. If no file is chosen, a new file can be created by answering ’Yes’ to the corresponding question.
It should be remembered that, once the new rates file has been created, its file name should be entered into the parameter file (cf. section 14.5) before it can serve as input for the demographic projection.

Population file
lets the user choose an existing r/a file of population data (with extension .BIN) from the current directory. LPOPUL is the default, as specified in the .PAR file.

Events file
lets the user choose an existing r/a file of events (with extension .BIN) from the current directory. LEVENT is the default, as specified in the .PAR file.

Output file
lets the user define the output file.

Browse output file
lets the user inspect the output text file (if it exists) by LIPRO’s built-in BROWSE program.

Number of periods
lets the user specify the number of projection intervals (NINTRV) for which scenarios are to be set. Default is 1.

Type of input rates
toggles between the three types of scenario setting: "fixed", "variable", and "recursive". "Fixed" is the default. If "variable" is selected, the user should make sure that the rates file contains data for at least NINTRV projection intervals.

Create scenarios
invokes the program MODRAT.

Quit
returns the user to the MAIN menu.

18. PROJECTION

In the previous chapters we have described the various preparatory steps required before a demographic projection can be executed with LIPRO. These steps are:

1. definition of the state space (chapter 14);
2. definition of the various model parameters (chapter 14);
3. creation of a file with initial population data (chapter 15);
4. creation of a file with occurrence-exposure rates and numbers of immigrants (chapter 15 for constant and consistent scenarios; chapter 17 for variable scenarios);
5. (optional) creation of a file with requirements for internal and external consistency (chapter 16).

Once all these preparations are completed, the PROJECTION command can be invoked. For each projection interval, the computations involve the following steps:

1. for given initial population and rates, calculate events, person years, and final population;

*. if consistency is required, then:
    2. for given projected numbers of events, calculate adjusted numbers of events such that all consistency constraints are satisfied;
    *. if consistent rates are required, then:
        3. calculate consistent rates, and update person years, adjusted events and final population;

        otherwise
        4. update final population, according to adjusted numbers of events.

These various steps change the contents of the following files:

1. LEVENT (unadjusted events)
   LPYEAR (person years)
   LPOPUL (final population)
2. LEVENC (adjusted events)

3.	LRATEC	(adjusted rates)
	LEVENC	(adjusted events)
	LPYEAR	(person years)
	LPOPUL	(final population)
4.	LPOPUL	(final population)

After projection, the contents of these files can be examined with the commands to be discussed in chapter 19.

The PROJECTION command is reached by choosing

P. Projection from the MAIN menu

A menu is displayed containing the following commands:

Output file
lets the user choose an output file, with extension .OUT, from the current directory. The output file of the PROJECTION command will contain messages from the projection program, including a summary of the parameter settings and aggregate results for the consistency algorithm, if applicable.

Browse output file
lets the user inspect the output text file (if any) by LIPRO's built-in BROWSE program.

Edit input file for consistency algorithm
lets the user edit the file LCONSI, the file name of which is specified in the parameter file. Details on how this input file should be prepared are given in chapter 16.

Projection
starts the actual projection.

Quit returns the user to the MAIN menu.

19. ANALYSIS

The LIPRO projection program produces results in the form of binary random access files. The analysis of these results therefore boils down to inspecting the contents of these r/a files.

The number of analytical facilities implemented in LIPRO itself is relatively limited. The facilities are restricted to the production of a number of tables, which are the following:

1. tables simply reproducing the contents of the r/a files in a readable form;
2. multi-state life tables;
3. tables of transition probabilities.

However, the mere fact that LIPRO’s analytical facilities are relatively limited should certainly *not* be interpreted to imply that the projection results can hardly be analysed. The contrary is true. LIPRO offers several ways in which its result can be "exported" to external programs, like spreadsheet programs or graphical software.

In addition, it should be noted that plans are now being developed for creating an interface between LIPRO and MDB. MDB is a program, developed by Frans Willekens of the NIDI, for the analysis and maintenance of multidimensional databases. Its options include flexible manipulation of multidimensional tables and several types of graphics.

This chapter discusses the various LIPRO commands for analysis of projection results, as well as methods by which projection results can be stored in a format in which they can serve as input for external programs.

19.1 | The ANALYSIS menu

The ANALYSIS menu is reached by choosing:

A. Analysis	from the MAIN menu

It offers the following commands:

Tables
enters the TABLES menu (section 19.2) for printing tables of population, person years, rates, events, and effects of imposing the consistency requirements.

Aggregate population tables
enters the AGGREGATE menu (section 19.3) for printing population tables, with flexible aggregation over age groups and options for calculating row and column percentages.

Life table analysis
enters the LIFE TABLE ANALYSIS menu (section 19.4) for the creation and analysis of multi-state life tables. Details can be found in chapter 6.

Transition probabilities
enters the TRANSITION PROBABILITIES menu (section 19.5) for printing age- and sex-specific matrices of transition probabilities and jump intensities.

Quit
returns the user to the MAIN menu.

19.2 | The TABLES command

LIPRO offers five types of tables in which the contents of the r/a files, be it before or after a projection has been calculated, can be presented in a readable form:

1. tables of population;
2. tables of person years;
3. tables of events;
4. tables of rates;
5. tables of inconsistent and consistent events, aggregated over all age groups, as well as their ratios (i.e. the multiplicative adjustment factor for each type of event as produced by the consistency algorithm).

Each set of tables requires two files:

a. An input file, specifying the form of the table;
b. An output file, containing the tables.

19.2.1. Input files for the TABLES command

The form of the input file differs slightly between the five types of tables. For this reason, their file names have different extensions:

.PIN	for types 1 and 2
.EIN	for types 3 and 4
.CIN	for type 5

The three types of input files are discussed below.

Input files with extension .PIN

These files contain the following parameters:

a. (LHEAD)	a heading printed at the top of each page
b. (ISEX1,ISEX2)	index of first and last sex for which tables have to be created. 3 corresponds to total over both sexes if NSEX=2
c. (IYR1,IYR2)	first and last year for which tables have to be created. IYR2 should be set equal to IYR1 in case table for only one year are required
d. (NWID0)	width of age column in table
e. (NWID)	width of remaining columns in table
f. (NDEC)	number of digits behind the decimal point

Input files with extension .EIN

These files contain the following parameters:

a. (LHEAD)	a heading printed at the top of each page
b. (ISEX1,ISEX2)	index of first and last sex for which tables have to be created. 3 corresponds to total over both sexes if NSEX=2
c. (IYR1,IYR2)	initial year of first period and initial year of last period for which tables have to be created
d. (NWID0)	width of age column in table
e. (NWID)	width of remaining columns in table
f. (NDEC)	number of digits behind the decimal point
g. (IPRTX)	a number of parameters, one for each internal state, indicating whether the table for exits from that state is to be printed: 1 = yes 0 = no

h. (IPRTN)	a number of parameters, one for each internal state, indicating whether the table for entries into that state is to be printed: 1 = yes 0 = no
i. (IPRTB)	a parameter indicating whether the table for births by position of mother is to be printed: 1 = yes 0 = no

Input files with extension .CIN
These files contain the following parameters:

a. (LHEAD)	a heading printed at the top of each page
b. (ISEX1,ISEX2)	index of first and last sex for which tables have to be created. 3 corresponds to total over both sexes if NSEX=2
c. (IYR1,IYR2)	initial year of first period and initial year of last period for which tables have to be created
d. (NWID0)	width of label column in table
e. (NWID)	width of remaining columns in table
f. (NDEC)	number of digits behind the decimal point for the tables with numbers of events
g. (NDECR)	number of digits behind the decimal point for the tables with ratios between inconsistent and consistent numbers of events.

The data are read from the files LEVENT and LEVENC.

19.2.2. Default values for parameters in TABLES input files

The various parameters in the TABLES input files have the following default values:

Parameter	*Default*
LHEAD	’’
ISEX1	1
ISEX2	1 if NSEX=1 3 if NSEX=2
IYR1	ITIME1
IYR2	ITIMEZ
NWID0	8
NWID	10
NDEC	0
NDECR	4
IPRTX	all zeros
IPRTN	all zeros
IPRTB	10

19.2.3. The TABLES menu

Tables can be produced by choosing:

A. Analysis	from the MAIN menu
T. Tables	from the ANALYSIS menu

The TABLES menu offers the following commands:

T. Type of tables
I. Input file
E. Edit input file
O. Output file
B. Browse output file
R. Random access file (input)
P. File of person years (input)
U. File of unadjusted events (input)
A. File of adjusted events (input)

C. Create tables

Q. Quit

Not all of these commands are actually in the menu. **U** and **A** are available only for table type 5; **R** for types 1-4; and **P** for type 4 (tables of rates).

Type of tables
lets the user define which type of tables one wants to produce. This command toggles between "population", "person years", "events", "rates", and "consistency algorithm". Type "population" is the default. If the type of tables is changed, the input file becomes undefined.

Input file
lets the user choose an existing input file (with the correct extension) from the current directory. If no file is chosen (by pressing ESC or F10), one may create a new input file by answering Yes to the corresponding question. If the file name of the input file to be created already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the input file has to be edited.

Edit input file
lets the user edit the parameters in the input file.

Output file
lets the user choose an output file from the current directory.

Browse output file
lets the user inspect the output text file by LIPRO's built-in BROWSE program.

Random access file
lets the user choose an existing .BIN file from the current directory, containing the data from which the tables are to be printed. The default file names depend on the type of table selected, as follows:

type 1: LPOPUL
type 2: LPYEAR
type 3: LEVENT (unadjusted events)
type 4: LRATES

File of person years
lets the user choose an existing .BIN file from the current directory, containing data on person years to be used in printing tables of rates. These person years are needed to calculate average rates across internal positions and/or age groups. If the file of person years does not exist, or if it does not contain data for each period, then the corresponding tables are calculated under the assumption that all internal states and/or age groups receive the same weight in calculating average rates. Default is the file LPYEAR.

File of unadjusted events
lets the user choose an existing .BIN file from the current directory, containing data on unadjusted events to be used in printing tables of type 5. Default is file LEVENT.

File of adjusted events
lets the user choose an existing .BIN file from the current directory, containing data on adjusted events to be used in printing tables of type 5. Default is file LEVENC.

Create tables
invokes the program for creating tables according to the type and input file specified.

Quit
returns the user to the ANALYSIS menu.

19.2.4 Example

As an example, we have created tables with intensities for the exit from and the entry into the state SING for the household model. The TABLES menu screen is given in figure 19.1. Note the presence of the command *File of person years*: person years are required in order to be able to aggregate intensities across states and/or age groups. The parameters specifying the contents and layout of the tables are stored in an input file named RATES.EIN. The contents of this input file are displayed in figure 19.2. The corresponding output file, named OUTPUT.OUT, is partly reproduced as table 19.1.

19.3 | The AGGREGATE command

The AGGREGATE command is in fact a special case of the more general TABLES command. Its purpose is to produce tables of population data with aggregation across age groups. In addition, it contains an extra option for printing tables with row percentages (i.e. across states) and column percentages (i.e. across broad age groups).

19.3.1. The AGGREGATE input file

The functioning of the AGGREGATE command is very similar to that of the TABLES command with tables type "population". AGGREGATE reads the parameters specifying the contents of the tables from an input file with extension .AIN. This input file contains the following parameters:

Figure 19.1. The TABLES menu

Figure 19.2. The EDIT INPUT FILE command

Table 19.1. Part of the output file for the TABLES command

```
Exit and entry rates of singles
Exits from state sing      Sex : female    Time : 1985-1989   File : REALRATE.BIN

             cmar      cunm      c1pa      sing      mar0      mar+      unm0
births     0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
15-19      0.0182    0.0000    0.0017    0.0000    0.0703    0.0009    0.1189
20-24      0.0066    0.0000    0.0024    0.0000    0.0530    0.0009    0.0935
25-29      0.0012    0.0000    0.0000    0.0000    0.0319    0.0000    0.0486
30-34      0.0000    0.0000    0.0000    0.0000    0.0153    0.0000    0.0520
35-39      0.0000    0.0000    0.0000    0.0000    0.0068    0.0000    0.0357
40-44      0.0000    0.0000    0.0000    0.0000    0.0053    0.0000    0.0122
45-49      0.0014    0.0000    0.0000    0.0000    0.0094    0.0000    0.0284
50-54      0.0015    0.0000    0.0000    0.0000    0.0058    0.0000    0.0139
55-59      0.0000    0.0000    0.0000    0.0000    0.0007    0.0016    0.0019
60-64      0.0000    0.0000    0.0000    0.0000    0.0000    0.0003    0.0028
65-69      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0027
70-74      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0017
75-79      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
80-84      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
85+        0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TOTAL      0.0018    0.0000    0.0004    0.0000    0.0136    0.0003    0.0265

             unm+      h1pa      nfra      othr      dead      rest     TOTAL
births     0.0000    0.0000    0.0000    0.0000    0.0046    0.0060    0.0106
 0- 4      0.0000    0.0000    0.0000    0.0000    0.0003    0.0062    0.0065
 5- 9      0.0000    0.0000    0.0000    0.0000    0.0002    0.0039    0.0041
10-14      0.0000    0.0000    0.0000    0.0000    0.0003    0.0024    0.0027
15-19      0.0011    0.0177    0.0037    0.0165    0.0004    0.0047    0.2540
20-24      0.0024    0.0110    0.0056    0.0077    0.0006    0.0070    0.1908
25-29      0.0030    0.0182    0.0022    0.0027    0.0010    0.0072    0.1159
30-34      0.0034    0.0133    0.0094    0.0069    0.0016    0.0052    0.1071
35-39      0.0004    0.0035    0.0000    0.0012    0.0022    0.0038    0.0537
40-44      0.0000    0.0000    0.0000    0.0004    0.0035    0.0029    0.0242
45-49      0.0000    0.0000    0.0007    0.0000    0.0048    0.0022    0.0469
50-54      0.0008    0.0000    0.0022    0.0000    0.0066    0.0017    0.0325
55-59      0.0011    0.0000    0.0002    0.0000    0.0097    0.0014    0.0167
60-64      0.0000    0.0000    0.0000    0.0021    0.0137    0.0012    0.0200
65-69      0.0000    0.0000    0.0002    0.0036    0.0214    0.0009    0.0288
70-74      0.0000    0.0000    0.0011    0.0027    0.0369    0.0006    0.0430
75-79      0.0000    0.0000    0.0019    0.0022    0.0639    0.0005    0.0685
80-84      0.0000    0.0000    0.0038    0.0000    0.1660    0.0004    0.1703
85+        0.0000    0.0000    0.0064    0.0000    0.2017    0.0003    0.2085
TOTAL      0.0008    0.0043    0.0023    0.0034    0.0305    0.0026    0.0864
```

a.	(LHEAD)	a heading printed at the top of each page
b.	(ISEX1,ISEX2)	index of first and last sex for which tables have to be created. 3 corresponds to total over both sexes if NSEX=2
c.	(IYR1,IYR2)	initial year of first period and initial year of last period for which tables have to be created
d.	(NWID0)	width of age column in table
e.	(NWID)	width of remaining columns in table
f.	(NDEC)	number of digits behind the decimal point
g.	(SCALEFAC)	a scaling factor indicating the ratio between the numbers to be printed in the table and the corresponding numbers in the r/a file. For example, if the r/a file measures the population in single individuals and SCALEFAC is set equal to 1e-3, then the output tables give population numbers in thousands
h.	(IPRTABS)	indicates whether tables of absolute numbers should be printed (1=yes, 0=no)
i.	(IPRTROW%)	indicates whether tables of row percentages should be printed (1=yes, 0=no)
j.	(IPRTCOL%)	indicates whether tables of column percentages should be printed (1=yes, 0=no)
k.	(ILOWAGE)	an array of 8 lower limits for the broad age groups to be constructed. By default, these lower limits are 0 for the first group and 999 for groups 2-8. If a table is desired of the population aged 60 and over only, classified in age groups of 10 years, then this array should be specified as (60, 70, 80, 999, 999, 999, 999, 999).

19.3.2. Default values for parameters in AGGREGATE input files

The parameters in the AGGREGATE input file have the following default values:

Parameter	*Default*
LHEAD	’ ’
ISEX1	1
ISEX2	1 if NSEX=1 3 if NSEX=2
IYR1	ITIME1
IYR2	ITIMEZ
NWID0	8
NWID	10
NDEC	0
SCALEFAC	1.0
IPRTABS	1
IPRTROW%	0

IPRTCOL%	0
ILOWAGE	(0, 999, 999, 999, 999, 999, 999, 999, 999)

19.3.3 The AGGREGATE menu

Tables can be produced by choosing:

A. Analysis	from the MAIN menu
A. Aggregate	from the ANALYSIS menu

The AGGREGATE menu offers the following commands:

Input file
lets the user choose an existing input file (with extension .AIN) from the current directory. If no file is chosen (by pressing ESC or F10), one may create a new input file by answering Yes to the corresponding question. If the file name of the input file to be created already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the input file has to be edited.

Edit input file
lets the user edit the parameters in the input file.

Output file
lets the user choose an output file from the current directory.

Browse output file
lets the user inspect the output text file by LIPRO's built-in BROWSE program.

Random access file
lets the user choose an existing .BIN file from the current directory, containing the population data from which the tables are to be printed. The default is LPOPUL.

Create tables
invokes the program for creating tables according to the input file specified.

Quit
returns the user to the ANALYSIS menu.

19.4 | The LIFE TABLE ANALYSIS command

The LIFE TABLE ANALYSIS command invokes the program STABLE. STABLE produces a number of life tables for an imaginary cohort, experiencing demographic events over its life cycle according to a particular set of rates. Starting point for the life table analysis is an r/a file of rates. In creating the life tables, STABLE sets the rates for international migration equal to zero. More technical details on STABLE are given in chapter 6.

The STABLE program is activated by choosing:

A. Analysis	from the MAIN menu
L. Life table analysis	from the ANALYSIS menu

The LIFE TABLE ANALYSIS menu offers the following commands:

Parameters
lets the user set the following parameters: column width for labels (default: 8); column width for numbers (default: 10); number of decimal places for totals (default: 0); number of decimal places for percentages (default: 4).

Rates
lets the user specify which rates are to constitute the basis of the life table analysis (see section 19.4.1).

Distribution of births enters a sub-menu in which the radix of the life table corresponding to the stable population can be entered or calculated (see section 19.4.2).

Life tables
produces life tables for the specified radix and rates. The following tables are produced:

a. number of surviving members by sex, age, and state;
   b. idem in % across states;
   c. number of person years by sex, age, and state. For the total across age groups, this table gives the expected number of years lived in a particular state;
   d. idem in % across states;
   e. number of births, by age and state of mother;
   f. idem in % across states;
   g. number of births, by age of mother and state of child;
   h. idem in % across states.

Fertility statistics
produces the fertility statistics listed in section 6.5 for the most recently computed life table.

Experience tables
enters a sub-menu for specifying and creating experience tables (see section 19.4.3).

Output file
lets the user specify the output file.

Browse output file
lets the user inspect the output text file (if any) by LIPRO's built-in BROWSE program.
It could happen that BROWSE gives the error message "Fatal error: file too large". This occurs in cases where the state space of the model is so large that the STABLE program occupies most of the available memory. The output file can then be inspected only after leaving the STABLE program, e.g., using the FILES command of the MAIN menu.

Quit returns to the MAIN menu.

19.4.1. The RATES command

This command enters a sub-menu in which the name of the r/a file of rates, as well as the year to be analysed, can be specified. The sub-menu contains the following commands:

File of rates
lets the user choose an existing file of rates (with extension .BIN) from the current directory. The selected file will be analysed by STABLE. Default is the file LRATES as specified in the parameter file.

Year to analyse
lets the user specify for which year the rates are to be analysed. Default is the first year in the file of rates, i.e. ITIME1 as specified in the parameter file.

Quit
returns to the LIFE TABLE ANALYSIS menu.

19.4.2. The DISTRIBUTION OF BIRTHS command

This command enters a sub-menu in which the radix of the life table corresponding to the stable population can be entered or calculated. The sub-menu offers the following commands:

Edit female radix
lets the user edit the radix (vector) of the life table, as well as indicate whether this radix is either the known radix for the stable population, or only a first guess. By default, the radix contains zeros everywhere, except in the first position. Also by default it is assumed to be the true stable radix.

Distribution of births
calculates the radix for the stable population by first creating life tables for each of the states for which the radix element entered is positive, and subsequently solving the eigenvalue problem discussed in chapter 6.2. However, when either the radix contains only one non-zero element, or the user has specified that the radix is the known radix for the stable population, this command has no effect (since there is no problem to solve).

Output file
lets the user specify the output file

Browse output file
lets the user inspect the output text file (if any) by LIPRO’s built-in BROWSE program.

Quit
returns to the LIFE TABLE ANALYSIS menu.

19.4.3. The EXPERIENCE TABLES command

This command enters a sub-menu for specifying and creating experience tables. Details about these experience tables are given in section 6.6. The sub-menu contains the following commands:

Input file
specifies the name of the file with input parameters. The input file for the EXPERIENCE TABLES command has extension .LET (standing for "Lifetable Experience Table"). If no file is chosen from the directory screen, one may create a new input file by answering Yes to the corresponding question; the file then has to be edited.

Edit input file
lets the user specify the events set for the experience tables. The input parameters include:

- a title;
- the births into a particular state, to be included in the set;
- the internal events, to be included in the set.

After issuing the *Edit input file* command, a screen is displayed with these three types of parameters. If the number of internal positions is larger than 15, only the internal events from the first 15 states are displayed. The following command bar is given:

Title Births Exits States Quit

The first three commands enter an edit screen in which the corresponding parameters can be edited. An event or birth to be included in the events set should be marked by a character that is *not* a period (’.’), hyphen (’-’), zero (’0’), or space (’ ’).[1] By default the events set is empty.

The *States* command applies to situations in which the number of states exceeds 15. Pressing ’S’ or [PgDn] scrolls the screen to the next page of 15 internal positions. Pressing Ctrl-S or [PgUp] scrolls one screen backwards.

Output file
lets the user specify the output file.

Browse output file
lets the user inspect the output text file (if any) by LIPRO’s built-in BROWSE program.

Create tables
creates the experience tables.

Quit
returns to the LIFE TABLE ANALYSIS menu.

19.4.4. Example

The example concerns the household model. First, suppose that we want to compute a life table. Since children can be born into either of the states CMAR, CUNM, C1PA, and OTHR, we first need to compute the stable distribution across states of birth. For this purpose, we select the *Edit female radix* command, and we enter a radix with positive numbers in positions 1, 2, 3, and 11, and zeros elsewhere. In addition, the status of the radix is specified as 2, indicating that the true stable radix is unknown. Now the stable distribution across states of births can be computed by the program.

---

[1] Marking an "impossible events" (cf. section 7.3) has no effect on the computation of the experience table.

Next, suppose that we want to analyse two sets of events: "Ever lived in a one-parent family" and "Ever been head of a one-parent family". The parameters for the experience tables are given in figures 19.3 and 19.4, respectively.

19.5 | The TRANSITION PROBABILITIES command

The TRANSITION PROBABILITIES command prints tables with age- and sex-specific matrices of rates and transition probabilities. Each row of a table corresponds with one of the internal states from which a direct jump can be experienced. Each column of a table corresponds with one of the states into which an individual can jump; these states include all internal states, as well as the external states (death, rest of the world).
Although jump intensities and transition probabilities are closely related concepts, there are two important differences:

1. a transition probability requires the specification of a time interval with a certain length, while an intensity is a timeless concept;
2. a transition probability reads in terms of positions at two different points in time, while an intensity reads in terms of events.

An example of a transition probability in the household model is "the probability that a 20 year old single male will be married at age 25 and have a child". This transition probability can be written as a function of, among other things, the length of the time period (here: 5 years), the intensity for the event "from SING to MAR0", and the intensity for the event "from MAR0 to MAR+".
Mathematically, the relationship between an intensity matrix **M**, a matrix of transition probabilities **T**, and the length of the time interval h, can be written as follows (cf. chapter 4):

for the exponential model: $\mathbf{T} = e^{\mathbf{M} \cdot h}$
for the linear model: $\mathbf{T} = (\mathbf{I} + ½h \cdot \mathbf{M}) \cdot (\mathbf{I} - ½h \cdot \mathbf{M})^{-1}$

The TRANSITION PROBABILITIES command computes probabilities according to the type of model (exponential or linear) as specified in the parameter file.

19.5.1. The TRANSITION PROBABILITIES input file
TRANSITION PROBABILITIES reads the parameters specifying the contents of the tables from an input file with extension .TIN. This input file contains the following parameters:

Figure 19.3. Example 1 of the EXPERIENCE TABLES command

Figure 19.4. Example 2 of the EXPERIENCE TABLES command

a.	(LHEAD)	a heading printed at the top of each page
b.	(ISEX1,ISEX2)	index of first and last sex for which tables have to be created
c.	(IAGE1,IAGE2)	index of first and last age group for which tables have to be created
d.	(IYR1,IYR2)	initial year of first period and initial year of last period for which tables have to be created
e.	(NWID0)	width of row labels in table
f.	(NWID)	width of remaining columns in table
g.	(NDEC)	number of digits behind the decimal point
h.	(SCALEFAC)	a scaling factor indicating the total to which the row sums of transition probabilities should add up. For example, if SCALEFAC is set equal to 100, then the transition probabilities are printed in terms of percentages.
i.	(IPRTRAT)	indicates whether intensity matrices should be printed (1=yes, 0=no)
j.	(IPRTTRANS)	indicates whether matrices of transition probabilities should be printed (1=yes, 0=no)

19.5.2. Default values for parameters in TRANSITION PROBABILITIES input files

The parameters in the TRANSITION PROBABILITIES input file have the following default values:

Parameter	*Default*
LHEAD	’’
ISEX1	1
ISEX2	NSEX
IAGE1	1
IAGE2	NAGE
IYR1	ITIME1
IYR2	ITIMEZ
NWID0	8
NWID	10
NDEC	0
SCALEFAC	1.0
IPRTRAT	0
IPRTPROB	1

19.5.3. The TRANSITION PROBABILITIES menu

Tables can be produced by choosing:

A. Analysis	from the MAIN menu
T. Transitions probabilities	from the ANALYSIS menu

The TRANSITION PROBABILITIES menu offers the following commands:

Input file
lets the user choose an existing input file (with extension .TIN) from the current directory. If no file is chosen (by pressing ESC or F10), one may create a new input file by answering Yes to the corresponding question. If the file name of the input file to be created already exists, the program verifies whether the existing file may be overwritten. If the answer is yes, the input file has to be edited.

Edit input file
lets the user edit the parameters in the input file.

Output file
lets the user choose an output file from the current directory.

Browse output file
lets the user inspect the output text file by LIPRO's built-in BROWSE program.

Random access file
lets the user choose an existing .BIN file from the current directory, containing the rates data from which the tables are to be printed. The default is LRATES.

Create tables
invokes the program for creating tables according to the input file specified.

Quit
returns the user to the ANALYSIS menu.

19.6 | Exporting LIPRO results

Basically, there are two methods by which LIPRO results can be exported to other programs in the form of ASCII files. These are the following:

1. using the CONVERT command discussed in section 15.2;
2. using one of the tables producing commands discussed in the present chapter, with output specified in the form of a disk file.

In order to increase the usefulness of the second method, two utilities have been included in the LIPRO program:

a. the option to vary the width of the printed tables;
b. the option to have the row and column labels in the tables be enclosed in double quotation marks. With this option in effect, tables can be quite easily read into worksheet programs, like LOTUS 1-2-3.

These utilities are discussed in section 20.1.

20. MISCELLANEOUS PROGRAM FEATURES

20.1 | The UTILITIES menu

The UTILITIES menu allows one to change the settings in the configuration file LIPRO.FIG. The command is selected by choosing:

U. Utilities from the MAIN menu

The UTILITIES MENU offers the following commands:

Screen colours
allows one to change the different colours in which LIPRO displays output on the screen. This command is discussed more fully in section 20.2.

Maximum table width
lets one specify the maximum width of the tables produced by the commands of chapter 19. The maximum width may range from 40 to 255. If the width of a table exceeds the maximum table width, it is split up into separate sub-tables.

Lotus .PRN format for tables
lets one specify whether the row and column labels in tables produced by the commands of chapter 19 are to be enclosed in double quotation marks. If they are, then the disk files containing the tables output can be easily read into Lotus with the Lotus /File/Import/Numbers command.

COMMAND.COM path
specifies the location of the file COMMAND.COM. An incorrect path name will result in a failure of the MAIN MENU's command MS/DOS INTERNAL COMMAND (see section 20.4).

PRINT.COM path
specifies the location of the file PRINT.COM. An incorrect path name will result in a failure of the directory screen's PRINT command.

Binary file conversion
invokes the program BIN68 for converting 8-byte r/a files to 6-byte format and vice versa. See section 20.5 for details.

20.2 | The SCREEN COLOURS command

The SCREEN COLOURS command allows one to change the different colours in which LIPRO displays output on the screen. It is activated by choosing:

U. Utilities	from the MAIN menu
S. Screen colours	from the UTILITIES menu

After the command has been activated, the screen displays the seven different combinations of background and foreground colours as currently set in the configuration file. These seven combinations are:

1. Files and directory information (lines 1 and 2 on the screen)
2. Menu and command information (line 3 on the screen)
3. Command bar (line 25 on the screen)
4. Ordinary text
5. Highlighted text
6. Block cursor
7. Directory information (line 4 on the screen in directory screens)

The screen also displays examples of the 16 different colours that can be chosen. Depending on the type of monitor, it could well be that not all colours appear as intended.

The following command bar is displayed:

E = Edit **Q = Quit**

Edit
allows the user to change the colour setting by entering a new colour number.

Quit
saves the new settings in the LIPRO.FIG file and returns the user to the UTILITIES menu.

20.3 | The EXECUTE A PROGRAM command

This command is a utility for executing a .COM or .EXE file without actually leaving LIPRO. It is selected by choosing:

X. Execute a program from the MAIN menu

An edit screen appears consisting of two fields:

1. the full path of the program to be executed, including its extension (.COM or .EXE). If no extension is given, .EXE is assumed. If no subdirectory is given, the program is assumed to be in the current directory, or in one of the directories specified in the MS/DOS search path;
2. (optional) command line parameters to be passed to the program.

Possible error codes include:

8. not enough memory
2. path not found
1. file not found

After leaving the edit screen, the program, if the program name entered is not empty, is loaded and executed.

20.3.1. Example

Suppose the following fields are entered:

1. c:\programs\myprog.com
2. par1 par2

This is equivalent to entering

```
myprog.com par1 par2
```

in response to the MS/DOS prompt, provided that the directory C:\PROGRAMS is either the current directory, or belongs to the current search path.

20.4 | The MS/DOS INTERNAL COMMAND command

This command is a utility for executing an internal MS/DOS command without actually leaving LIPRO. It is selected by choosing:

I. Internal MS/DOS command from the MAIN menu

An edit screen appears consisting of a single field, where the name of the command, as well as any parameters if required, are to be entered. After leaving the edit screen, the command is executed, if the command name entered is not empty.

A necessary condition for this utility to be successful is that the COMMAND.COM file is placed in the directory specified by the configuration file LIPRO.FIG (see under the UTILITIES command, section 20.1).

Possible error codes include:

2. path not found
1. file not found

20.4.1. Example

Suppose the following field is entered:

```
copy lipro1.def lipro2.def
```

This is equivalent to entering

```
copy lipro1.def lipro2.def
```

in response to the MS/DOS prompt.

20.5 | The BIN68 program

As was explained in section 13.2, different versions of LIPRO may differ in the number of bytes occupied by floating point numbers: the standard version and alternative version 1 use 8 bytes per number, while alternative version 2 uses 6 bytes per number. Therefore, the binary r/a files produced by LIPRO are not directly transferable between different versions of the program.

The BIN68 program converts r/a files produced by the 8-byte LIPRO versions to a format that can be read by the 6-byte LIPRO version, and vice versa. It is invoked by entering:

U. Utilities	from the MAIN menu
B. Binary file conversion	from the UTILITIES menu

The BIN68 program enters a menu with the following commands:

Input file (r/a)
specifies the file to be read. Its default extension is .BIN.

Output file (r/a)

specifies the file to be created. Its default extension is .BIN.

Mode
specifies the mode of conversion: *from 8 to 6* (default) converts an 8-byte r/a input file to a 6-byte r/a output file; *from 6 to 8* does the reverse.

Convert
starts conversion.

Quit
returns the user to the UTILITIES menu.

21. LINKING USER PROFILES

For each combination of age group, sex, and internal position, as well as for their marginal totals, a user profile contains two numbers describing the use of social security (or any other quantity for which the user-profile approach may be considered to be useful):

- the fraction of the population using social security;
- the average costs per user.

By multiplying these two numbers, one obtains the average costs per head of the population, for each combination of age, sex, and internal position.

A user profile can be combined with a table of the population, classified by age, sex, and internal position, to yield aggregate numbers of users and aggregate outlays. Similarly, by combining a user profile with a table of the *projected population*, one obtains a projection of the number of users and aggregate outlays, under the assumption of constant age-, sex-, and internal position-specific use of social security.

From this description of the user profile approach, it is immediately evident that there should be a one-to-one correspondence between the dimensions of the user profile and the dimensions of the state space used in the demographic projection: both types of tables should be in terms of the same number of age groups, sexes, and internal positions.

The computer program SOCPROF, distributed jointly with the LIPRO projection program, does essentially two things:

- creation and maintenance of user profiles;
- producing tables obtained by combining tables of the population with user profiles.

The program SOCPROF uses two binary r/a files:

1. a file containing the user profiles. The name of this file will be referred to as LPROF throughout this chapter;
2. a file containing population data. This file corresponds to the file LPOPUL as defined in the LIPRO parameter file.

Both files should correspond to the dimensions of the state space, as defined in the LIPRO definition file. The program SOCPROF reads the names of the relevant definition file and parameter file from LIPRO's configuration file LIPRO.FIG. Therefore, it is highly recommended that the SOCPROF program is *always* invoked via the *Execute a program* command of LIPRO's MAIN menu (see section 20.3).

The output files produced by the SOCPROF program can be read into Lotus with the Lotus /File/Import/Numbers command (cf. section 20.1).

21.1 | The SOCPROF data files

A set of user profiles is stored on disk in the form of a binary r/a file. It contains data for NARR social security schemes (user profiles), where NARR may range from 1 to 18. For each user profile, for both males and females, for each age group including total, and for each internal position including total, the file contains two numbers:

- fraction of population with benefit;
- average amount per recipient.

This type of r/a file will be termed a *SOCPROF data file*. All SOCPROF data files have file name extensions .SPD.

A so-called *SOCPROF parameter file* corresponds to each SOCPROF data file, with the same file name as the SOCPROF data file, except for its file name extension .SPP. A SOCPROF parameter file contains the following parameters:

*	NSCH	The number of user profiles currently defined in the SOCPROF data file
*	LSCHNAME(i)	i=1···NSCH. The names of the NSCH social security schemes. A name consists of a character string of maximum length 12.
*	FACNTOT	A scaling factor for aggregate numbers. For example, if combination of a user profile and a population distribution yields 2,000 recipients, then a value of 1e-3 for FACNTOT will result in a number 2 in the output tables.
*	FACBTOT	A scaling factor for aggregate outlays.

*	FACNCAP	A scaling factor for number of recipients per capita.
*	FACBCAP	A scaling factor for average outlays per capita.
*	NDECNTOT	The number of decimal digits to be used for printing aggregate numbers.
*	NDECBTOT	The number of decimal digits to be used for printing aggregate outlays.
*	NDECNCAP	The number of decimal digits to be used for printing numbers of recipients per capita.
*	NDECBCAP	The number of decimal digits to be used for printing average outlays per capita.
*	NDECINDX	The number of decimal digits to be used for printing index numbers.
*	NWID	The number of character positions to be used for printing numbers.
*	NWIDYEAR	The number of character positions to be used for printing years in time series tables.
*	NWIDAGE	The number of character positions to be used for printing labels for age groups.
*	NLAB1,NLAB2	Index numbers for first and last age group, respectively, to be included in the potential labour force. For example, if the potential labour force is to be defined as the population aged 20-64 with 5 year age intervals, then one should set NLAB1=5 and NLAB2=13.

The ranges and default values for these parameters are as follows:

Parameter	*Minimum*	*Maximum*	*Default*
NSCH	0	18	0
LSCHNAME(i)	-	-	’’
FACNTOT	0	-	1e-3
FACBTOT	0	-	1e-9
FACNCAP	0	-	1
FACBCAP	0	-	1e-3
NDECNTOT	0	10	3
NDECBTOT	0	10	3
NDECNCAP	0	10	3
NDECBCAP	0	10	3
NDECINDX	0	10	1
NWID	4	24	10
NWIDYEAR	4	24	6
NWIDAGE	4	24	8
NLAB1	1	NAGE-1	5
NLAB2	1	NAGE-1	13

21.2 | Calling the SOCPROF program

The SOCPROF program is invoked as follows:

X. Execute a program from the MAIN menu

Next, the following fields should be entered:

1. SOCPROF
2. LPROF

If the second field is omitted, the default file name SOCPROF.BIN is assumed. The file name extension .BIN is always automatically added and should *not* be included in LPROF.
The program SOCPROF offers a menu which is displayed in figure 21.1. Note that the name of the user profile file, together with the number of currently defined user profiles, is displayed in the second line of the screen.

Figure 21.1. The MAIN menu of the SOCPROF program

Definitions
enters a menu in which the various parameters discussed in section 21.1 are defined.

Show profiles
creates tables of data in the various user profiles.

Edit profiles
allows one to modify the contents of the user profiles.

Time series
produces time series tables of aggregate numbers of users and aggregate outlays.

Full tables
produces tables of numbers of users, average outlays, average outlays and total outlays by age, sex, and internal position.

Quit
returns to LIPRO's MAIN menu.

Each of these commands is discussed more fully in the sections to follow.

21.3 | The DEFINITIONS menu

SOCPROF's DEFINITIONS menu offers the following commands:

Add profile
allows the user to add a new profile to the set of profiles in file LPROF. The maximum number of profiles in one single file is 18. If a new profile is added, a name (consisting of at most 12 characters) has to be entered for the corresponding social security scheme. The newly-created profile is filled with zeros and may be modified with the EDIT PROFILES command (see section 21.5).

Rename profiles
enters an edit screen in which the names of all profiles currently defined may be modified.

Edit parameters
enters an edit screen in which the parameters controlling the construction and printing of output tables can be modified. An example of this edit screen is displayed in figure 21.2.

Quit
returns to SOCPROF's MAIN menu.

Figure 21.2. The EDIT PARAMETERS command

21.4 | The SHOW PROFILES menu

The SHOW PROFILES menu contains commands for inspecting the contents of the user profiles currently defined in the LPROF r/a file. The menu is displayed in figure 21.3 and offers the following commands:

Figure 21.3. The SHOW PROFILES menu

Type of table
toggles between three types of tables:

- fraction of the population with benefit (default);
- average amount per recipient;
- average amount per capita.

Profile
toggles between the various profiles currently defined. By default, the first profile in the LPROF r/a file is selected for producing tables.

Sex
toggles between the sexes *female* (default) and *male*.

Output file
defines the name of the file (or device) to which tables are to be sent. By default, tables are displayed on the screen.

Browse output file
allows one to inspect the contents of the output file.

Create table
produces a table with the currently defined profile.

Quit
returns to SOCPROF's MAIN menu.

21.5 | The EDIT PROFILES menu

The EDIT PROFILES command allows one to modify the contents of the user profiles. It offers the following commands:

Profile
toggles between the various profiles currently defined. By default, the first profile in the LPROF r/a file is selected for producing tables.

Sex
toggles between the sexes *female* (default) and *male*.

Edit table
enters a submenu for editing the data, to be discussed below.

Quit
returns to SOCPROF's MAIN menu.

21.5.1. The EDIT TABLE command

This command enters a screen like the one displayed in figure 21.4. The screen initially contains the data on "fraction of the population with benefit" for the first 5 internal positions and the first 19 age groups. The following command bar is displayed:

Edit Table Age State Quit

Figure 21.4. The EDIT TABLE command of the EDIT PROFILES menu

Edit
converts the screen into an edit screen, allowing one to modify the data.

Table
toggles between the two tables of the user profile: "fraction with benefit" and "amount per recipient".

Age
scrolls to the page with the next set of 19 age groups (including marginal total).

State
scrolls to the page with the next set of 5 internal positions (including marginal total).

Quit
returns to the EDIT PROFILES menu.

21.6 | The TIME SERIES menu

The TIME SERIES command produces time series tables of aggregate numbers of users and aggregate outlays, as well as index numbers. For each year of the projection period, these tables contain the following variables:

R	total number of recipients
R-index	index number of R, first year = 100
E	total expenditure (aggregate outlays)
E-index	index number of E
R/P	number of recipients per capita
R/P-index	index number of R/P
E/P	expenditure per capita
E/P-index	index number of E/P
R/L	number of recipients per capita of the potential labour force
R/L-index	index number of R/L
E/L	expenditure per capita of the potential labour force
E/L-index	index number of E/L

These tables are produced from the TIME SERIES menu, which offers the following commands:

Profile
allows one to select the user profiles (social security schemes) to be included in the table. An edit screen like the one displayed in figure 21.5 is entered. All user profiles marked with ’1’ are included in the table. If more than one user profile is selected, a table is produced with the results for the *total* over the selected user profiles.

Sex
enters an edit screen in which one can select the sexes for which tables have to be produced. *TOTAL* refers to the sum of males and females.

Figure 21.5. The PROFILE command of the TIME SERIES menu

Method
toggles between four methods of handling differences between age groups and/or internal positions (see section 11.3.3 for an explanation of these methods):

* by age and state: user profiles are both age- and state-specific (default);
* by age, not state: user profiles are age-specific but not state-specific, i.e. the numbers for the total over all states are used;
* by state, not age: user profiles are state-specific but not age-specific, i.e. the numbers for the total over all age groups are used;
* for total population only: user profiles are neither age-specific nor state-specific, i.e. the numbers for the total over all states and all age groups are used.

Output file
lets the user choose an output file from the current directory.

Browse output file
lets the user inspect the output text file by LIPRO's built-in BROWSE program.

Create tables
invokes the program for creating tables. The tables are based on the population data in file LPOPUL, for the year ITIME1 up to ITIMEZ, as defined in the

DEFINITIONS menu (cf. section 14.5). A sample output file is given in table 21.1.

Quit
returns the user to SOCPROF's MAIN menu.

Table 21.1. Output of the TIME SERIES Command

```
Profile = AOW     Sex = female

Population file = REALPOP.BIN

Year        R  index         E  index    R/P  index    E/P  index    R/L  index    E/L  index
1985  908.856  100.0  1147.181  100.0  0.064  100.0  0.080  100.0  0.104  100.0  0.132  100.0
1990 1038.097  114.2  1317.036  114.8  0.070  110.3  0.089  110.9  0.112  107.4  0.142  108.0
1995 1145.306  126.0  1457.287  127.0  0.075  118.1  0.096  119.0  0.119  114.2  0.152  115.2
2000 1229.659  135.3  1569.170  136.8  0.079  123.8  0.101  125.2  0.125  120.1  0.160  121.4
2005 1317.164  144.9  1684.137  146.8  0.083  130.3  0.106  132.0  0.132  126.8  0.169  128.4
2010 1434.801  157.9  1837.394  160.2  0.089  140.2  0.114  142.2  0.143  136.6  0.183  138.6
2015 1670.497  183.8  2136.689  186.3  0.103  161.4  0.131  163.6  0.168  161.3  0.215  163.4
2020 1853.869  204.0  2382.542  207.7  0.113  177.8  0.145  181.0  0.190  181.6  0.244  184.9
2025 2032.766  223.7  2631.141  229.4  0.124  194.4  0.160  199.3  0.214  204.5  0.277  209.7
2030 2195.756  241.6  2865.514  249.8  0.134  210.4  0.175  217.5  0.239  229.3  0.313  237.1
2035 2296.952  252.7  3017.843  263.1  0.141  222.1  0.186  231.2  0.259  248.4  0.341  258.5
2040 2293.111  252.3  3032.177  264.3  0.143  224.6  0.189  235.3  0.263  252.0  0.348  264.0
2045 2218.556  244.1  2949.217  257.1  0.140  220.5  0.187  232.2  0.256  244.7  0.340  257.8
2050 2130.698  234.4  2841.686  247.7  0.137  214.8  0.182  227.0  0.246  235.8  0.328  249.1
```

21.7 | The FULL TABLES menu

The FULL TABLES command produces tables of numbers of users, average outlays, average outlays and total outlays by age, sex, and internal position. It offers a menu with the following commands:

Profile
allows one to select the user profiles (social security schemes) for which tables are to be produced.

Sex
enters an edit screen in which one can select the sexes for which tables have to be produced. *TOTAL* refers to the sum of males and females.

Year
allows one to enter the year to which the tables are to refer. The year parameter determines the record in the r/a population file to be used in the construction of the tables.

Type of tables
allows one to select up to five types of tables to be printed:

- number of recipients (by age and state)
- number of recipients per capita
- total outlays
- outlays per capita
- outlays per recipient (average conditional outlays)

An edit screen is entered in which these types of tables can be marked with ’1’ in order to force printing.

Output file
lets the user choose an output file from the current directory.

Browse output file
lets the user inspect the output text file by LIPRO’s built-in BROWSE program.

Create tables
invokes the program for creating tables. Each table contains one additional column ("NO STATE") and one additional row ("NO AGE"), giving the results of the computations according to the methods "By age, not state" and "By state, not age", respectively (see section 21.6). The cell appearing in the column "NO STATE" and row "NO AGE" gives the result for method "For total population only".

Quit
returns the user to SOCPROF’s MAIN menu.

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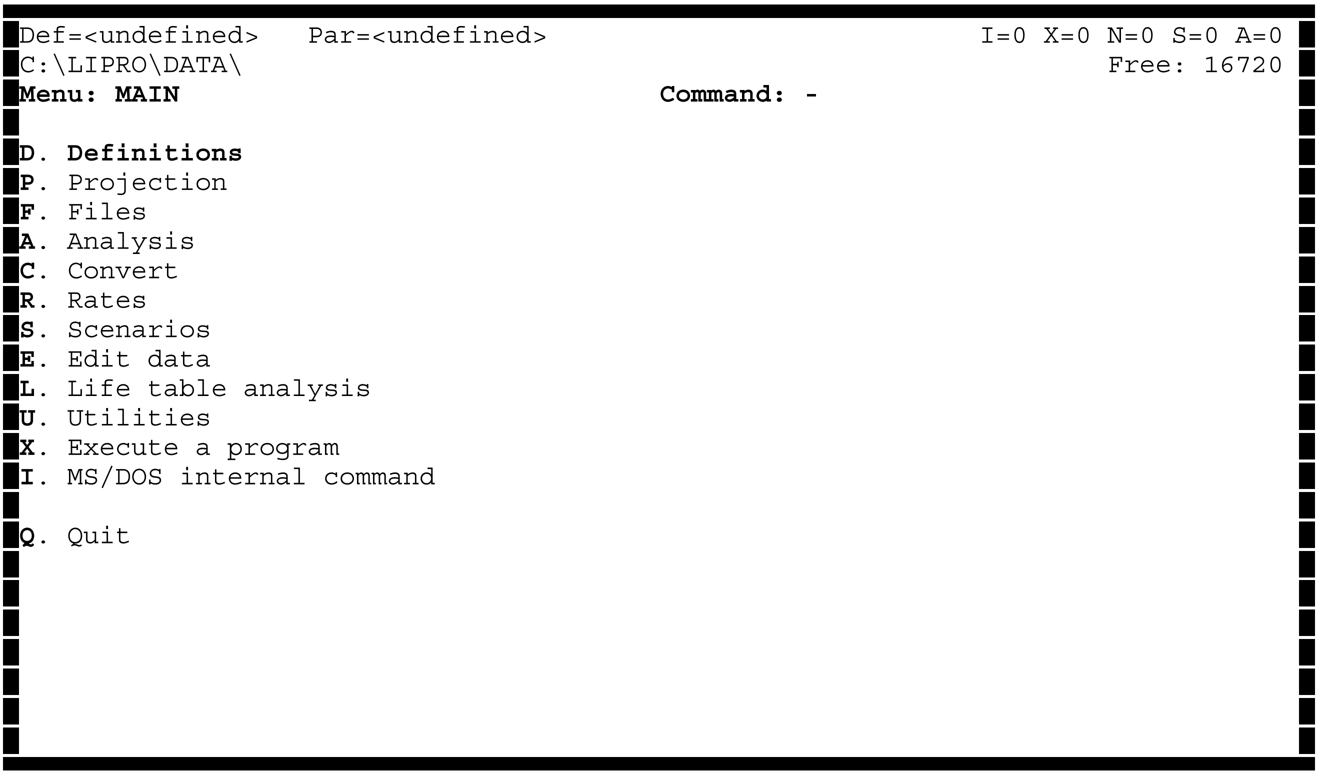
Author Index

Subject Index to parts I, II and III

Italics indicate pages where definitions are given

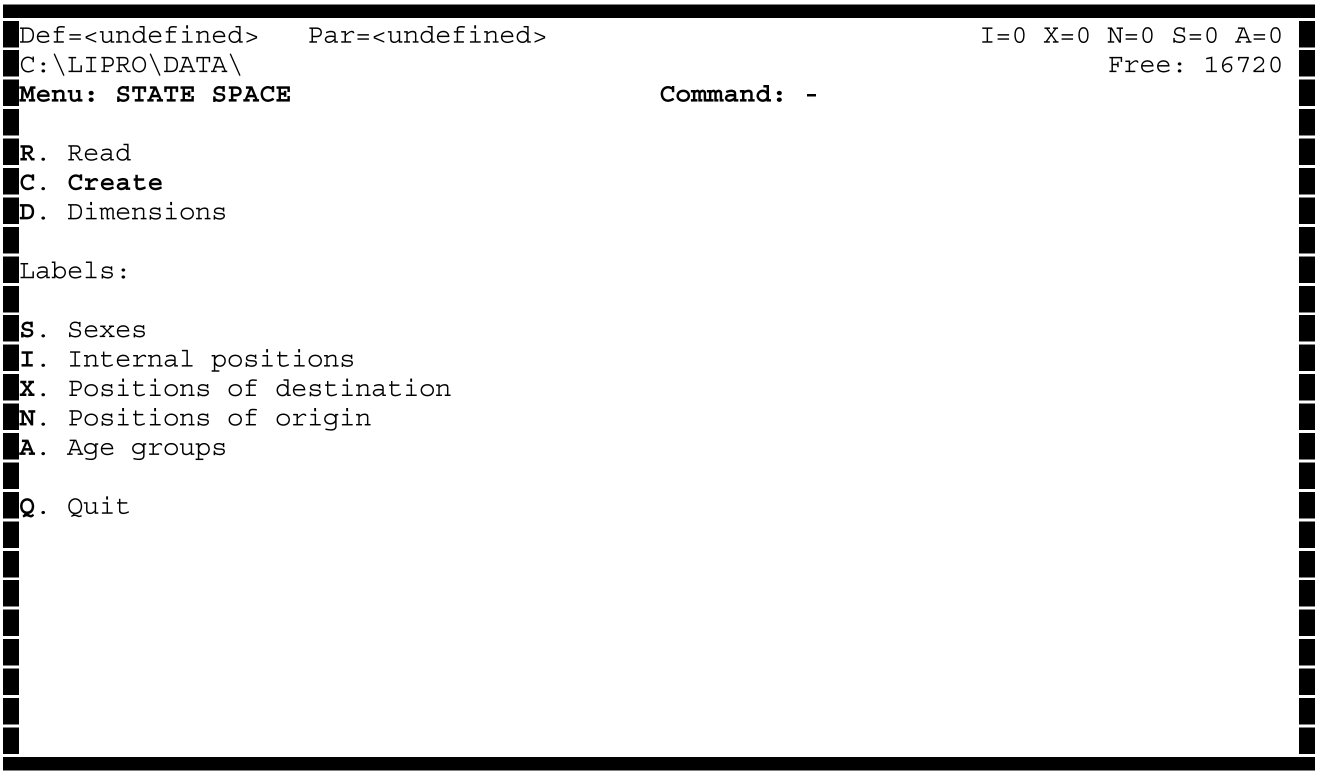
Subject Index to LIPRO User's Guide

fig 14.1



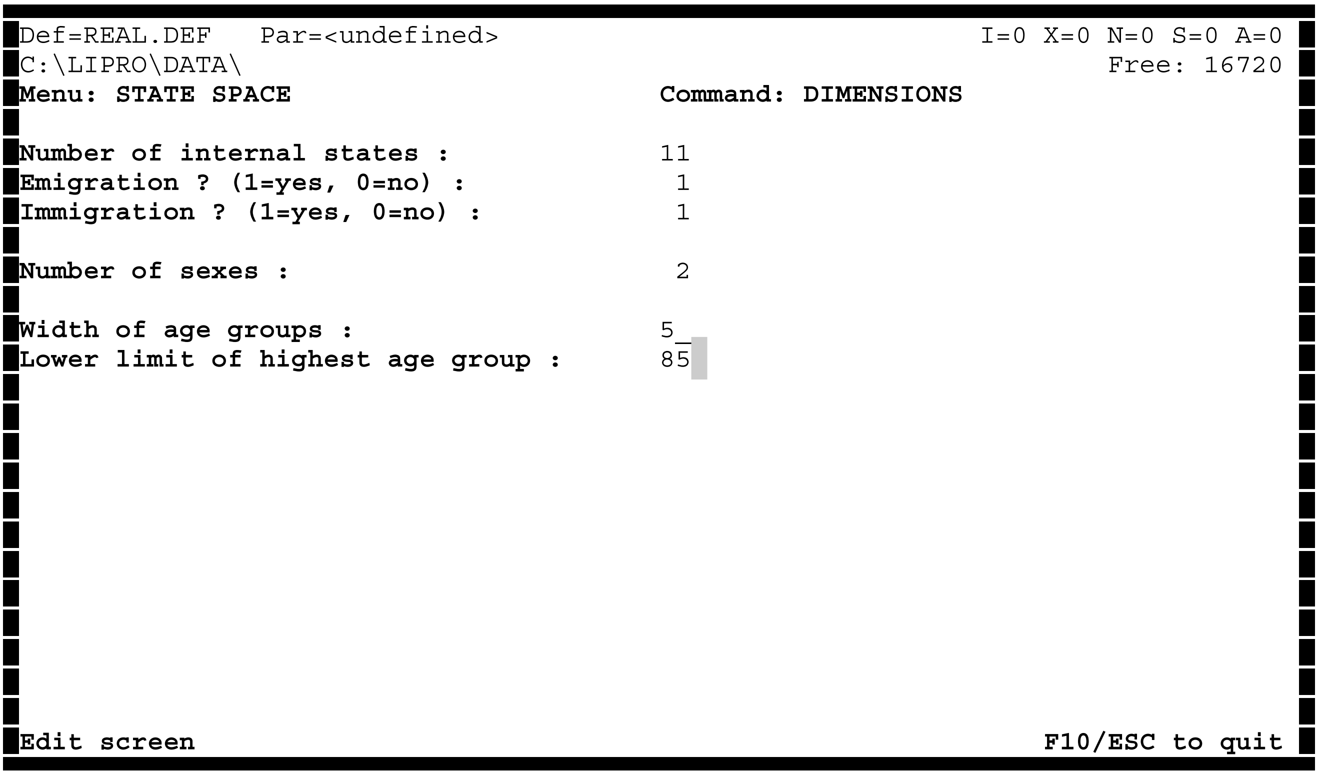
```
Def=<undefined>   Par=<undefined>                            I=0 X=0 N=0 S=0 A=0
C:\LIPRO\DATA\                                                       Free: 16720
Menu: MAIN                              Command: -

D. Definitions
P. Projection
F. Files
A. Analysis
C. Convert
R. Rates
S. Scenarios
E. Edit data
L. Life table analysis
U. Utilities
X. Execute a program
I. MS/DOS internal command

Q. Quit
```

fig 14.2



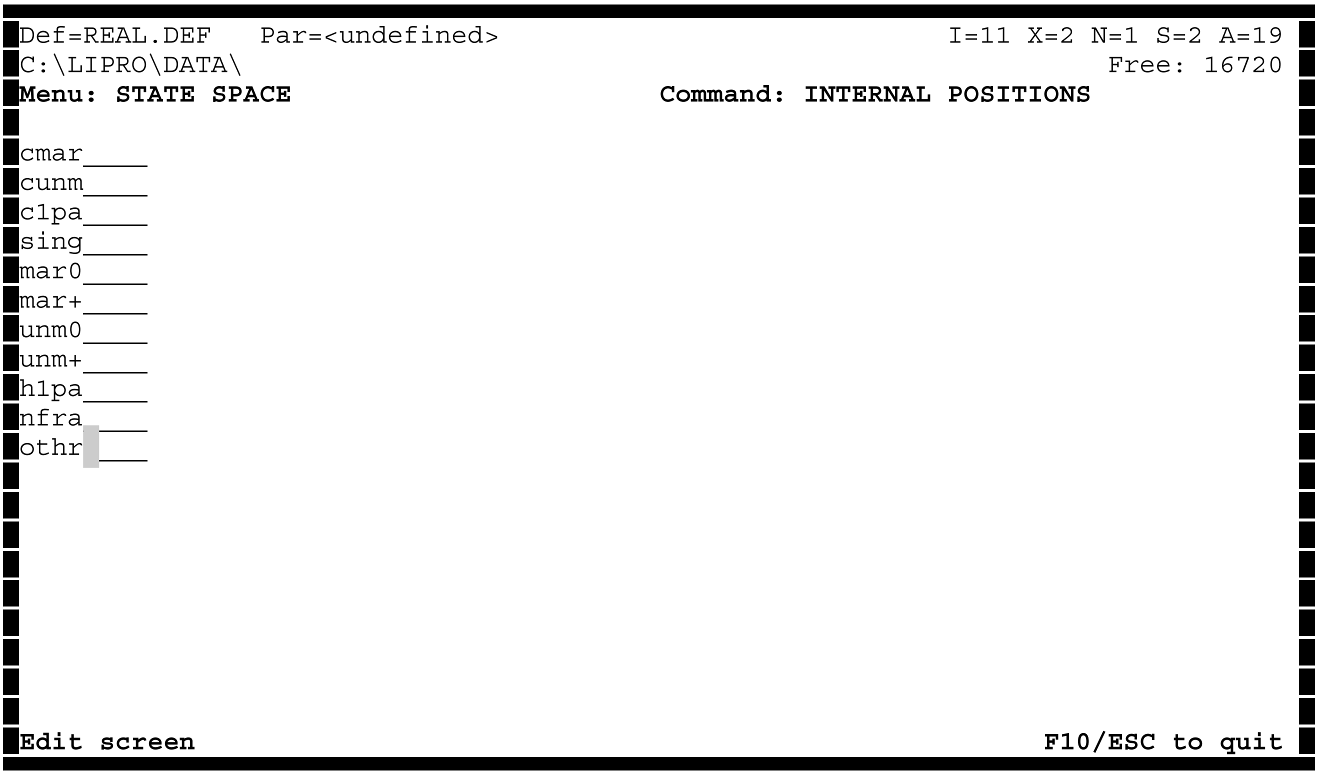
```
Def=<undefined>   Par=<undefined>                             I=0 X=0 N=0 S=0 A=0
C:\LIPRO\DATA\                                                         Free: 16720
Menu: STATE SPACE                       Command: -

R. Read
C. Create
D. Dimensions

Labels:

S. Sexes
I. Internal positions
X. Positions of destination
N. Positions of origin
A. Age groups

Q. Quit
```

fig 14.3



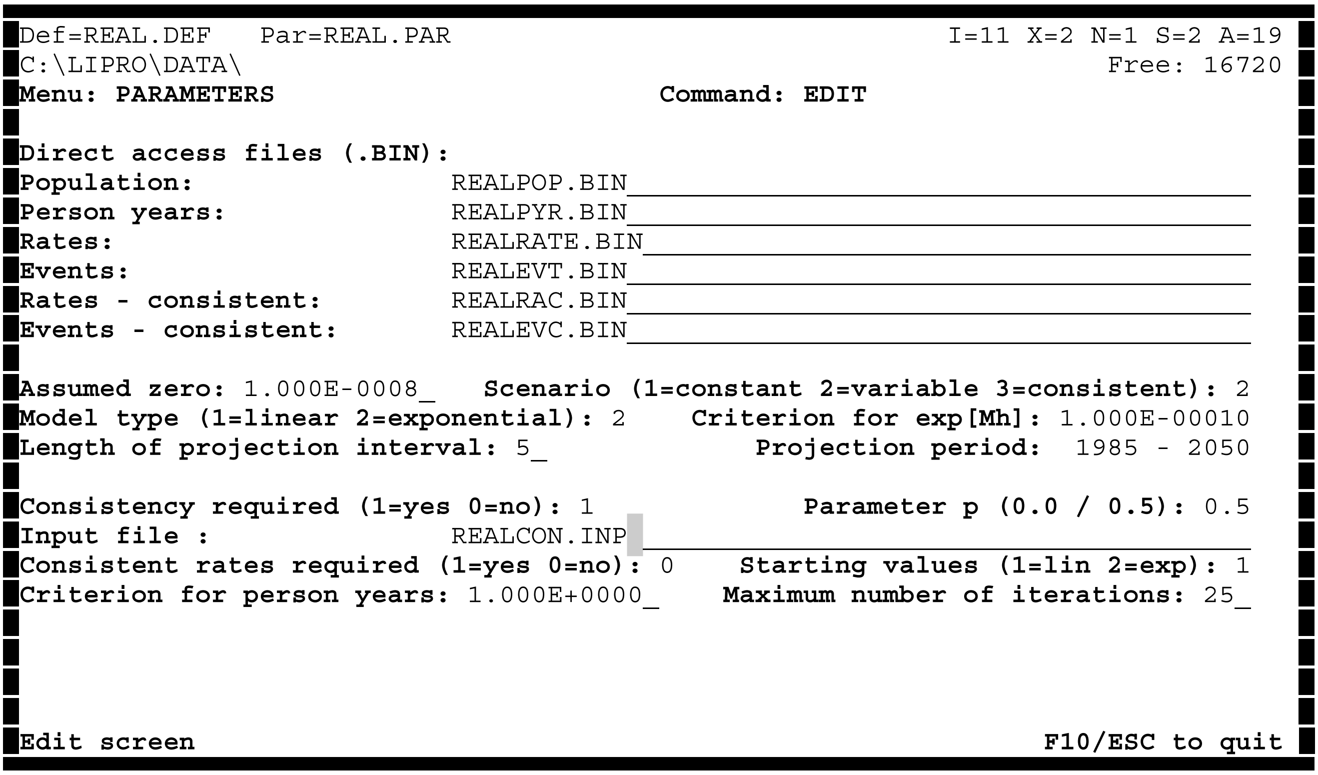
```
Def=REAL.DEF   Par=<undefined>                                  I=0 X=0 N=0 S=0 A=0
C:\LIPRO\DATA\                                                          Free: 16720
Menu: STATE SPACE                       Command: DIMENSIONS

Number of internal states :             11
Emigration ? (1=yes, 0=no) :             1
Immigration ? (1=yes, 0=no) :            1

Number of sexes :                        2

Width of age groups :                   5_
Lower limit of highest age group :      85











Edit screen                                                        F10/ESC to quit
```

fig 14.4



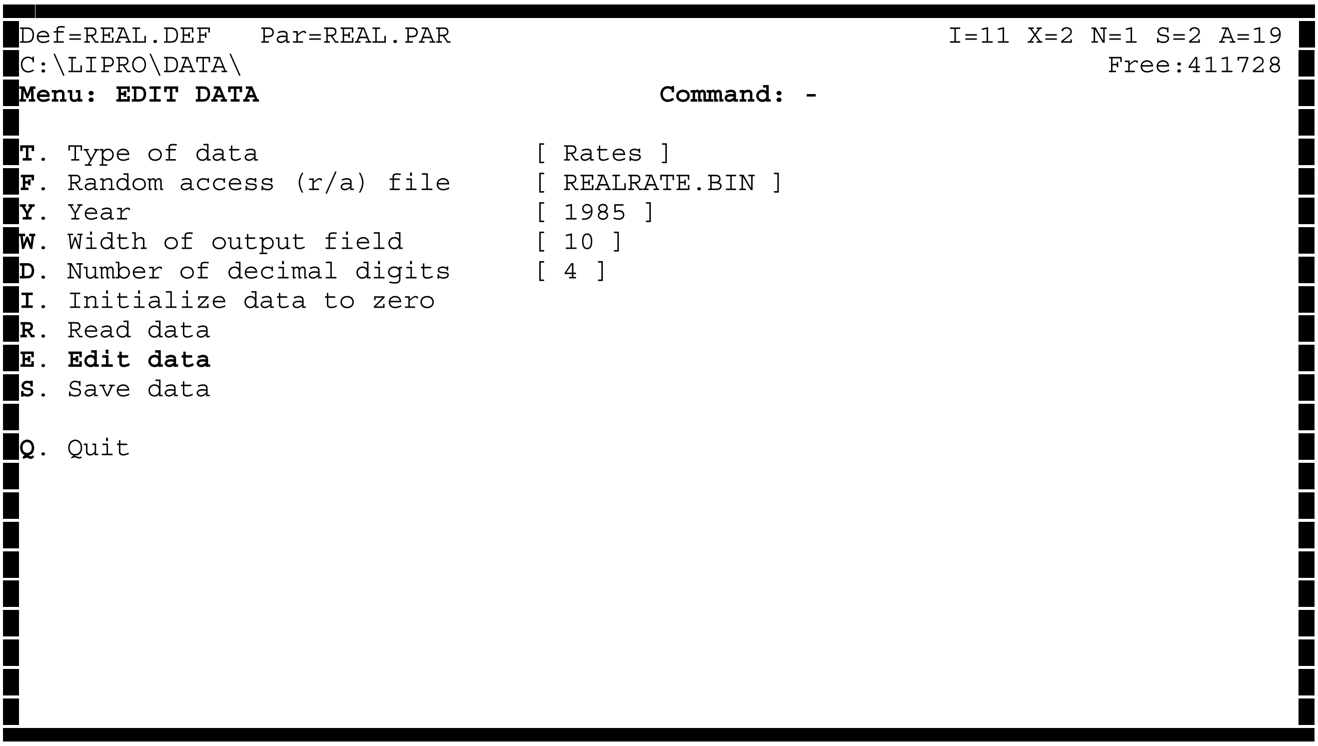
```
Def=REAL.DEF   Par=<undefined>                          I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                    Free: 16720
Menu: STATE SPACE                        Command: INTERNAL POSITIONS

cmar____
cunm____
c1pa____
sing____
mar0____
mar+____
unm0____
unm+____
h1pa____
nfra____
othr____








Edit screen                                                 F10/ESC to quit
```

fig 14.5



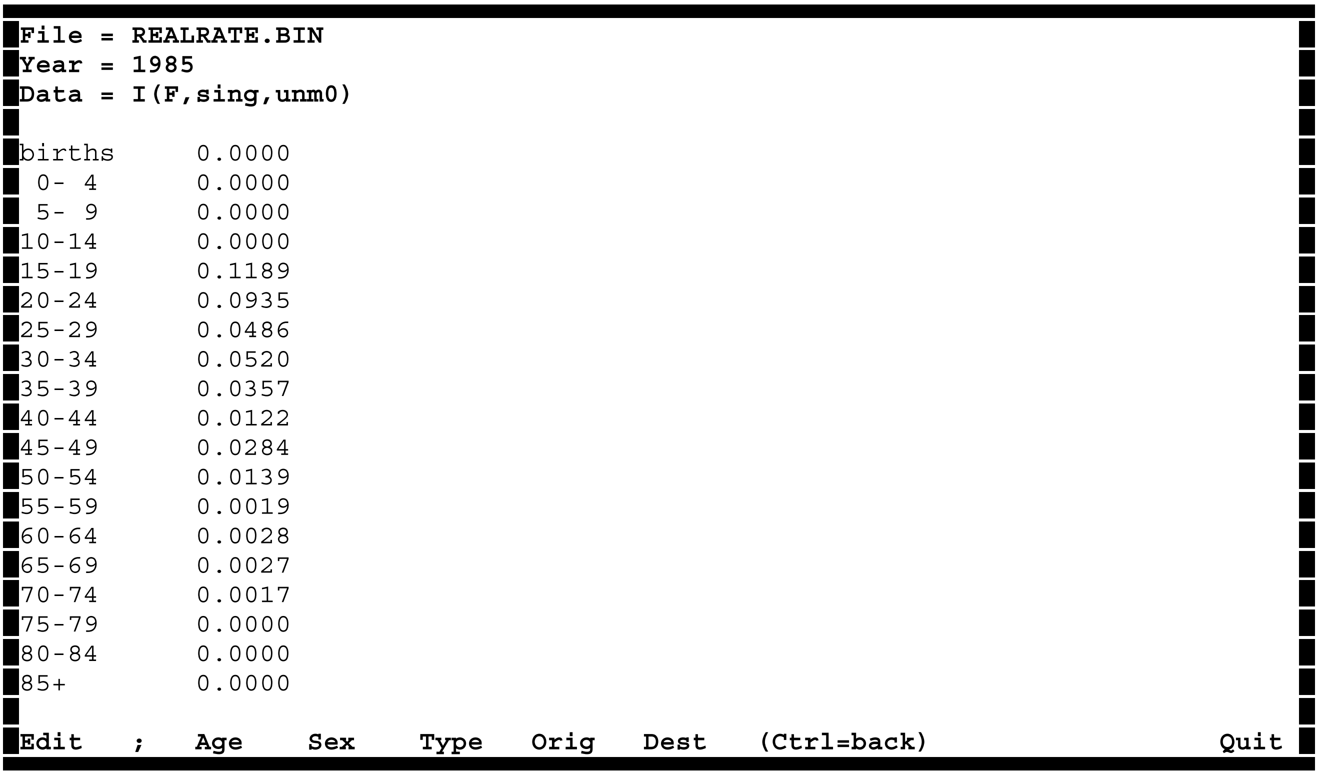
```
Def=REAL.DEF   Par=REAL.PAR                                 I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                        Free: 16720
Menu: PARAMETERS                        Command: EDIT

Direct access files (.BIN):
Population:                 REALPOP.BIN_______________________________________
Person years:               REALPYR.BIN_______________________________________
Rates:                      REALRATE.BIN______________________________________
Events:                     REALEVT.BIN_______________________________________
Rates - consistent:         REALRAC.BIN_______________________________________
Events - consistent:        REALEVC.BIN_______________________________________

Assumed zero: 1.000E-0008_   Scenario (1=constant 2=variable 3=consistent): 2
Model type (1=linear 2=exponential): 2    Criterion for exp[Mh]: 1.000E-00010
Length of projection interval: 5_             Projection period:  1985 - 2050

Consistency required (1=yes 0=no): 1           Parameter p (0.0 / 0.5): 0.5
Input file :                REALCON.INP_______________________________________
Consistent rates required (1=yes 0=no): 0    Starting values (1=lin 2=exp): 1
Criterion for person years: 1.000E+0000_    Maximum number of iterations: 25_




Edit screen                                                    F10/ESC to quit
```

fig 15.1



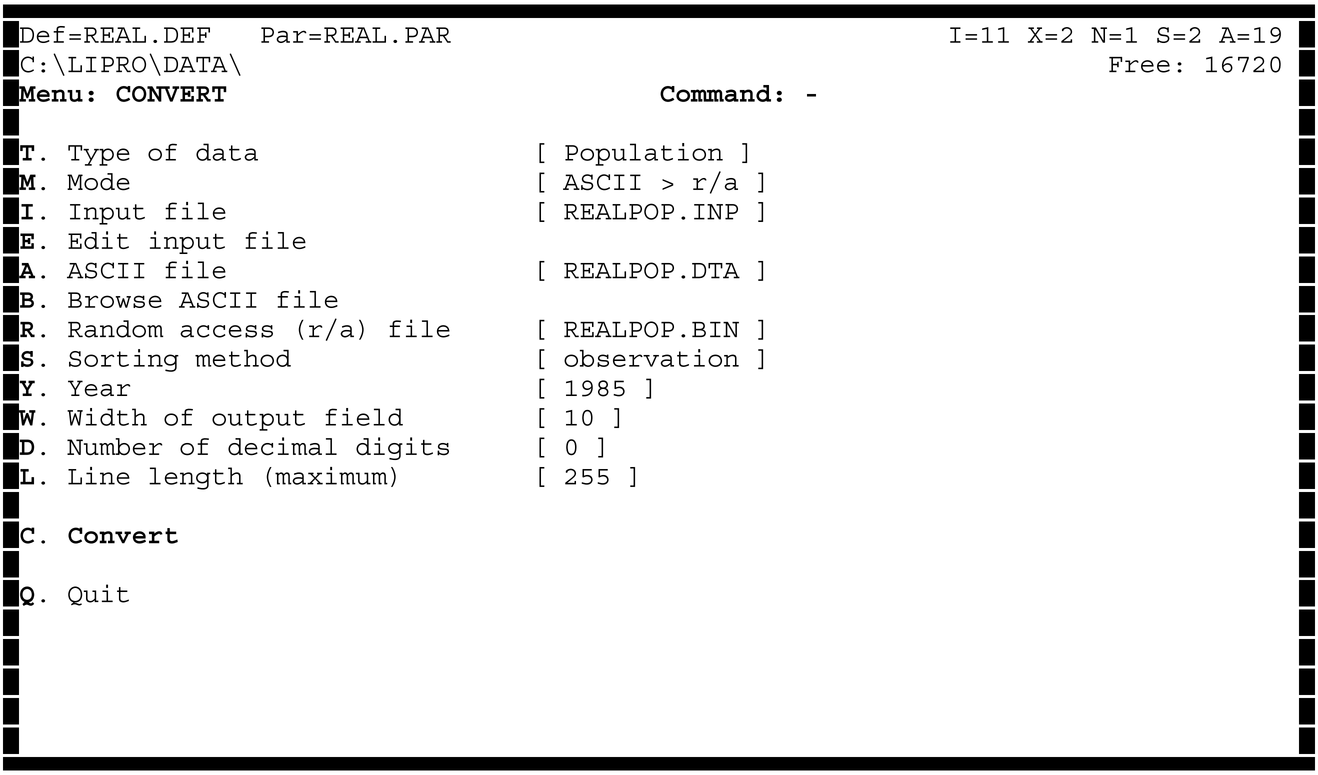
```
Def=REAL.DEF   Par=REAL.PAR                               I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                      Free:411728
Menu: EDIT DATA                          Command: -

T. Type of data                   [ Rates ]
F. Random access (r/a) file       [ REALRATE.BIN ]
Y. Year                           [ 1985 ]
W. Width of output field          [ 10 ]
D. Number of decimal digits       [ 4 ]
I. Initialize data to zero
R. Read data
E. Edit data
S. Save data

Q. Quit
```

fig 15.2



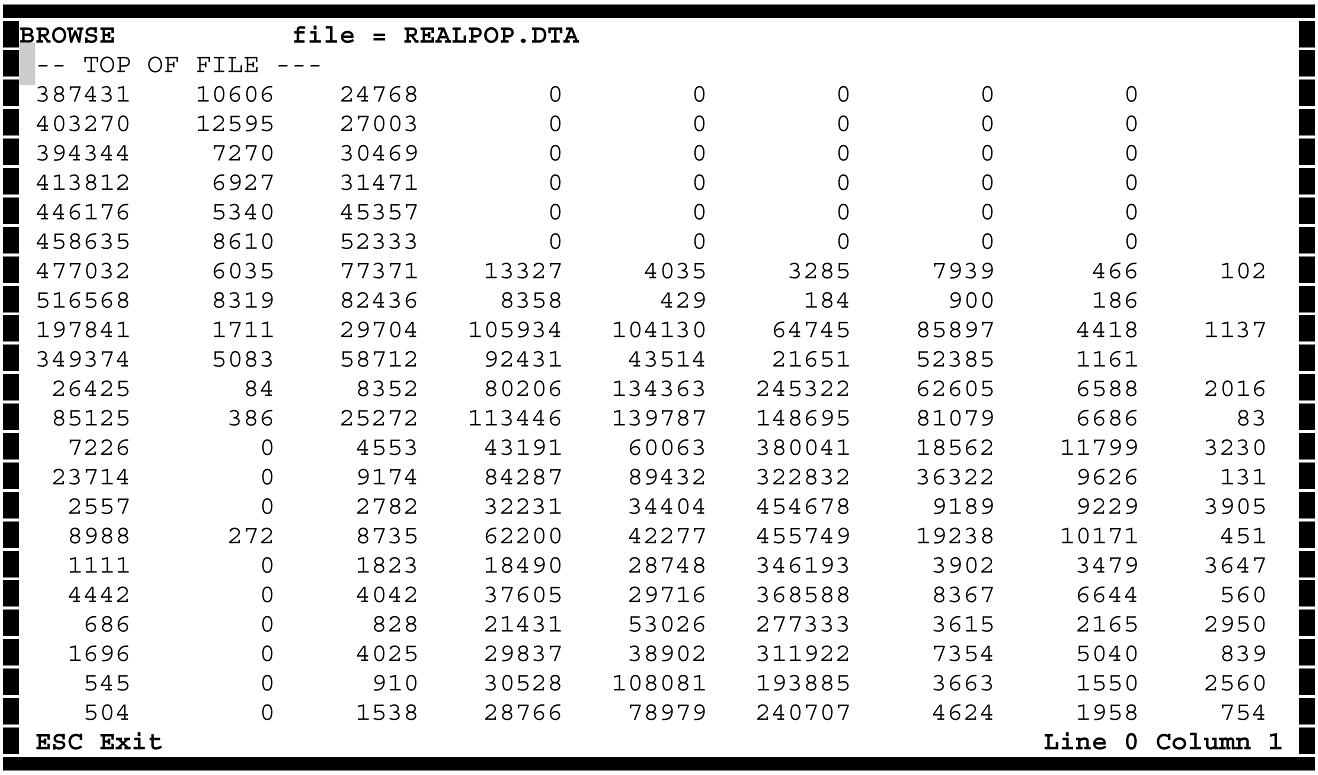
```
File = REALRATE.BIN
Year = 1985
Data = I(F,sing,unm0)

births     0.0000
 0- 4      0.0000
 5- 9      0.0000
10-14      0.0000
15-19      0.1189
20-24      0.0935
25-29      0.0486
30-34      0.0520
35-39      0.0357
40-44      0.0122
45-49      0.0284
50-54      0.0139
55-59      0.0019
60-64      0.0028
65-69      0.0027
70-74      0.0017
75-79      0.0000
80-84      0.0000
85+        0.0000

Edit   ;   Age    Sex    Type   Orig   Dest   (Ctrl=back)                  Quit
```

fig 15.3



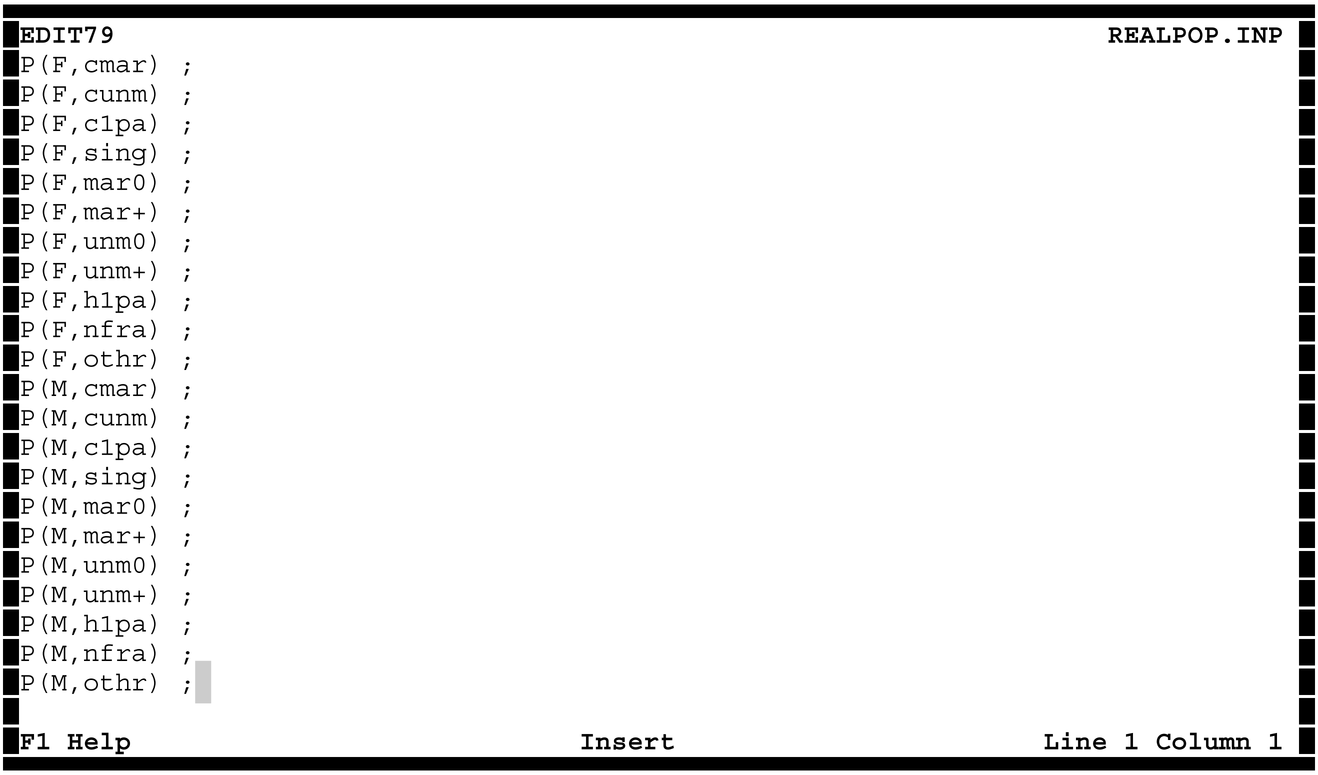
```
Def=REAL.DEF   Par=REAL.PAR                                  I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                           Free: 16720
Menu: CONVERT                               Command: -

T. Type of data                  [ Population ]
M. Mode                          [ ASCII > r/a ]
I. Input file                    [ REALPOP.INP ]
E. Edit input file
A. ASCII file                    [ REALPOP.DTA ]
B. Browse ASCII file
R. Random access (r/a) file      [ REALPOP.BIN ]
S. Sorting method                [ observation ]
Y. Year                          [ 1985 ]
W. Width of output field         [ 10 ]
D. Number of decimal digits      [ 0 ]
L. Line length (maximum)         [ 255 ]

C. Convert

Q. Quit
```

fig 15.4



```
BROWSE           file = REALPOP.DTA
 -- TOP OF FILE ---
 387431    10606    24768        0        0        0        0        0
 403270    12595    27003        0        0        0        0        0
 394344     7270    30469        0        0        0        0        0
 413812     6927    31471        0        0        0        0        0
 446176     5340    45357        0        0        0        0        0
 458635     8610    52333        0        0        0        0        0
 477032     6035    77371    13327     4035     3285     7939      466     102
 516568     8319    82436     8358      429      184      900      186
 197841     1711    29704   105934   104130    64745    85897     4418    1137
 349374     5083    58712    92431    43514    21651    52385     1161
  26425       84     8352    80206   134363   245322    62605     6588    2016
  85125      386    25272   113446   139787   148695    81079     6686      83
   7226        0     4553    43191    60063   380041    18562    11799    3230
  23714        0     9174    84287    89432   322832    36322     9626     131
   2557        0     2782    32231    34404   454678     9189     9229    3905
   8988      272     8735    62200    42277   455749    19238    10171     451
   1111        0     1823    18490    28748   346193     3902     3479    3647
   4442        0     4042    37605    29716   368588     8367     6644     560
    686        0      828    21431    53026   277333     3615     2165    2950
   1696        0     4025    29837    38902   311922     7354     5040     839
    545        0      910    30528   108081   193885     3663     1550    2560
    504        0     1538    28766    78979   240707     4624     1958     754
 ESC Exit                                                        Line 0 Column 1
```

fig 15.5



```
P(F,cmar) ;
P(F,cunm) ;
P(F,c1pa) ;
P(F,sing) ;
P(F,mar0) ;
P(F,mar+) ;
P(F,unm0) ;
P(F,unm+) ;
P(F,h1pa) ;
P(F,nfra) ;
P(F,othr) ;
P(M,cmar) ;
P(M,cunm) ;
P(M,c1pa) ;
P(M,sing) ;
P(M,mar0) ;
P(M,mar+) ;
P(M,unm0) ;
P(M,unm+) ;
P(M,h1pa) ;
P(M,nfra) ;
P(M,othr) ;
```

FIG 17.1

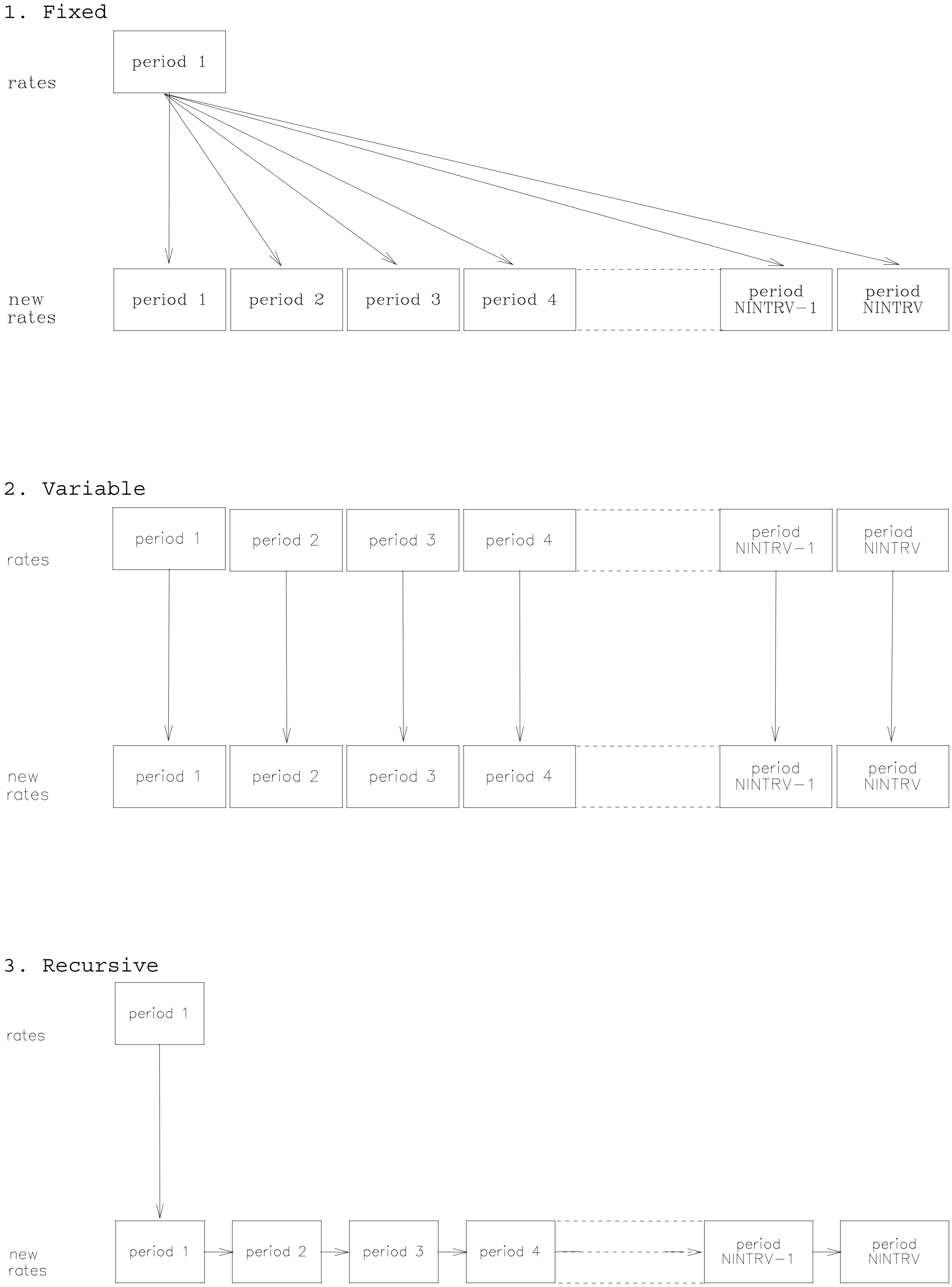
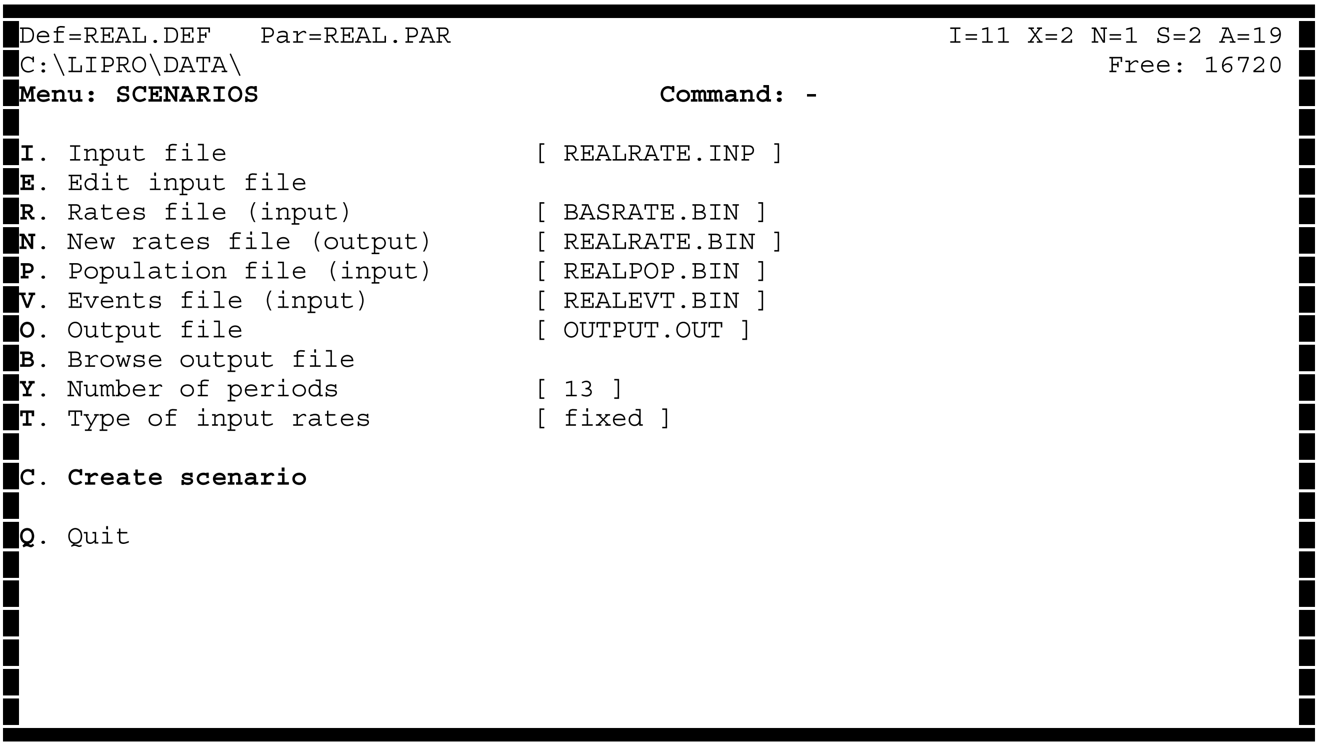
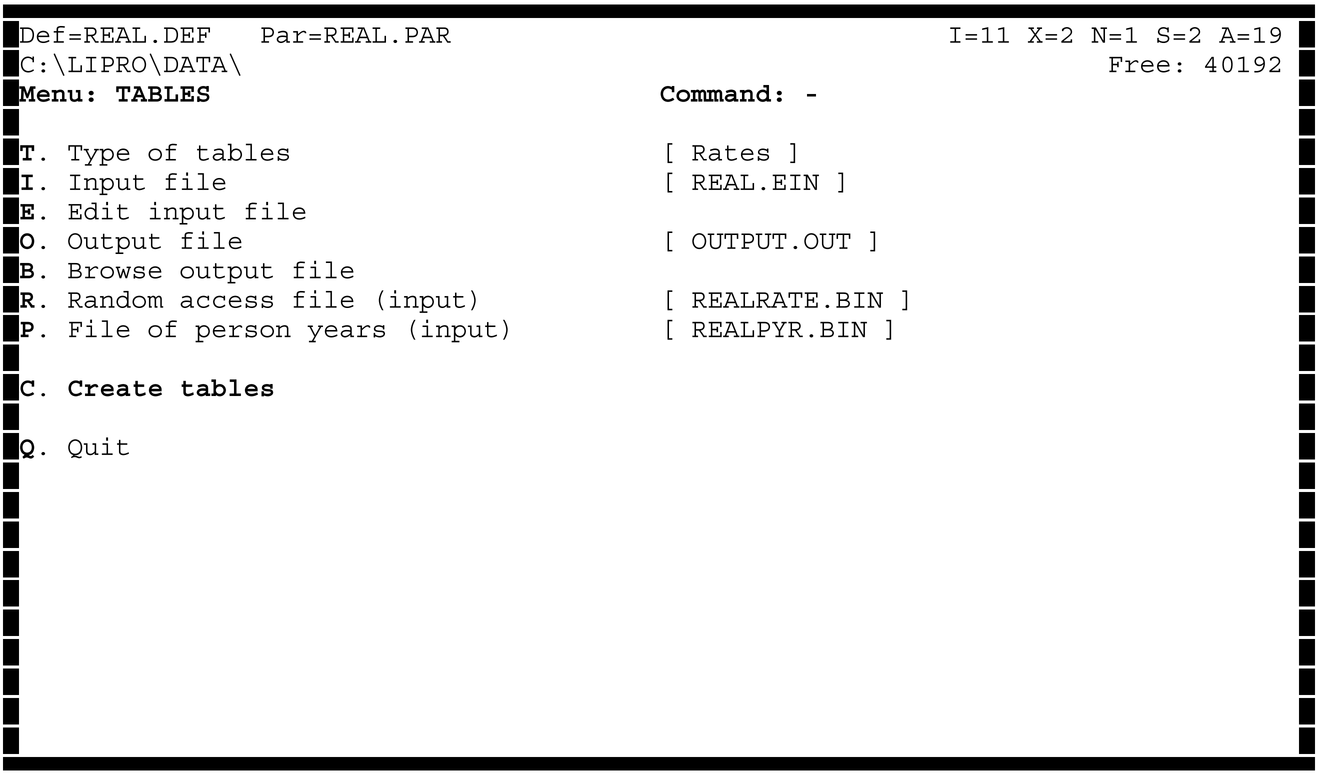

1. Fixed
rates
period 1
new rates
period 1
period 2
period 3
period 4
period NINTRV−1
period NINTRV
2. Variable
rates
period 1
period 2
period 3
period 4
period NINTRV−1
period NINTRV
new rates
period 1
period 2
period 3
period 4
period NINTRV−1
period NINTRV
3. Recursive
rates
period 1
new rates
period 1
period 2
period 3
period 4
period NINTRV−1
period NINTRV

fig 17.2



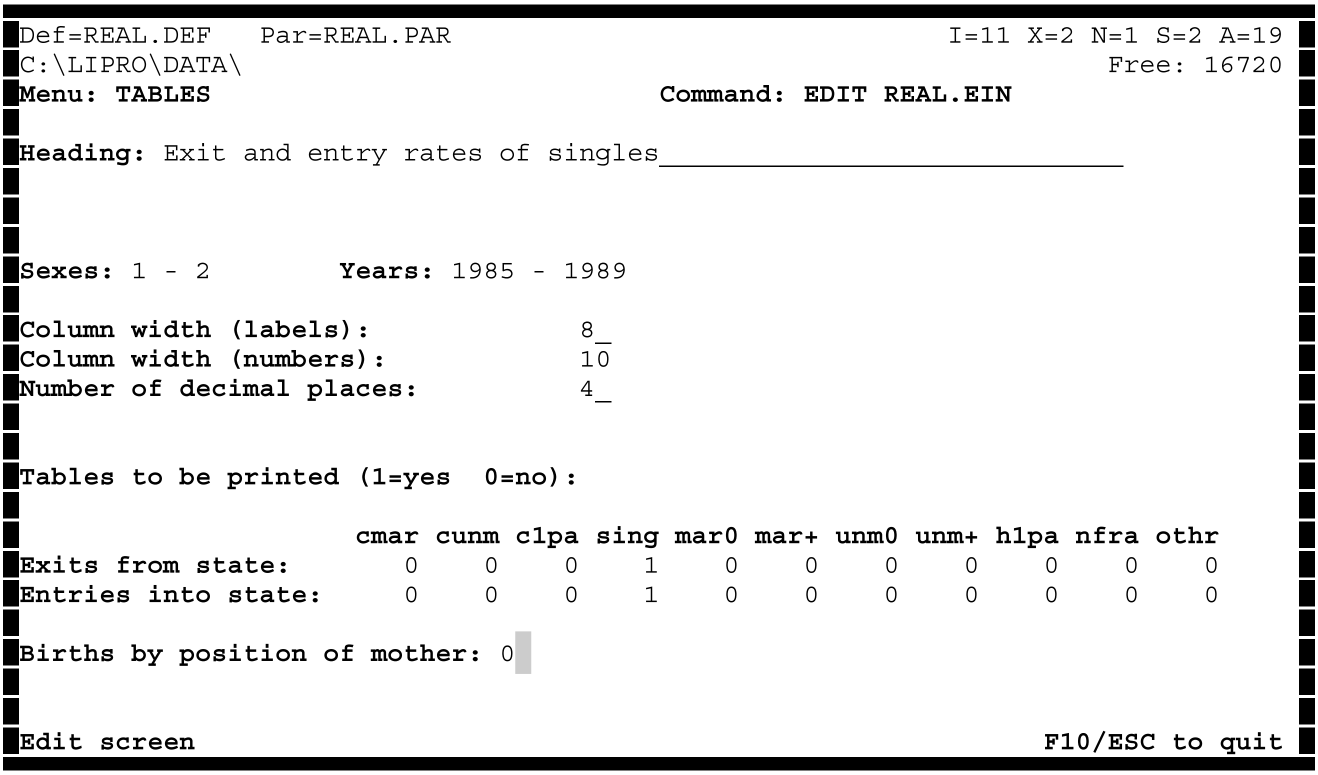
```
Def=REAL.DEF   Par=REAL.PAR                         I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                Free: 16720
Menu: SCENARIOS                        Command: -

I. Input file                     [ REALRATE.INP ]
E. Edit input file
R. Rates file (input)             [ BASRATE.BIN ]
N. New rates file (output)        [ REALRATE.BIN ]
P. Population file (input)        [ REALPOP.BIN ]
V. Events file (input)            [ REALEVT.BIN ]
O. Output file                    [ OUTPUT.OUT ]
B. Browse output file
Y. Number of periods              [ 13 ]
T. Type of input rates            [ fixed ]

C. Create scenario

Q. Quit
```

fig 19.1



```
Def=REAL.DEF   Par=REAL.PAR                              I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                     Free: 40192
Menu: TABLES                               Command: -

T. Type of tables                          [ Rates ]
I. Input file                              [ REAL.EIN ]
E. Edit input file
O. Output file                             [ OUTPUT.OUT ]
B. Browse output file
R. Random access file (input)              [ REALRATE.BIN ]
P. File of person years (input)            [ REALPYR.BIN ]

C. Create tables

Q. Quit
```

FIG 19.2



```
Def=REAL.DEF   Par=REAL.PAR                            I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                   Free: 16720
Menu: TABLES                              Command: EDIT REAL.EIN

Heading: Exit and entry rates of singles_____________________________

Sexes: 1 - 2        Years: 1985 - 1989

Column width (labels):             8_
Column width (numbers):            10
Number of decimal places:          4_


Tables to be printed (1=yes  0=no):

                     cmar cunm c1pa sing mar0 mar+ unm0 unm+ h1pa nfra othr
Exits from state:       0    0    0    1    0    0    0    0    0    0    0
Entries into state:     0    0    0    1    0    0    0    0    0    0    0

Births by position of mother: 0


Edit screen                                                F10/ESC to quit
```

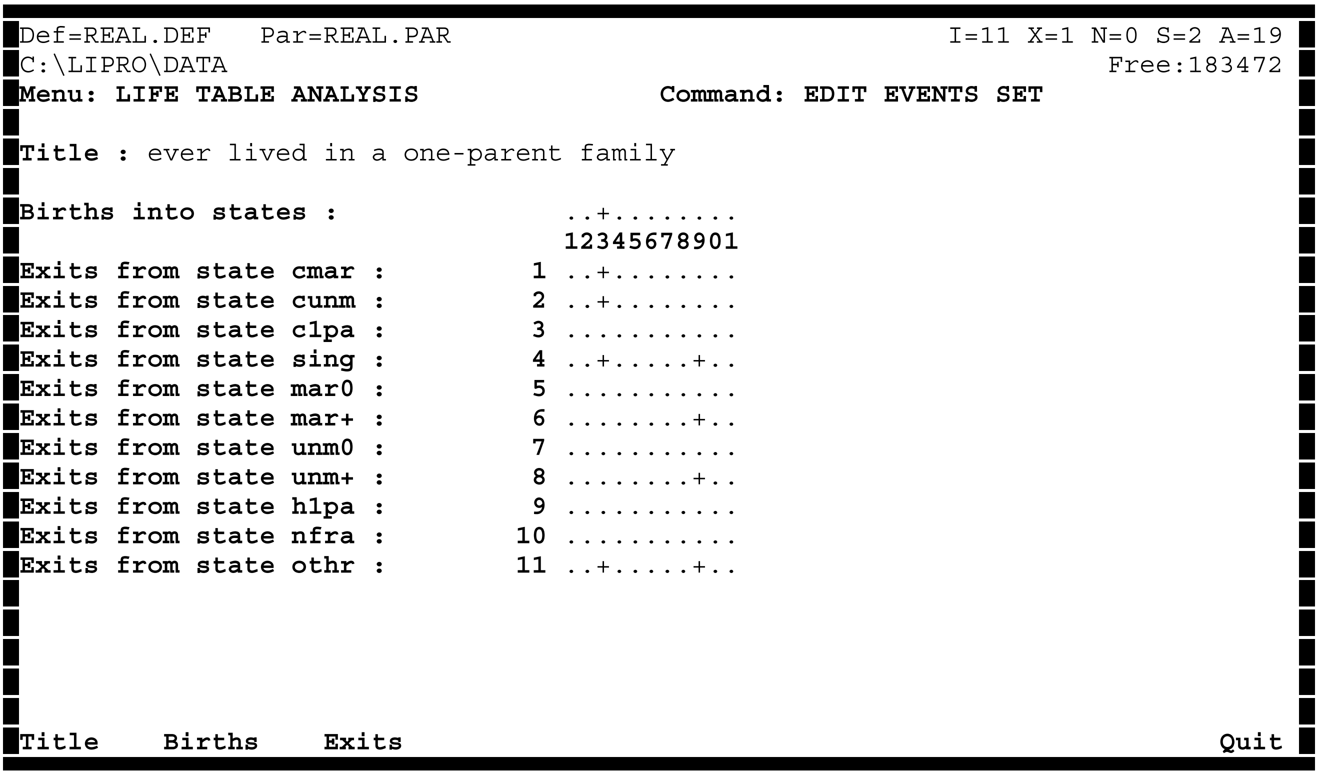
```
tabel 19.1

Exit and entry rates
Exits from state sing       Sex : female    Time : 1985-1989   File : REALRATE.BIN

             cmar      cunm      c1pa      sing      mar0      mar+      unm0
births      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
15-19       0.0182    0.0000    0.0017    0.0000    0.0703    0.0009    0.1189
20-24       0.0066    0.0000    0.0024    0.0000    0.0530    0.0009    0.0935
25-29       0.0012    0.0000    0.0000    0.0000    0.0319    0.0000    0.0486
30-34       0.0000    0.0000    0.0000    0.0000    0.0153    0.0000    0.0520
35-39       0.0000    0.0000    0.0000    0.0000    0.0068    0.0000    0.0357
40-44       0.0000    0.0000    0.0000    0.0000    0.0053    0.0000    0.0122
45-49       0.0014    0.0000    0.0000    0.0000    0.0094    0.0000    0.0284
50-54       0.0015    0.0000    0.0000    0.0000    0.0058    0.0000    0.0139
55-59       0.0000    0.0000    0.0000    0.0000    0.0007    0.0016    0.0019
60-64       0.0000    0.0000    0.0000    0.0000    0.0000    0.0003    0.0028
65-69       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0027
70-74       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0017
75-79       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
80-84       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
85+         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TOTAL       0.0290    0.0000    0.0041    0.0000    0.1984    0.0038    0.4123

             unm+      h1pa      nfra      othr      dead      rest     TOTAL
births      0.0000    0.0000    0.0000    0.0000    0.0046    0.0060    0.0106
 0- 4       0.0000    0.0000    0.0000    0.0000    0.0003    0.0062    0.0065
 5- 9       0.0000    0.0000    0.0000    0.0000    0.0002    0.0039    0.0041
10-14       0.0000    0.0000    0.0000    0.0000    0.0003    0.0024    0.0027
15-19       0.0011    0.0177    0.0037    0.0165    0.0004    0.0047    0.2540
20-24       0.0024    0.0110    0.0056    0.0077    0.0006    0.0070    0.1908
25-29       0.0030    0.0182    0.0022    0.0027    0.0010    0.0072    0.1159
30-34       0.0034    0.0133    0.0094    0.0069    0.0016    0.0052    0.1071
35-39       0.0004    0.0035    0.0000    0.0012    0.0022    0.0038    0.0537
40-44       0.0000    0.0000    0.0000    0.0004    0.0035    0.0029    0.0242
45-49       0.0000    0.0000    0.0007    0.0000    0.0048    0.0022    0.0469
50-54       0.0008    0.0000    0.0022    0.0000    0.0066    0.0017    0.0325
55-59       0.0011    0.0000    0.0002    0.0000    0.0097    0.0014    0.0167
60-64       0.0000    0.0000    0.0000    0.0021    0.0137    0.0012    0.0200
65-69       0.0000    0.0000    0.0002    0.0036    0.0214    0.0009    0.0288
70-74       0.0000    0.0000    0.0011    0.0027    0.0369    0.0006    0.0430
75-79       0.0000    0.0000    0.0019    0.0022    0.0639    0.0005    0.0685
80-84       0.0000    0.0000    0.0038    0.0000    0.1660    0.0004    0.1703
85+         0.0000    0.0000    0.0064    0.0000    0.2017    0.0003    0.2085
TOTAL       0.0120    0.0638    0.0375    0.0459    0.5396    0.0582    1.4048


Exit and entry rates
Entries into state sing     Sex : female    Time : 1985-1989   File : REALRATE.BIN

             cmar      cunm      c1pa      sing      mar0      mar+      unm0
births      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
15-19       0.0400    0.0406    0.0412    0.0000    0.0069    0.0119    0.0686
20-24       0.0853    0.0911    0.0786    0.0000    0.0065    0.0012    0.0558
25-29       0.0649    0.1794    0.0578    0.0000    0.0104    0.0007    0.0560
30-34       0.0000    0.0000    0.0000    0.0000    0.0088    0.0016    0.0715
35-39       0.0000    0.0000    0.0000    0.0000    0.0112    0.0000    0.1023
40-44       0.0000    0.0000    0.0000    0.0000    0.0226    0.0000    0.2283
45-49       0.0000    0.0000    0.0000    0.0000    0.0227    0.0021    0.2947
50-54       1.0000    1.0000    1.0000    0.0000    0.0228    0.0020    0.3254
55-59       1.0000    1.0000    1.0000    0.0000    0.0150    0.0000    0.2853
60-64       1.0000    1.0000    1.0000    0.0000    0.0287    0.0007    0.2542
65-69       1.0000    1.0000    1.0000    0.0000    0.0532    0.0019    0.1376
```

```
70-74        1.0000    1.0000    1.0000    0.0000    0.0883    0.0015    0.0191
75-79        1.0000    1.0000    1.0000    0.0000    0.1023    0.0000    0.1929
80-84        1.0000    1.0000    1.0000    0.0000    0.0330    0.0000    0.0553
85+          1.0000    1.0000    1.0000    0.0000    0.0004    0.0000    0.0345
TOTAL        8.1901    8.3111    8.1776    0.0000    0.4327    0.0236    2.1816

              unm+      h1pa      nfra      othr    births      rest     TOTAL
births       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4        0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9        0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14        0.0000    0.0000    0.0000    0.0000    0.0000  114.0888  114.0888
15-19        0.0256    0.0935    0.1507    0.0353    0.0000 2854.0632 2854.5774
20-24        0.0178    0.0530    0.1603    0.0283    0.0000 4848.3842 4848.9620
25-29        0.0077    0.0382    0.0823    0.0441    0.0000 2994.3158 2994.8572
30-34        0.0222    0.0147    0.0290    0.0164    0.0000 1344.5647 1344.7290
35-39        0.0258    0.0098    0.0000    0.0037    0.0000  755.9303  756.0831
40-44        0.0629    0.0127    0.4201    0.0310    0.0000  552.8472  553.6248
45-49        0.0461    0.0373    0.0000    0.0207    0.0000  611.3515  611.7751
50-54        0.0568    0.0285    0.0000    0.0192    0.0000  717.2449  720.6996
55-59        0.0811    0.1079    0.0000    0.0254    0.0000  901.0753  904.5899
60-64        0.0880    0.0825    0.0000    0.0493    0.0000  962.5684  966.0718
65-69        0.0859    0.0782    0.0000    0.0432    0.0000  855.5875  858.9875
70-74        0.0000    0.0793    0.0000    0.0236    0.0000  652.8940  656.1059
75-79        0.0000    0.1405    0.0000    0.0349    0.0000  395.4238  398.8943
80-84        0.0000    0.0737    0.0000    0.0082    0.0000  523.5014  526.6716
85+          0.0000    0.0941    0.0000    0.0089    0.0000  724.8192  727.9571
TOTAL        0.5198    0.9438    0.8424    0.3922    0.000019808.660119838.6750
```

```
Exit and entry rates
Exits from state sing       Sex : male      Time : 1985-1989   File : REALRATE.BIN

                cmar      cunm      c1pa      sing      mar0      mar+      unm0
births        0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
15-19         0.0140    0.0000    0.0041    0.0000    0.0501    0.0010    0.0868
20-24         0.0083    0.0001    0.0033    0.0000    0.0818    0.0030    0.1031
25-29         0.0022    0.0006    0.0004    0.0000    0.0446    0.0029    0.0593
30-34         0.0000    0.0000    0.0026    0.0000    0.0245    0.0036    0.0369
35-39         0.0000    0.0000    0.0010    0.0000    0.0138    0.0052    0.0224
40-44         0.0000    0.0000    0.0000    0.0000    0.0161    0.0061    0.0311
45-49         0.0000    0.0000    0.0000    0.0000    0.0177    0.0016    0.0148
50-54         0.0000    0.0000    0.0000    0.0000    0.0067    0.0013    0.0210
55-59         0.0000    0.0000    0.0000    0.0000    0.0037    0.0021    0.0230
60-64         0.0000    0.0000    0.0000    0.0000    0.0006    0.0000    0.0019
65-69         0.0000    0.0000    0.0000    0.0000    0.0004    0.0000    0.0072
70-74         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0097
75-79         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0022
80-84         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0070
85+           0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0140
TOTAL         0.0245    0.0007    0.0114    0.0000    0.2599    0.0268    0.4403

                unm+      h1pa      nfra      othr      dead      rest     TOTAL
births        0.0000    0.0000    0.0000    0.0000    0.0060    0.0062    0.0122
 0- 4         0.0000    0.0000    0.0000    0.0000    0.0004    0.0063    0.0067
 5- 9         0.0000    0.0000    0.0000    0.0000    0.0002    0.0051    0.0053
10-14         0.0000    0.0000    0.0000    0.0000    0.0007    0.0020    0.0028
15-19         0.0014    0.0000    0.0017    0.0578    0.0010    0.0040    0.2220
20-24         0.0019    0.0000    0.0009    0.0140    0.0012    0.0067    0.2241
25-29         0.0028    0.0000    0.0000    0.0082    0.0017    0.0081    0.1307
30-34         0.0046    0.0013    0.0017    0.0025    0.0024    0.0068    0.0869
35-39         0.0032    0.0030    0.0012    0.0017    0.0036    0.0061    0.0611
40-44         0.0105    0.0184    0.0000    0.0052    0.0058    0.0053    0.0985
45-49         0.0023    0.0377    0.0031    0.0000    0.0097    0.0042    0.0911
50-54         0.0019    0.0076    0.0034    0.0000    0.0153    0.0038    0.0610
55-59         0.0033    0.0000    0.0044    0.0025    0.0254    0.0033    0.0678
60-64         0.0000    0.0000    0.0000    0.0000    0.0384    0.0029    0.0438
65-69         0.0000    0.0000    0.0026    0.0059    0.0584    0.0021    0.0765
70-74         0.0000    0.0000    0.0052    0.0018    0.0901    0.0011    0.1080
75-79         0.0000    0.0000    0.0000    0.0000    0.1347    0.0007    0.1377
80-84         0.0000    0.0000    0.0000    0.0000    0.2476    0.0004    0.2551
85+           0.0000    0.0000    0.0000    0.0000    0.2926    0.0004    0.3070
TOTAL         0.0318    0.0681    0.0242    0.0996    0.9354    0.0756    1.9983


Exit and entry rates
Entries into state sing     Sex : male      Time : 1985-1989   File : REALRATE.BIN

                cmar      cunm      c1pa      sing      mar0      mar+      unm0
births        0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
15-19         0.0228    0.0225    0.0254    0.0000    0.0282    0.0246    0.0686
20-24         0.0534    0.0557    0.0571    0.0000    0.0150    0.0072    0.0558
25-29         0.0717    0.1097    0.0674    0.0000    0.0135    0.0071    0.0560
30-34         0.0509    0.0177    0.0452    0.0000    0.0188    0.0098    0.0715
35-39         0.0409    0.0699    0.0460    0.0000    0.0146    0.0095    0.1023
40-44         0.0020    0.0000    0.0031    0.0000    0.0041    0.0054    0.2283
45-49         0.0000    0.0000    0.0000    0.0000    0.0057    0.0059    0.2947
50-54         1.0000    1.0000    1.0000    0.0000    0.0086    0.0055    0.3254
55-59         1.0000    1.0000    1.0000    0.0000    0.0081    0.0017    0.2853
60-64         1.0000    1.0000    1.0000    0.0000    0.0169    0.0017    0.2542
65-69         1.0000    1.0000    1.0000    0.0000    0.0110    0.0072    0.1376
70-74         1.0000    1.0000    1.0000    0.0000    0.0159    0.0068    0.0191
```

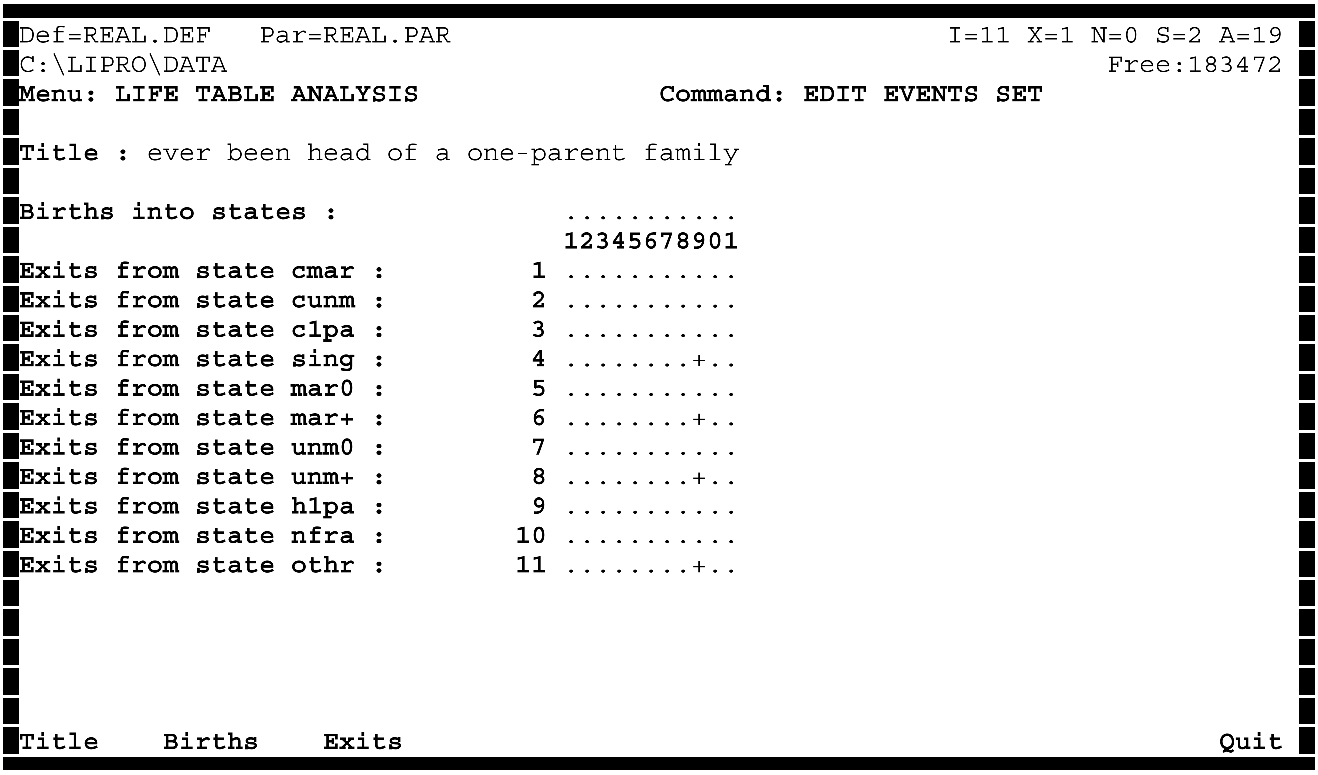
```
75-79       1.0000    1.0000    1.0000    0.0000    0.0388    0.0000    0.1929
80-84       1.0000    1.0000    1.0000    0.0000    0.0556    0.0000    0.0553
85+         1.0000    1.0000    1.0000    0.0000    0.0577    0.0000    0.0345
TOTAL       8.2417    8.2755    8.2443    0.0000    0.3126    0.0924    2.1816

              unm+      h1pa      nfra      othr    births      rest     TOTAL
births      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 0- 4       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5- 9       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
10-14       0.0000    0.0000    0.0000    0.0000    0.0000   72.5340   72.5340
15-19       0.0125    0.0000    0.0549    0.0199    0.0000 2269.0319 2269.3113
20-24       0.0078    0.0019    0.1087    0.0278    0.0000 6785.9999 6786.3904
25-29       0.0072    0.0580    0.0984    0.0389    0.0000 6236.4450 6236.9729
30-34       0.0044    0.0713    0.0997    0.0281    0.0000 3636.7945 3637.2119
35-39       0.0055    0.0380    0.0258    0.0433    0.0000 2107.6173 2108.0132
40-44       0.0062    0.0593    0.0000    0.0462    0.0000 1230.1845 1230.5392
45-49       0.0044    0.0242    0.0000    0.0273    0.0000  983.6541  984.0163
50-54       0.0104    0.0785    0.0056    0.0214    0.0000  784.5185  787.9739
55-59       0.0126    0.0738    0.0429    0.0095    0.0000  733.8528  737.2867
60-64       0.0169    0.1325    0.0000    0.1007    0.0000  646.7663  650.2893
65-69       0.0121    0.0877    0.0000    0.0437    0.0000  465.9826  469.2819
70-74       0.0011    0.1762    0.0099    0.0044    0.0000  278.6301  281.8634
75-79       0.0000    0.2887    0.0407    0.0243    0.0000  142.1434  145.7288
80-84       0.0000    0.2469    0.0312    0.0204    0.0000  216.7066  220.1159
85+         0.0000    0.2939    0.0363    0.0000    0.0000  302.4656  305.8879
TOTAL       0.1010    1.6311    0.5539    0.4560    0.000026893.327026923.4172
```

fig 19.3



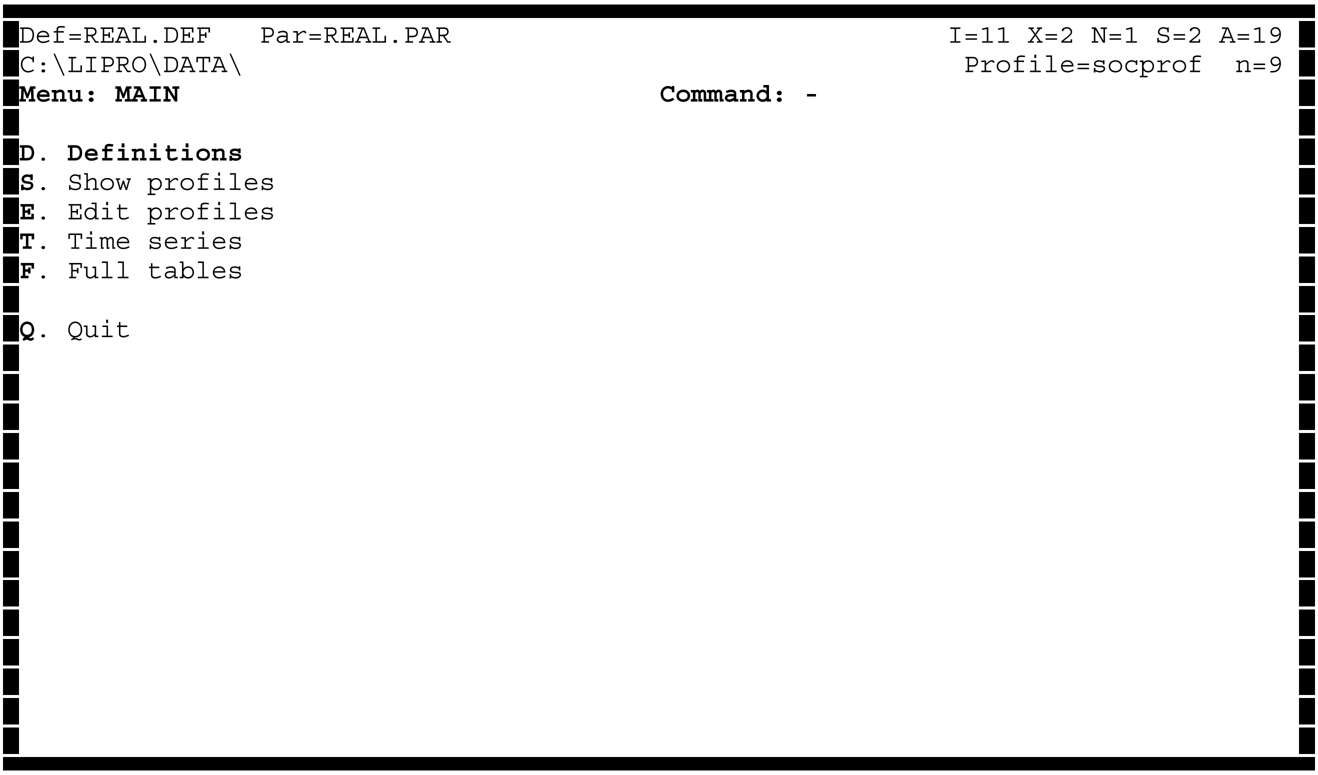
```
Def=REAL.DEF   Par=REAL.PAR                               I=11 X=1 N=0 S=2 A=19
C:\LIPRO\DATA                                                       Free:183472
Menu: LIFE TABLE ANALYSIS               Command: EDIT EVENTS SET

Title : ever lived in a one-parent family

Births into states :              ..+........
                                  12345678901
Exits from state cmar :         1 ..+........
Exits from state cunm :         2 ..+........
Exits from state c1pa :         3 ...........
Exits from state sing :         4 ..+.....+..
Exits from state mar0 :         5 ...........
Exits from state mar+ :         6 ........+..
Exits from state unm0 :         7 ...........
Exits from state unm+ :         8 ........+..
Exits from state h1pa :         9 ...........
Exits from state nfra :        10 ...........
Exits from state othr :        11 ..+.....+..





Title    Births    Exits                                                   Quit
```

fig 19.4



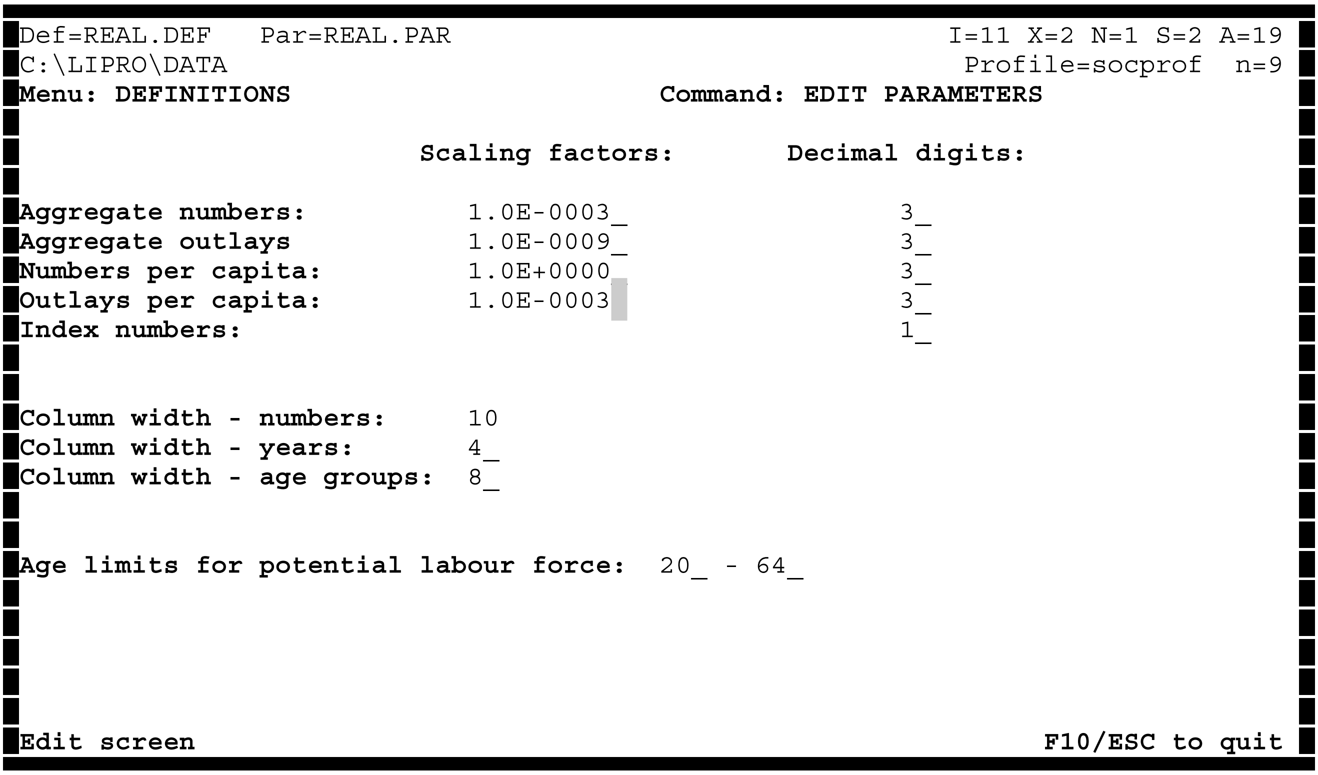
```
Def=REAL.DEF   Par=REAL.PAR                           I=11 X=1 N=0 S=2 A=19
C:\LIPRO\DATA                                                   Free:183472
Menu: LIFE TABLE ANALYSIS               Command: EDIT EVENTS SET

Title : ever been head of a one-parent family

Births into states :                  ...........
                                      12345678901
Exits from state cmar :             1 ...........
Exits from state cunm :             2 ...........
Exits from state c1pa :             3 ...........
Exits from state sing :             4 ........+..
Exits from state mar0 :             5 ...........
Exits from state mar+ :             6 ........+..
Exits from state unm0 :             7 ...........
Exits from state unm+ :             8 ........+..
Exits from state h1pa :             9 ...........
Exits from state nfra :            10 ...........
Exits from state othr :            11 ........+..





Title    Births    Exits                                                  Quit
```

fig 21.1



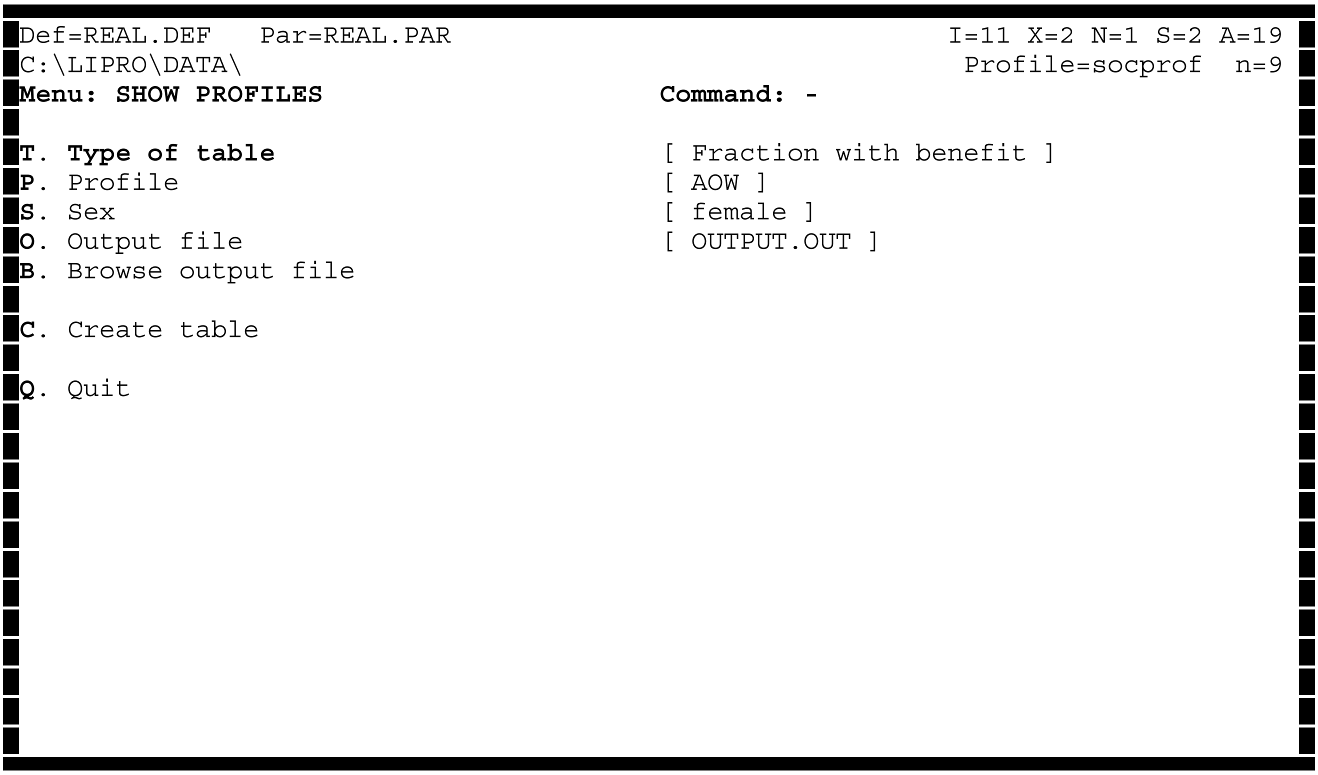
```
Def=REAL.DEF   Par=REAL.PAR                        I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                      Profile=socprof  n=9
Menu: MAIN                              Command: -

D. Definitions
S. Show profiles
E. Edit profiles
T. Time series
F. Full tables

Q. Quit
```

fig 21.2



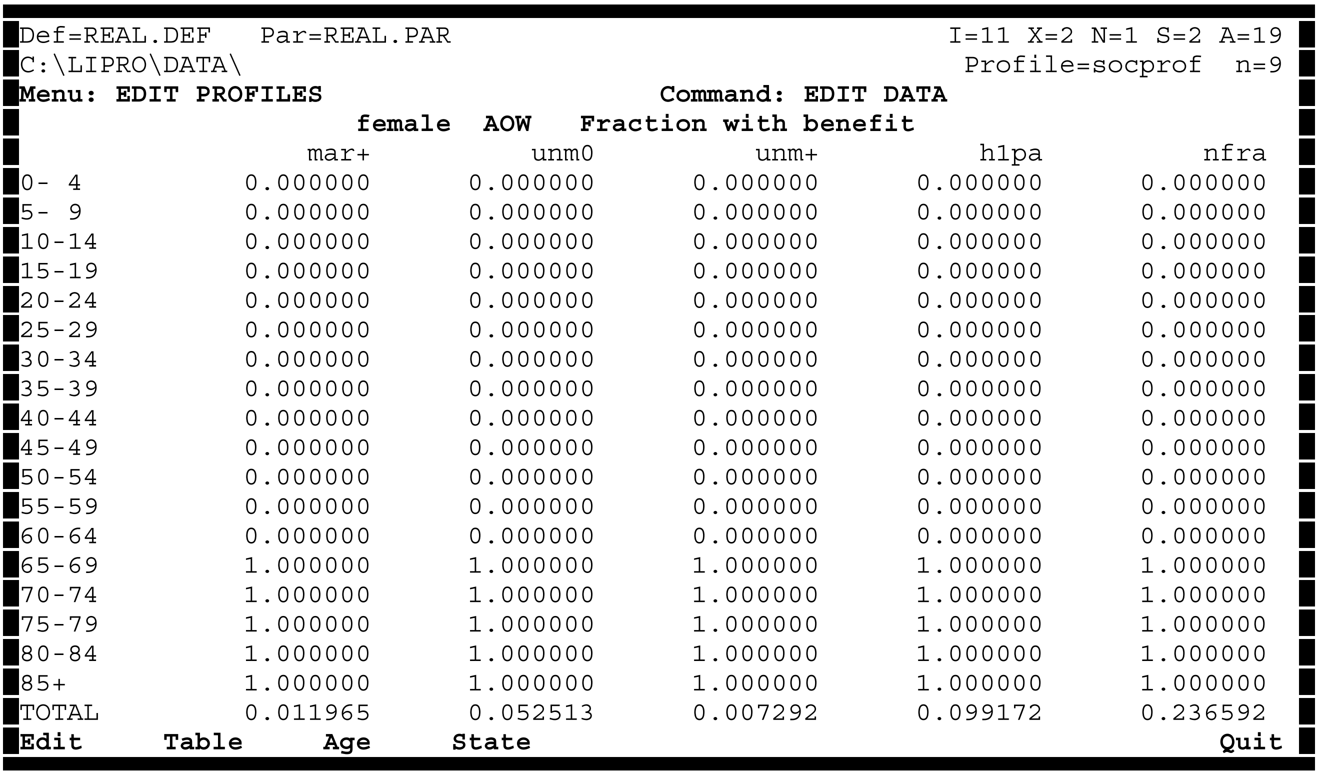
```
Def=REAL.DEF   Par=REAL.PAR                           I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA                                          Profile=socprof  n=9
Menu: DEFINITIONS                       Command: EDIT PARAMETERS


                         Scaling factors:       Decimal digits:

Aggregate numbers:          1.0E-0003_                 3_
Aggregate outlays           1.0E-0009_                 3_
Numbers per capita:         1.0E+0000_                 3_
Outlays per capita:         1.0E-0003                  3_
Index numbers:                                         1_


Column width - numbers:     10
Column width - years:       4_
Column width - age groups:  8_


Age limits for potential labour force:  20_ - 64_





Edit screen                                                  F10/ESC to quit
```

fig 21.3



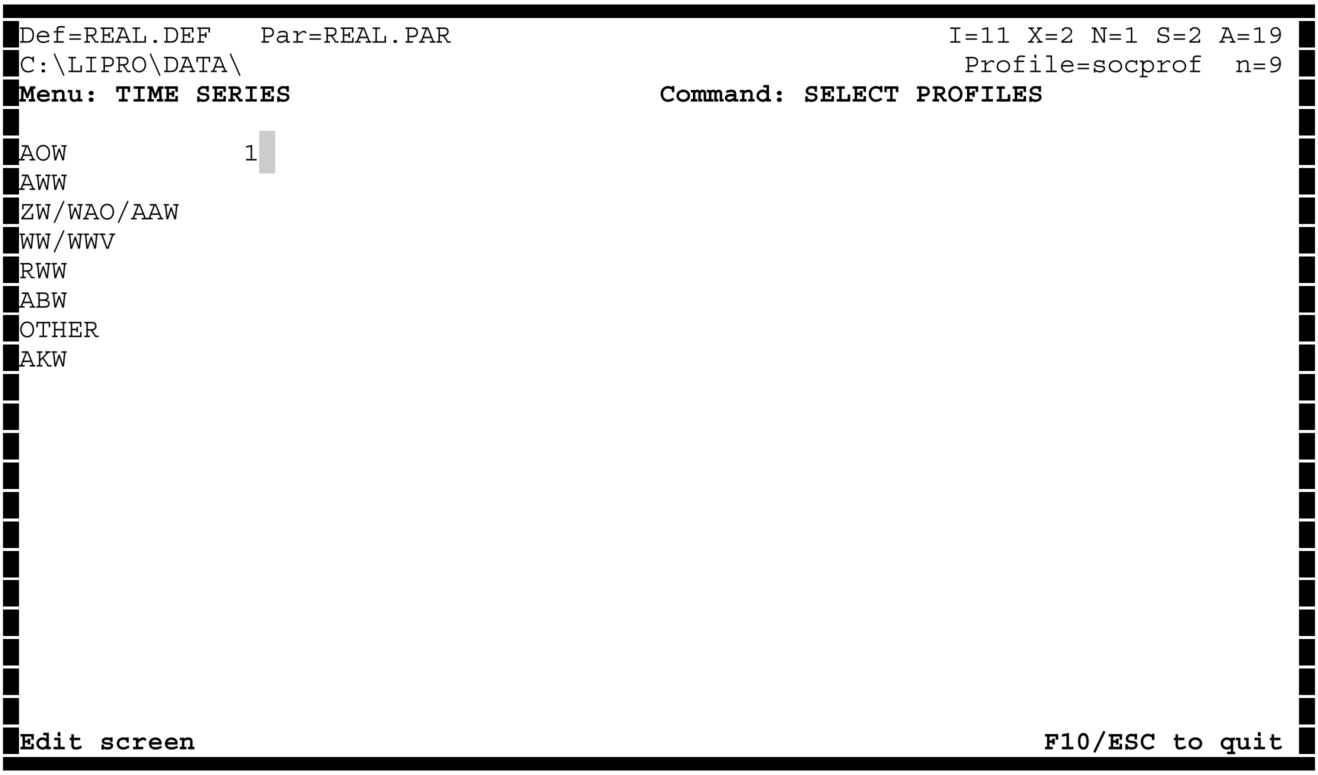
```
Def=REAL.DEF   Par=REAL.PAR                             I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                           Profile=socprof  n=9
Menu: SHOW PROFILES                     Command: -

T. Type of table                        [ Fraction with benefit ]
P. Profile                              [ AOW ]
S. Sex                                  [ female ]
O. Output file                          [ OUTPUT.OUT ]
B. Browse output file

C. Create table

Q. Quit
```

fig 21.4



```
Def=REAL.DEF   Par=REAL.PAR                                   I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                  Profile=socprof  n=9
Menu: EDIT PROFILES                         Command: EDIT DATA
                     female  AOW   Fraction with benefit
                  mar+          unm0          unm+          h1pa          nfra
0- 4          0.000000      0.000000      0.000000      0.000000      0.000000
5- 9          0.000000      0.000000      0.000000      0.000000      0.000000
10-14         0.000000      0.000000      0.000000      0.000000      0.000000
15-19         0.000000      0.000000      0.000000      0.000000      0.000000
20-24         0.000000      0.000000      0.000000      0.000000      0.000000
25-29         0.000000      0.000000      0.000000      0.000000      0.000000
30-34         0.000000      0.000000      0.000000      0.000000      0.000000
35-39         0.000000      0.000000      0.000000      0.000000      0.000000
40-44         0.000000      0.000000      0.000000      0.000000      0.000000
45-49         0.000000      0.000000      0.000000      0.000000      0.000000
50-54         0.000000      0.000000      0.000000      0.000000      0.000000
55-59         0.000000      0.000000      0.000000      0.000000      0.000000
60-64         0.000000      0.000000      0.000000      0.000000      0.000000
65-69         1.000000      1.000000      1.000000      1.000000      1.000000
70-74         1.000000      1.000000      1.000000      1.000000      1.000000
75-79         1.000000      1.000000      1.000000      1.000000      1.000000
80-84         1.000000      1.000000      1.000000      1.000000      1.000000
85+           1.000000      1.000000      1.000000      1.000000      1.000000
TOTAL         0.011965      0.052513      0.007292      0.099172      0.236592
Edit     Table     Age     State                                              Quit
```

fig 21.5

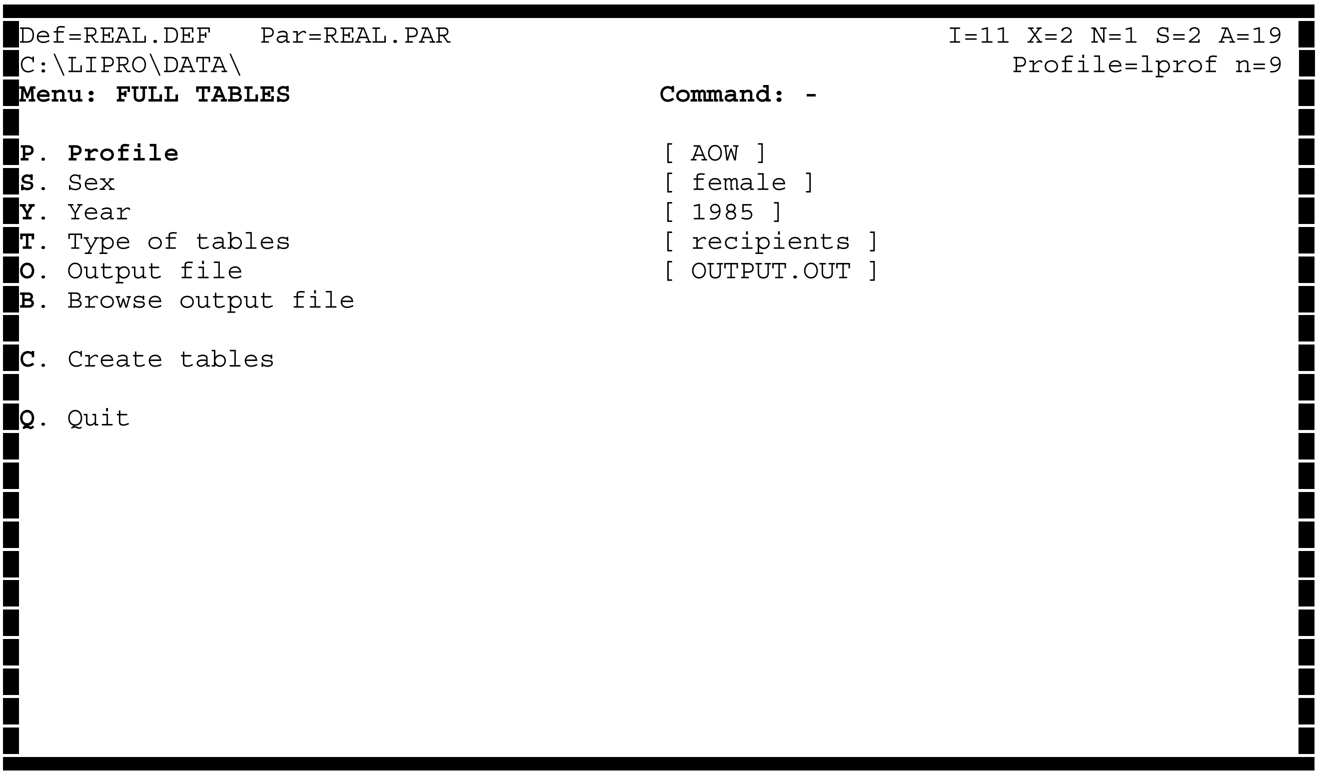


```
Def=REAL.DEF   Par=REAL.PAR                                 I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                               Profile=socprof  n=9
Menu: TIME SERIES                       Command: SELECT PROFILES

AOW           1
AWW
ZW/WAO/AAW
WW/WWV
RWW
ABW
OTHER
AKW











Edit screen                                                       F10/ESC to quit
```

Table 21.1 TIME SERIES

```
Profile = AOW     Sex = female

Population file = REALPOP.BIN

Year           R     index           E     index       R/P     index       E/P     index       R/L     index
E/L    index
1985     908.856     100.0    1147.181     100.0     0.064     100.0     0.080     100.0     0.104     100.0
0.132    100.0
1990    1038.097     114.2    1317.036     114.8     0.070     110.3     0.089     110.9     0.112     107.4
0.142    108.0
1995    1145.306     126.0    1457.287     127.0     0.075     118.1     0.096     119.0     0.119     114.2
0.152    115.2
2000    1229.659     135.3    1569.170     136.8     0.079     123.8     0.101     125.2     0.125     120.1
0.160    121.4
2005    1317.164     144.9    1684.137     146.8     0.083     130.3     0.106     132.0     0.132     126.8
0.169    128.4
2010    1434.801     157.9    1837.394     160.2     0.089     140.2     0.114     142.2     0.143     136.6
0.183    138.6
2015    1670.497     183.8    2136.689     186.3     0.103     161.4     0.131     163.6     0.168     161.3
0.215    163.4
2020    1853.869     204.0    2382.542     207.7     0.113     177.8     0.145     181.0     0.190     181.6
0.244    184.9
2025    2032.766     223.7    2631.141     229.4     0.124     194.4     0.160     199.3     0.214     204.5
0.277    209.7
2030    2195.756     241.6    2865.514     249.8     0.134     210.4     0.175     217.5     0.239     229.3
0.313    237.1
2035    2296.952     252.7    3017.843     263.1     0.141     222.1     0.186     231.2     0.259     248.4
0.341    258.5
2040    2293.111     252.3    3032.177     264.3     0.143     224.6     0.189     235.3     0.263     252.0
0.348    264.0
2045    2218.556     244.1    2949.217     257.1     0.140     220.5     0.187     232.2     0.256     244.7
0.340    257.8
2050    2130.698     234.4    2841.686     247.7     0.137     214.8     0.182     227.0     0.246     235.8
0.328    249.1
```

fig 21.7



```
Def=REAL.DEF   Par=REAL.PAR                                I=11 X=2 N=1 S=2 A=19
C:\LIPRO\DATA\                                                  Profile=lprof n=9
Menu: FULL TABLES                        Command: -

P. Profile                               [ AOW ]
S. Sex                                   [ female ]
Y. Year                                  [ 1985 ]
T. Type of tables                        [ recipients ]
O. Output file                           [ OUTPUT.OUT ]
B. Browse output file

C. Create tables

Q. Quit
```

Changes in household structure may have profound consequences for a wide range of areas in demography and social policy. Household projection models developed in demography over the past few decades are predominantly of the headship rate type, in which the dynamic processes of household formation and dissolution, which underlie changes in household structure, essentially are treated as a black box. In contrast, this book describes and applies a *dynamic* household projection model which explicitly focusses on the *flows* underlying household changes. The model, called LIPRO ("LIfestyle PROjections"), is based on the metholology of multidimensional demography, but includes several extensions to solve the particular problems of household modelling.

After a review of existing household models, the book gives a comprehensive treatment of the LIPRO methodology. Next, the model is applied to study future household dynamics in the Netherlands and its implications for social security expenditure. One of the main findings is a dramatic increase in the number of one-person households during the next few decades.

The final part of the book constitutes a complete user's guide to the computer program LIPRO 2.0. Although originally developed for household projections, LIPRO 2.0 can in fact be used for a wide range of calculations in multidimensional demography. The computer program itself can be found on a diskette, enclosed in this volume.