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International Institute for Applied Systems Analysis □ A-2361 Laxenburg Austria

Telephone: +43 2236 715210 □ Telex: 079137 iiasa a □ Telefax: +43 2236 71313

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ABSTRACT

Within IIASA's project on "Population and Sustainable Development: A Case Study of Mauritius" an interactive software tool describing the dynamics of population-development-environment interactions was developed. In contrast to similar existing models, population is not only an input variable but it is a driving force of the system.

The population module provides the structure of the population by age, sex, level of education and labor force participation. For the future, different levels of fertility, mortality, migration, progression in education and labor force entrance and exit can easily be specified by the user. Changes in those variables in the past have been remarkable. Dependency ratios, calculated in several levels of refinement, show an amazing decline over the period 1962-1990. With different demographic developments, the past three decades would not have brought a significant decline in dependency ratios and may thus possibly have hindered or at least delayed economic development.

In the coming decades the population of Mauritius will grow by some 30-40 per cent and it will age considerably. Changes in the socio-demographic composition of the population caused by recent and expected changes in the education and labor force distribution, however, indicate that further economic development is strongly favored during the next two decades.

TABLE OF CONTENTS

MODELING THE POPULATION OF MAURITIUS

Christopher Prinz

1. INTRODUCTION

This paper describes the role of *population* within IIASA's project on "Population and Sustainable Development: A Case Study of Mauritius". The core part of the project is the development of a user-friendly software tool describing the dynamics of population-development-environment interactions, to be used both as a planning tool and as a teaching tool. The population module is one part of the model, the respective results being an important part of the input for the other modules, namely the economy module, the land use module and the water module.

What can demographers add to the not only controversial but sometimes even confusing debate concerning the role of population in environmental degradation? What linkages between variables are relevant in this discussion? What can demographers identify as most important variables that should be included in a population-environment model?

The direct effect of the number of people on environmental variables is insignificant. While the sheer number of people is hardly relevant, it is the behavior of the people which matters. Certain population characteristics strongly influence the behavior of the people. Four variables seem to be most relevant for a population-development-environment model: age, sex, education and labor force participation. Education is sex and age-dependant, labor force participation is sex, age and education-dependant. Higher labor force participation increases the labor force and reduces the size of the dependant population (children, elderly, housewives, etc.), which is itself mainly determined by the age structure. Higher education increases economic productivity and as a consequence competitiveness on the world market, and it promotes technological progress. Both higher levels of education and of labor force participation result in higher standards of living and thus create new areas of environmental degradation. However, higher education may also increase the awareness of environmental issues and longer term concerns.

In the model only few population components influence the environment module directly. Land demand from housing (in the land use module) and gross water intake (in the water module) are a direct function of total population size. Most of the effects of population size and structure on the environment work via economic behavior. The population module influences the economy module directly through labor supply by educational group and through consumption by age and educational level, and indirectly through age-specific government expenditures (pension, health, education expenditures).

2. THE POPULATION MODULE

2.1. Specification of the Model

A model which provides the structure of the population by sex, age, level of education and labor force participation has been selected as most appropriate. Since it should be possible to move into or out of the labor force and to move up to a higher educational status, the most suitable model would be one of the multi-state type. In a multi-state population projection model, which is discussed in detail in for example Willekens and Drewe (1984), the starting population is subdivided into several groups, the so-called states of the model. In each projection step, an individual moves with a certain likelihood to one of the other states. Thus, the system provides at every point in time the distribution of the Mauritian population by sex, age, labor force participation and level of education. The structure by sex and age is a result of fertility and mortality rates. The structure of educational level and labor force participation is a result of progression rates in educational status and rates in and out of the labor force.

Educational status is divided into primary, secondary and tertiary education. Labor force status is a binary variable: working and unemployed people are considered as part of the labor force, all others belong to the non-labor force group. Consequently, the model considers six states, which are also shown in Figure 1: 'primary education - in labor force', 'primary education - not in labor force', 'secondary education - in labor force', 'secondary education - not in labor force', 'tertiary education - in labor force', and 'tertiary education - not in labor force'.

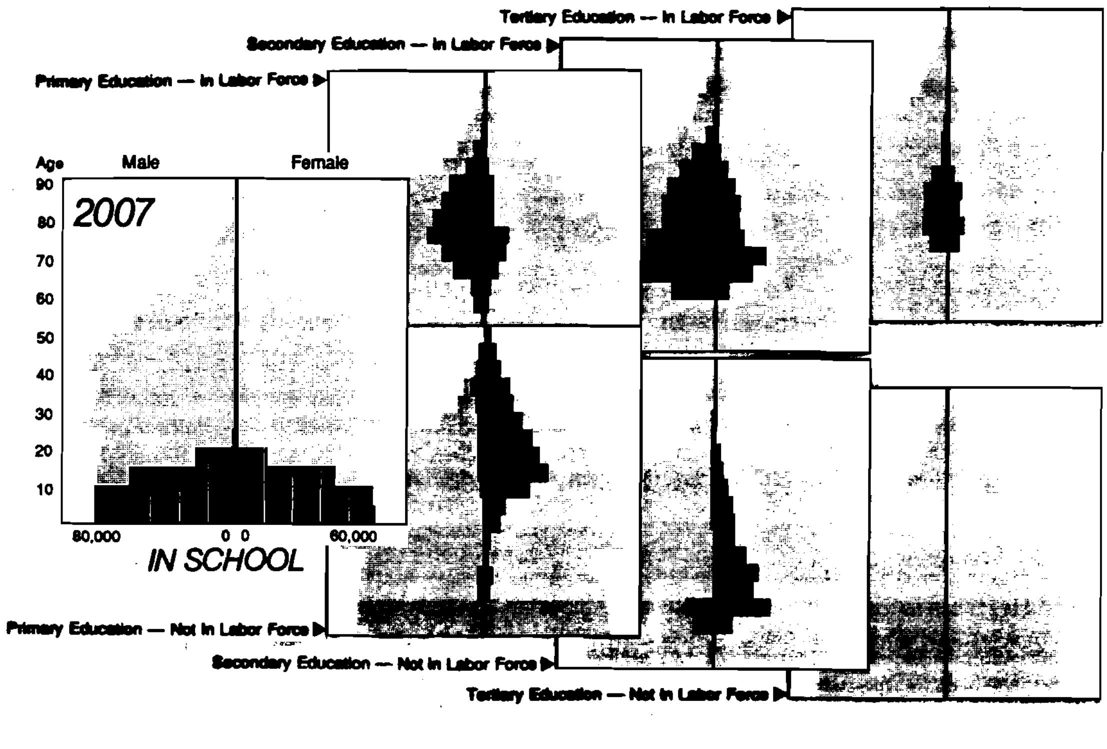

Figure 1. States considered in the population module.

As shown in Figure 1, we introduced an additional seventh state: 'in school', which comprises the population in school and before school age. In this manner it is possible to determine the educational distribution of the population on the basis of school leaving rates and--as another advantage--the school population can be derived directly.

Every individual is born into the group 'in school'. In the course of a lifetime, i.e. moving from one age to the next, and depending on sex, each individual is exposed to a certain risk to die, to leave school at a certain educational level, to move into or out of the labor force, and--for women--to give birth to a child. Moving into the labor force is restricted to age groups 15 and over; moving up to a higher level of education is by assumption not possible once the individual left the status 'in school'.

Projection in demography is calculating survivors down cohort lines of those living at a given point of time, calculating births in each successive period, and adding a suitable allowance for migration. In a multi-state approach, these general calculations are complemented by calculations keeping track of the distribution of individuals over states considered.

The following formulas have been applied to estimate the future population:

Indices:	x,y	five-year age groups (x,y = 1,...,18)
	i,j	states (i,j = 1,...,7)
	t	time

Variables:

$P[x,i,t]$	Population in age group x and state i at time t
$W[x,i,t]$	Female population in age group x and state i at time t
$f[x,i,t]$	Fertility rate in age group x and state i at time t
$S[x,i,t]$	Survival ratio in age group x and state i at time t, with $S[x,i,t] = L[x,i,t]/L[x\text{-}1,i,t]$ and $S[1,i,t] = L[1,i,t]/5*l[0,i,t]$
$L[x,i,t]$	Number of person-years lived by individuals in age group x and state i at time t
$l[x,i,t]$	Number of survivors in age group x and state i at time t, with l[0,i,t] = 100,000 (=radix)
$M[x,i,t \rightarrow t+1]$	Number of immigrants minus outmigrants in age group x, state i and time interval t to t+1
$t_{OUT}[x,i \rightarrow j,t]$	Transition rate from state i to j in age group x at time t
$T_{IN}[x,i \leftarrow j,t]$	Absolute number of transitions into state i from state j in age group x at time t

Formulas:

a. for age group 0-4, i.e. x = 1:
(all children are born into state i = 1, 50% of all births are girls and 50% boys)

$$P[x,1,t+1] = \sum_{y=4}^{10} \sum_{j=1}^{7} \{W[y,j,t] * \frac{1}{2} * (f[y,j,t] + f[y+1,j,t+1] * S[y+1,j,t])\} * \\ * \frac{5}{2} * S[x,1,t] + M[x,1,t \rightarrow t+1]$$

b. for age groups 5-9 to 80-84, i.e. x = 2,...,17:
(calculations are done separately for women and men)

$$P[x,i,t+1] = (P[x-1,i,t] * (1 - \sum_{j=1}^{7} \{t_{OUT}[x-1,i \rightarrow j,t]\})) * S[x,i,t] + \\ + \sum_{j=1}^{7} \{T_{IN}[x,i \leftarrow j,t]\} + M[x,i,t \rightarrow t+1]$$

c. for age group 85 and over, i.e. x = 18:
(calculations are done separately for women and men)

$$P[x,i,t+1] = P[x-1,i,t] * S[x,i,t] + P[x,i,t] * S[x+1,i,t] + M[x,i,t \rightarrow t+1]$$

The projection is done in five year steps. Transitions between states occur between ages 5 and 85, that is, they affect only age groups 2-17. S[x,i,t], L[x,i,t] and l[x,i,t] are obtained from Mauritian lifetables.

2.2. Using the Model

Using the model described above is straightforward once the required input data have been collected. Data on the Mauritian population distribution by status were estimated from the 1990 census and will be discussed in detail in Section 3.1. Mortality rates were taken from the Central Statistical Office publications, as were age-specific fertility rates. Fertility rates by educational level were estimated using census information on the number of children born by completed education. Figures on total net migration were distributed over sex, age and status by combining migration theory with certain assumptions. Transition rates from school to any of the other states were estimated on the basis of age-specific school enrolment ratios. Transitions into and out of the labor force were estimated from education-specific labor force participation rates. Both school enrolment ratios and labor force participation rates were available from the census. The procedures used to estimate transition rates are described in more detail in the Appendix.

secondary and tertiary educated women was clearly below replacement level. Life expectancy at birth increased by 10 years for women and 6 years for men during the last three decades; in 1990 it was 73 and 65 years for women and men, respectively.

Table 1. Main input parameters for the population model, Mauritius 1990.

Fertility (Total Fertility Rate)	Total 2.30	Primary 2.54	Secondary 1.93	Tertiary 1.61
Mortality (Life expectancy at birth)	Women 73.0	Men 65.0		
Migration (Annual net migration)	Total -500			
Economic activity (Labor force participation rate of women aged 35-39)	Total 46%	Primary 40%	Secondary 60%	Tertiary 100%
Education (School enrolment ratios)	5-9 98%	10-14 80%	15-19 37%	20-24 3%

Between 1965 and 1985 migration was almost constant in Mauritius: a net of around 3500 people left the country annually. Since then, net emigration declined to only 500 people in 1990. Economic activity among men was always high, equal to European countries. Among women it increased steadily during the last three decades up to a level comparable to European countries with low female labor force participation rates, like Italy or the Netherlands. Likewise, school enrolment increased steeply during the last decades, especially among females. Today, almost as many females as males are enrolled in school, e.g. 80% at age 10-14 and 37% at age 15-19.

Now we sit at the computer with the main menu of the population-economy-environment system in front of us. Three options within this main menu of the program are relevant for the user: 'scenario retrieval,' 'scenario setting' and 'results presentation'. Within the 'scenario retrieval' option the user can choose among several predefined scenarios. Choosing the option 'population data' within the 'scenario setting' routine, the user has the possibility to manipulate the demographic parameters directly. Each parameter, namely fertility, mortality, net migration, school exit, labor force entrance and labor force exit, can be addressed in a separate sub-menu. Within each of those menus one can manipulate the given age and sex-specific input data by either

i) changing the respective starting vector, or
ii) specifying a 5-year percentage increase or decrease within a certain period, or
iii) setting new parameters for each subsequent year.

Manipulating those parameters is graphically supported by relevant information on the respective parameters on the right side of the screen. Two figures are presented to inform the user about possible consequences resulting from the changes implemented.

In the case of fertility, mortality and migration, the upper figure gives the age-pattern of the respective variable (fertility rates, mortality rates, and net migration) both for the starting year and the current year. The lower figure shows a time series (usually 1990-2050) of the relevant summary indicator, the Total Fertility Rate (TFR), life expectancy at birth (by sex), and total net migration (by sex). Figure 2 gives an example of that situation.

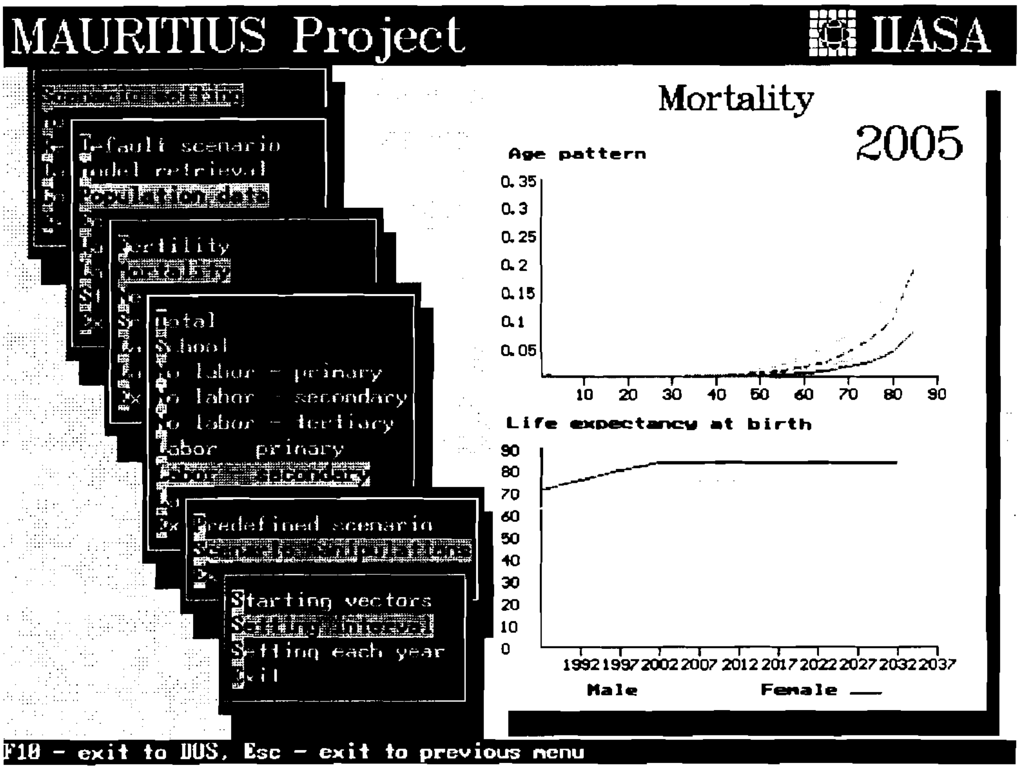

Figure 2. Scenario setting in the case of mortality.

In the case of school exit and labor force entrance and exit, the lower figure again presents a time series of an artificial summary indicator, namely the sum of the age-specific transition rates, which does not give useful information per se but shows the changes over time one has implemented. The upper figure again gives information for the starting year and the current year. It shows the age-specific school enrolment ratios or the age-specific labor force participation rates for scenarios on school exit or labor force participation, respectively. These ratios (rates) are calculated backwards from the specified transition rates. Figures 3a and 3b show the respective screens from the computer model.

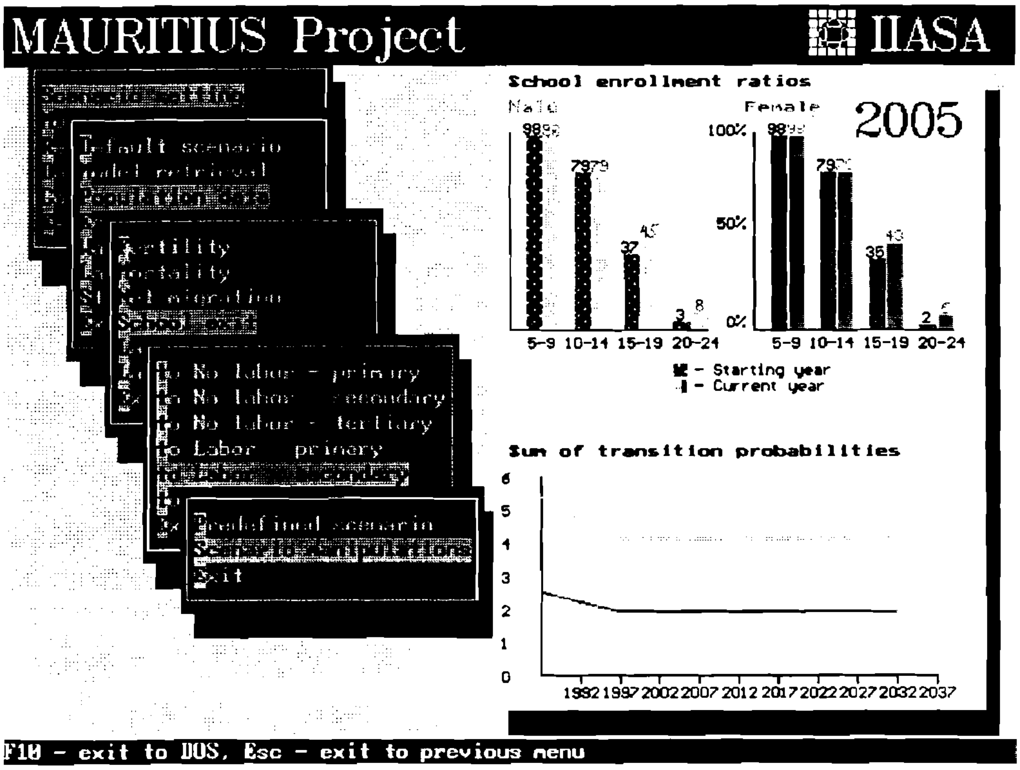

Figure 3a. Scenario setting in the case of school exit.

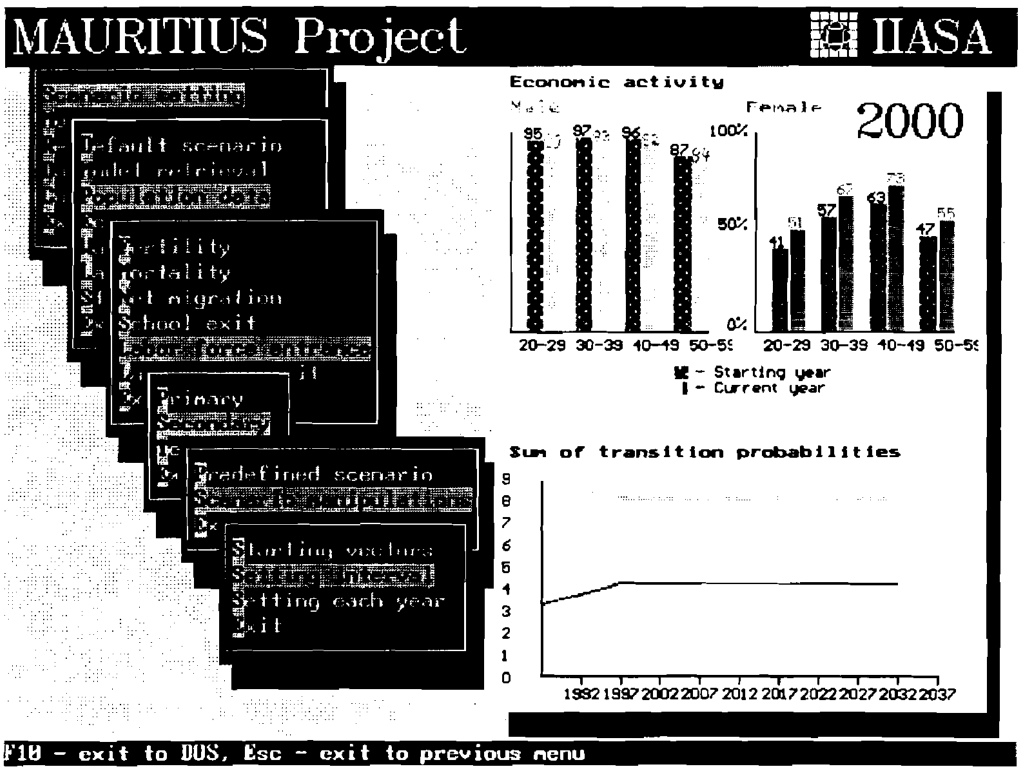

Figure 3b. Scenario setting in the case of labor force entrance.

Now we run the model. Any scenario the user has specified can be saved afterwards. Then we choose the 'results presentation' option. Results are presented in three different forms: age pyramids, tables (which can be saved to a file to be used for further calculations, etc.), and maps. The following sub-menus are available: 'labor force pyramid', 'education pyramid', 'multistate pyramid', 'one-state pyramid', 'time table', 'year table', 'summary table', and 'population map'. Both the pyramids and the maps give information for the starting year and--by pushing any key on the keyboard--for each subsequent year. These "moving pictures" give an excellent impression of changes in the Mauritian population.

The 'labor force pyramid' presents the age pyramids of the population 'in school' and those in the labor force and not in the labor force (in both cases aggregated over educational levels). Similarly, the 'education pyramid' presents the age pyramids of the three educational groups (aggregated over labor force status) plus again of the population 'in school'. Figures 4a and 4b give examples of both types of pyramids. The 'multistate pyramid' comprises age pyramids of all seven states, while the 'one-state pyramids' present each state separately. The 'population map' option shows the spatial distribution of the total population across the island of Mauritius, which is shown in Figure 5. It not only shows the distribution in 1990, but also the future distribution on the basis of either proportional or in the 1980s observed settlement patterns.

There are also numerical results in the form of tables, e.g. for those who are interested in further calculations. The 'summary table' gives time series (usually 1990-2050) of the main aggregates: the primary educated labor force, the secondary educated labor force, the tertiary educated labor force, the school population, the retired population (aged 60 years and over), the population not in the labor force (below age 60), and the total population. The 'time series table' gives, for each state and both sexes separately, the age distribution (in 5-year age groups) of the population in the starting year and in each subsequent year. The 'status table' gives, for each selected year and both sexes separately, the age distribution of the population in each of the seven states including the total population age structure.

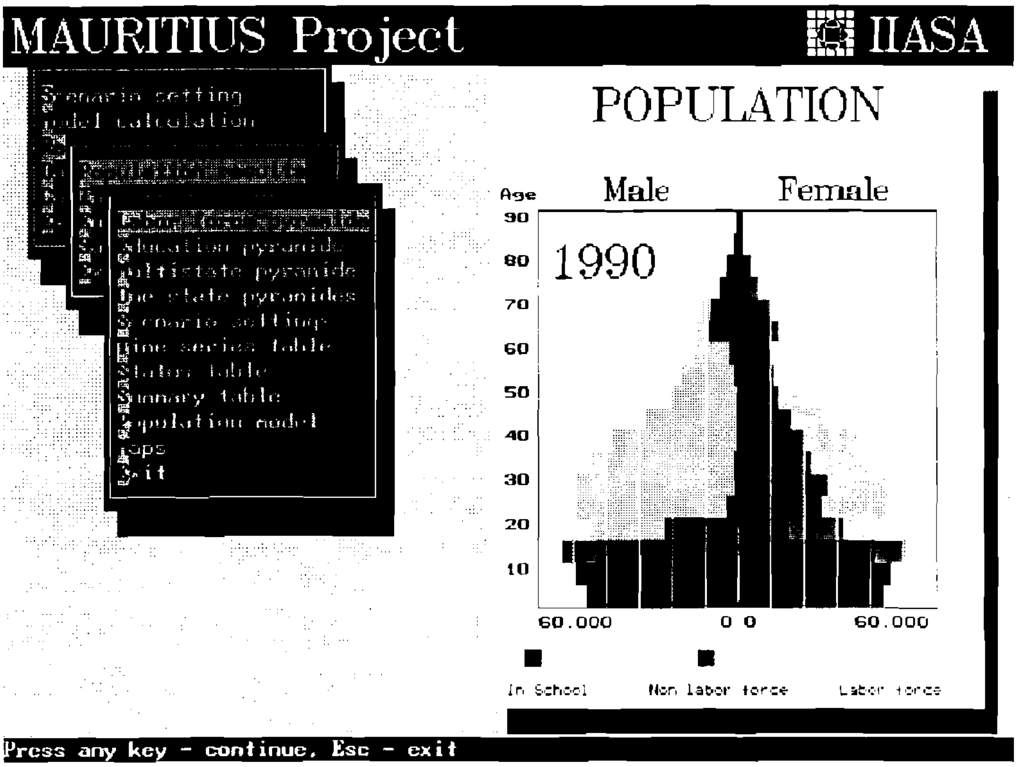

Figure 4a. Results presentation in form of pyramids: Labor force.

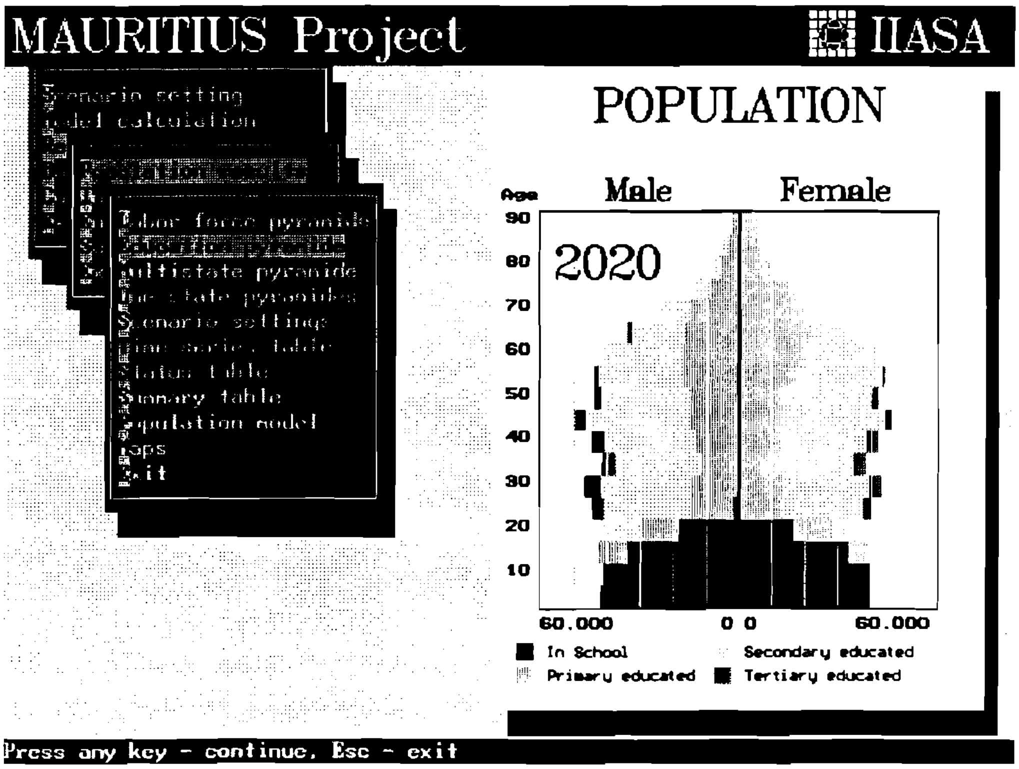

Figure 4b. Results presentation in form of pyramids: Education.

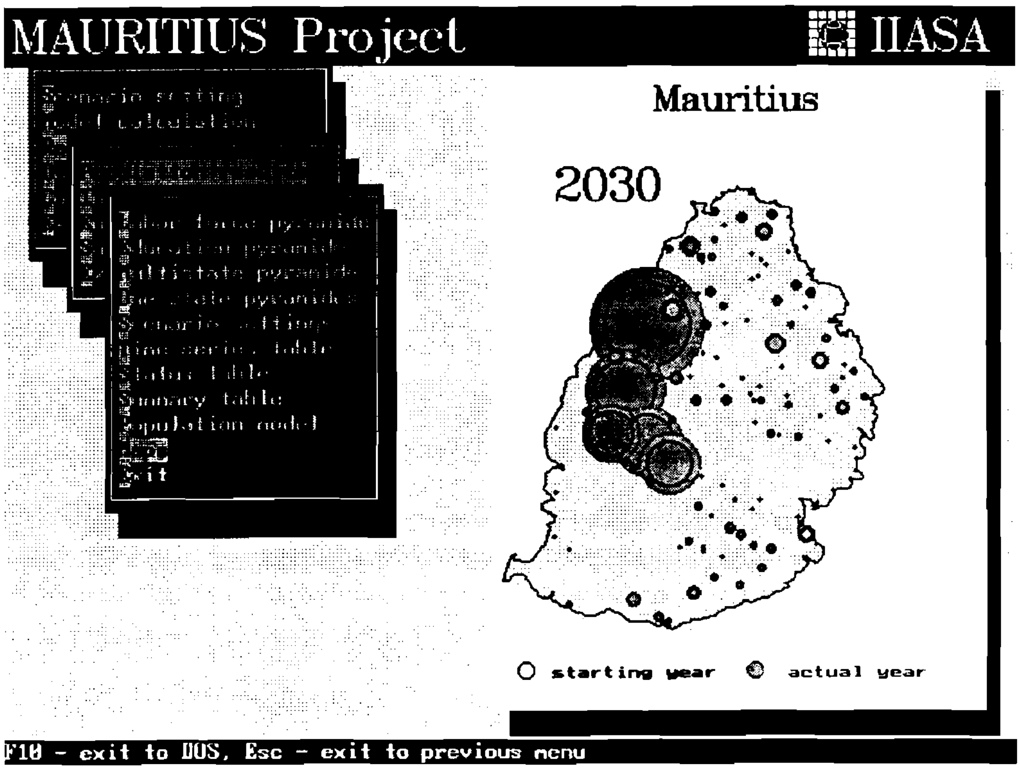

Figure 5. Results presentation in form of maps: Population distribution.

3. POPULATION STRUCTURE OF MAURITIUS

3.1. Demographic Changes Since 1962

The main source of information used for the model was the Mauritian 1990 Population Census, held during the night of 1-2 July. In this census, 37 questions were asked, including questions about age, sex, marital status, citizenship, address, address 5 years ago, age at marriage, number of children ever born, religion, school attendance, educational qualification, occupation, activity status, employment status and place of work. From the census results we could reliably derive (partly estimate) the population distribution across the seven states considered in our model. Part of that information is given in Table 2, together with the same information for the year 1962. The 1962 population distribution was estimated from several local sources, such as the Digest of Educational Statistics (several issues), publications from previous population censuses and additional material from the Ministry of Economic Planning and Development.

3.1.1. General population trends

Between 1962 and 1990, the Mauritian population increased from less than 700,000 people to more than 1 million. During that period, the proportion of children declined from 54.5% to 38.5%. This decline corresponded to an increase in the proportion of people in working age (from 40% in 1962 to 53% in 1990) as well as an increase in the proportion of people aged 60 years and over (from 5.4% to 8.4%).

Table 2. Labor force distribution by sex, age and education, 1962 and 1990.

Year/ age-group	Labor force by education (in %)						Labor force in % of adult population	
	Primary educated		Secondary educated		Tertiary educated			
	fem	mal	fem	mal	fem	mal	fem	mal
1962:								
15-24	71	66	29	34	0	0	8	64
25-44	85	76	15	22	0	2	21	97
45-64	93	91	7	7	0	2	23	86
65+	100	81	0	17	0	2	6	24
total	85	77	15	22	0	1	15	80
1990:								
15-24	51	44	49	56	0	0	37	77
25-44	56	49	42	48	2	3	44	97
45-64	78	74	21	23	1	3	27	77
65+	90	87	9	10	1	3	4	16
total	58	52	40	45	2	3	35	82

In 1962, the proportions of women aged 15-24 and 25-44 in the labor force were only 8% and 21%, respectively. By 1990, 37% and 44% of those groups of the female population were part of the labor force. Together with the aging of the population and the higher educational attainment of women, this increase was responsible for a very significant increase in the overall percentage of women in the labor force: from 15% in 1962 to 35% in 1990 (see Table 2). Due to the high number of young adults the respective figure for men increased also slightly from 80% in 1962 to 82% in 1990, while the proportion of working men aged 45 years and over clearly declined.

The educational qualifications of the labor force also changed drastically. In 1962, the proportion of women with only primary education was 85% in the age group 25-44 and 93% in the age group 45-64 (see Table 2). By 1990, the proportions declined to 56% and 78%, respectively. Similarly, the proportion of men with at least secondary education increased from 24% and 9% for age groups 25-44 and 45-64, respectively, in 1962 to 51% and 26% by 1990. Those changes are explained by strong shifts in school enrolment ratios during that period. Enrolment among females aged 10-14 years increased from around 50 to 80%, and among females aged 15-19 years from around 10 to 35%. Among males, the increase in school enrolment started some years earlier and thus was less marked during the observed period. Interestingly, by 1990 school enrolment ratios no longer differ by sex.

3.1.2. Dependency ratios based on economic activity, productivity and age of dependents

Especially with regard to economic development, it is essential to look at dependency ratios, which calculate the number of dependents per active. High dependency ratios impede economic development, while low dependency ratios favor development. Since the model provides the population distribution over labor force status and education status, it is possible to calculate a much more appropriate dependency ratio than the commonly used 'Total Dependency Ratio' (TDR) which only considers the age structure of the population. A *real* 'Total Dependency Ratio considering Economic Activity' (TDR_EA) can be calculated, which uses the labor force and the population not in the labor force (school population, housewives, disabled people, retired people, etc.).

To make the TDR_EA more realistic, information on education status of the labor force can be incorporated. Productivity increases with educational attainment, so different weights for the three education statuses seem plausible. As information on productivity by education is not available, information on average salary by education status is used instead. Average salary in Mauritius currently is--expressed as a ratio--about 1:2:4 for primary, secondary and tertiary educated people. Assuming a strong but not perfect correlation between productivity and salary, the following weights were considered reasonable for the calculation of a 'Total Dependency Ratio considering Economic Activity and Productivity' (TDR_EA+P): '1' for the primary, '1.5' for the secondary, and '2' for the tertiary educated labor force.

Dependents do not impose an equal burden on the economy. Above all, the burden is correlated with age. Per capita health expenditure in Mauritius is relatively low below age 60, but increases steeply thereafter. Per capita education expenditure is very high (especially for students) and concerns only the population below age 25. As a result, the adult population not in the labor force (mainly housewives) is less of a financial burden. The following weights were used for the calculation of a 'Total Dependency Ratio considering Economic Activity and Age of Dependents' (TDR_EA+AD): '2' for the school population, '1' for the adult non-labor force population, and again '2' for the retired population.

In the following a dependency ratio including everything above is used. It is calculated by using economic activity and different weights for different groups of actives and dependents, and it is called 'Total Dependency Ratio considering Economic Activity, Productivity and Age of Dependents' (TDR_EA+P+AD).

Table 3 gives the respective dependency ratios for 1962 and 1990 together with the change during that period. It also gives the distribution of the dependency ratio considering economic activity, productivity and age of dependents over the three types of dependents (school population, non-working adults, and retirees), and the respective ratios calculated for the male and female population separately.

Table 3. Alternative dependency ratios (dependents per 100 actives), 1962 and 1990.

Dependency ratio	1962	1990	Change
TDR:	103	60	-42 %
TDR_EA:	259	146	-44 %
TDR_EA+P:	232	118	-49 %
TDR_EA+AD:	360	217	-40 %
TDR_EA+P+AD:	321	175	-45 %
of which men:	158	100	-37 %
women:	1162	350	-70 %
due to school:	207	103	-50 %
adults:	87	42	-52 %
retirees:	27	29	+7 %

In 1962, the Total Dependency Ratio (TDR) was 103; 100 people aged 15-59 years supported 103 children and elderly people. However, considering economic activity (TDR_EA) it turns out that in reality 100 actives had to care for 259 dependents. Adding information on productivity and age of dependents (TDR_EA+P+AD) even results in a figure of 321 dependent equivalents per 100 active equivalents in the year 1962. The reduction in dependency caused by the consideration of productivity by education (TDR_EA+P) is clearly more than made up for by the increase in dependency caused by the inclusion of age of dependents (TDR_EA+AD). While the absolute level of dependency differs strongly by the extent of refinement of the simple total dependency ratio, the rate of change turns out to be surprisingly robust. Within 30 years, the dependency ratios were nearly cut in half. The TDR declined by 42%--mainly due to the remarkable decline in fertility--down to a level of 60 in 1990, the most refined TDR_EA+P+AD declined by 45% down to a level of 175 dependent equivalents per 100 active equivalents. The robustness of changes in different dependency ratios during the last three decades is a result of the decline in fertility which dominated changes in economic activity and productivity. In the future the opposite may be true, making changes in those dependency ratios as much dependent on the level of refinement as the levels of the different ratios.

The bottom of the table uses only the TDR_EA+P+AD, which in the following will be called 'Socio-Economic Dependency Ratio' (SEDR). According to the SEDR in 1990 there was one dependent man per active man, but still 3.5 dependent women per active woman although the ratio for women declined by 70% during the period 1962-1990. Comparing the three groups of dependents it turns out that the share of dependents of school age and working age clearly declined, to 59% and 24%, respectively, while the share of retirees among all dependents doubled within 30 years (17% in 1990).

The development of the dependency ratios is correlated with the economic boom in Mauritius. At least, the sharp decline coincided with the economic development during the past decades. It will be interesting to see alternative developments of both the simple TDR and the refined SEDR and the economy in the future under alternative population and economy scenarios to learn more about the correlation of economic development and population dependency.

3.2. Future Demographic Trends

Based on 1990 input data, the model is capable of calculating future scenarios of the population of Mauritius. The following section focuses on population issues. Impacts on the economy and the environment will be discussed in forthcoming publications.

3.2.1. Three socio-demographic scenarios

We will now describe the settings of the three population scenarios. Unlike most other population projection models, this model requires assumptions not only on fertility, mortality and migration, but also on rates of progression in educational status and rates of changing labor force participation. Each of the five variables considered can be specified status-specific. We will discuss the three scenarios in each of the five variables sequentially.

a. Fertility

In 1990, the overall Total Fertility Rate (TFR) was 2.3 children per woman, 2.54 among primary educated, 1.93 among secondary educated, and 1.61 among tertiary educated women. Three assumptions were made:

i) 'High fertility': back to a TFR of 3.0 by 2000, continuing fertility differentials by educational group. This corresponds to an increase in fertility rates by 30% and reflects an unexpected setback in demographic transition.

ii) 'Replacement fertility': reach a TFR of 2.1 by 2000, continuing fertility differentials by educational group. This corresponds to a decline in fertility rates by 10% and it is the assumption usually made for long term projections.
iii) 'European fertility': down to a TFR of 1.5 by 2010, converging fertility differentials by educational group. This corresponds to a decline in fertility rates by 35%, 30% and 20% for primary, secondary and tertiary educated women, respectively. It reflects a further decline in fertility as was observed in Europe during the last decades.

b. Mortality

The most recent Mauritian life table calculated for the period 1988-90 gave a life expectancy at birth of 73 years for women and 65 years for men. Information by educational group was not available and will therefore not be considered in our scenarios. Again, three assumptions were made:

i) 'Constant mortality': keep currently observed life expectancies at birth (73 and 65 years for women and men, respectively) constant. It assumes that due to stagnating development no improvement in mortality can be realized.
ii) 'European mortality': reach life expectancies of 80 and 72 years, for women and men, respectively by the year 2010. This corresponds to a decline in mortality rates by 41% for both sexes up to the current European level.
iii) 'Low mortality': reach life expectancies of 85 and 80 years, for women and men, respectively by 2030. This corresponds to a decline in mortality rates by 58% for women and 66% for men to a level higher than anywhere in the Western world in 1990, reflecting a long term improvement in quality of life in Mauritius.

c. Migration

In 1990, net migration to and from Mauritius was close to zero: 500 people left the country, roughly as many men as women. Information on the educational distribution was not available. It was assumed that one-third of the migrants have primary education, one-third secondary education and one-third tertiary education, reflecting the higher propensity to migrate among higher educated people. Three assumptions concerning the level of net migration were made:

i) 'Net emigration': back to a level of 3,000 emigrants per year by 1995, a level which was observed during the period 1965-1985. It reflects a situation where stagnating development favors emigration.
ii) 'Zero net migration': assuming net migration to be zero, i.e. an almost constant development as regards migration.
iii) 'Net immigration': up to 5,000 immigrants per year by 1995, reflecting a situation where rapid development demands immigration of labor.

d. Economic activity

Assumptions concerning economic activity refer to women only, since the activity of men is assumed not to change. In 1990, labor force participation of women at ages 35 to 39 (the age at which women return to work after childbearing, if they do, and at which maximum activity rates were observed) was 46% overall, 40% among primary educated, 60% among secondary educated, and around 95% among tertiary educated women. Only labor force entrance rates were manipulated, while labor force exit rates were kept constant. Again, three assumptions were made:

i) 'Low activity': back to an overall level of 35% for women at age 35-39 by 2000; 26, 50 and 95% among primary, secondary and tertiary educated women, respectively. This assumption is equivalent to a decline in activity to the level observed in 1983. It corresponds to a decline in labor force entrance rates by 35% for primary educated and 25% for secondary educated women.
ii) 'Increased activity': up to an overall level of 55% for women at age 35-39 by 2000; 50%, 70% and 95% among primary, secondary and tertiary educated women, respectively, a level which was observed in Germany during the 1980s. It corresponds to an increase in labor force entrance rates by 35% for primary educated and 25% for secondary educated women.
iii) 'European activity': up to an overall level of 75% for women at age 35-39 by 2010; 65, 85 and 95% among primary, secondary and tertiary educated women, respectively, reflecting a steady increase in economic activity to a level of European high activity countries. It corresponds to an increase in labor force entrance rates by 90% for primary educated and 80% for secondary educated women.

e. Education

By 1990, differences in school enrolment ratios by sex had virtually disappeared. At age 10-14 school enrolment was around 80%, at age 15-19 still 36%, and at age 20-24 only 3%. Changing school exit rates in one age group affects all subsequent age groups. For example, increasing the proportion in school at secondary level by lowering school exit rates at primary level and--at the same time--keeping school exit rates at secondary level constant automatically increases the proportion in school at tertiary level. As a consequence, changes in subsequent age groups may in fact need to be of the opposite direction. Three assumptions were made:

i) 'Constant enrolment': keep 80%, 36%, and 3% enrolment at the respective age groups as observed in 1990, reflecting a situation where no further improvement in schooling can be realized.
ii) 'Increased enrolment': up to a level of 80%, 45% and 7% for both sexes for age groups 10-14, 15-19 and 20-24, respectively by 2000. It corresponds to a decline in school exit rates at secondary level by 25% and a simultaneous increase at tertiary level by 140% (following from the explanation above).
iii) 'High enrolment': up to a level of 90%, 60% and 12% for both sexes for age groups 10-14, 15-19 and 20-24, respectively by 2010. It corresponds to a decline in school exit rates at primary level by 50%, a simultaneous decline at

secondary level by 35% and a simultaneous increase at tertiary level by 180% (again, following from the explanation above).

Having five variables and three assumptions each, one can specify 243 combinations, i.e. 243 different scenarios. Since by far not all 243 combinations are "useful" and since it is impossible to handle more than a few scenarios, only 3 combinations are considered in the following. For more extensive assumptions and results concerning fertility, mortality and migration the reader is referred to Prinz (1991). In this paper emphasis will be put on the interplay between fertility, mortality and migration on the one hand and economic activity and education on the other hand.

f. Combinations

The three scenarios were selected to reflect no, continued and rapid socio-demographic development. The following combinations of variables were selected:

Scenario 1. *'No socio-demographic development'*: combining 'high fertility' with 'constant mortality', 'net emigration', 'low activity' and 'constant enrolment'. It assumes constant mortality and school enrolment, together with an increase in fertility and emigration and a decline in activity rates.

Scenario 2. *'Continued socio-demographic development'*: combining 'replacement fertility' with 'European mortality', 'zero net migration', 'increased activity' and 'increased enrolment'. It assumes moderate increases in life expectancy and socio-economic variables (enrolment and activity), together with a moderate decline in fertility and emigration.

Scenario 3. *'Rapid socio-demographic development'*: combining 'European fertility' with 'low mortality', 'net immigration', 'European activity' and 'high enrolment'. This scenario assumes a European situation by the year 2010 with further improvement in mortality until 2030.

For both the 'no development' and the 'rapid development' scenarios additional calculations with zero net migration were done to investigate the impact of migration, which in contrast to the other socio-demographic variables highly depends on political measures, or rather the impact of all other assumptions given a zero net migration (scenarios 1a and 3a).

3.2.2. Selected results

Some major population developments are presented in Table 4. Despite the low level of fertility assumed in some of the scenarios, the Mauritian population will still increase until 2030 even in the case of low fertility and zero net migration (scenario 3a). This is entirely due to the young age structure and is a good example for the momentum of population growth. Figure 6 shows an increase in total population size by around 25% by 2030 for the 'rapid development' scenario without immigration (scenario 3a), while an additional influx of 5000 people annually would result in an increase of almost 50% by 2040 (scenario 3). But even with immigration negative population growth is observed in the long run. Without socio-demographic development (scenario 1) projected population growth is very similar to the growth observed under scenario 3 up until 2030, while growth continues almost linearly in the long run, to almost 1.7 million people by 2050. Eliminating emigration (scenario 1a), the Mauritian population would double by the year 2060 with the 'no development' assumptions.

Table 4. Projected population developments by scenario, 1990-2050.

	Population size (1000)	Labor force (1000)	Proportion aged 0-19 (in %)	Proportion aged 60+ (in %)	Socio-econ. dependency ratio
1990	1022	419	38	8	175
No socio-demographic development (scenario 1):					
2020	1377	551	35	13	163
2050	1676	654	36	14	168
No socio-demographic development, zero migration (scenario 1a):					
2020	1463	600	35	13	158
2050	1895	758	36	14	164
Continued socio-demographic development (scenario 2):					
2020	1304	600	26	17	129
2050	1271	547	23	26	149
Rapid socio-demographic development (scenario 3):					
2020	1395	684	24	17	113
2050	1471	677	18	33	133
Rapid socio-demographic development, zero migration (scenario 3a):					
2020	1251	613	24	18	118
2050	1147	505	17	35	142

The total labor force will increase between 30% (no development) and 60% (rapid development) by the year 2020 (see Table 4). Comparing scenarios 3 and 3a shows that in the long run 5000 immigrants annually would keep the total labor force stable, while without immigration the labor force would shrink very rapidly. Although there is a difference in total population size of around 200,000 people, 'no development' and 'rapid development' scenarios give almost the same size of the labor force by the year 2050 because of the high labor force participation rates of women under 'rapid development'.

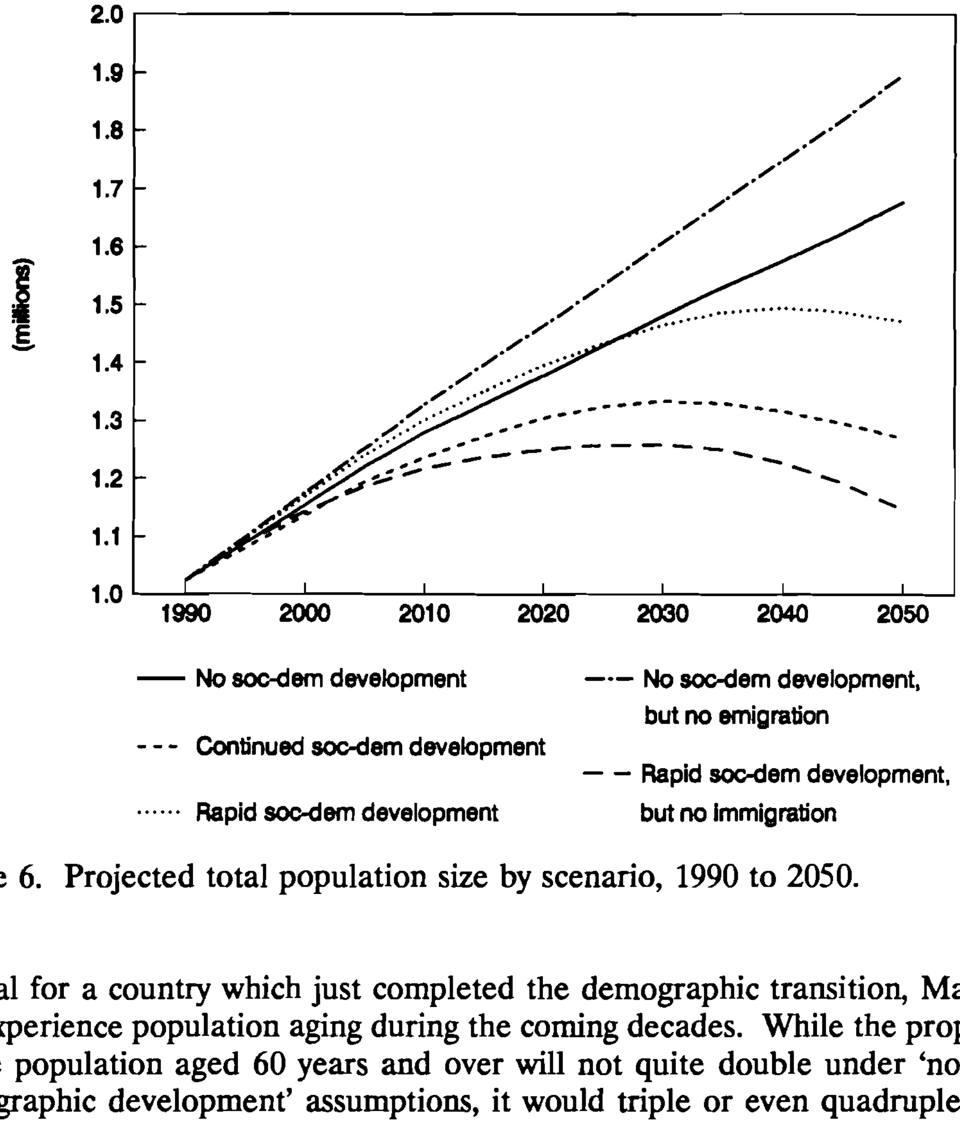

Figure 6. Projected total population size by scenario, 1990 to 2050.

Typical for a country which just completed the demographic transition, Mauritius will experience population aging during the coming decades. While the proportion of the population aged 60 years and over will not quite double under 'no socio-demographic development' assumptions, it would triple or even quadruple under 'continued' and 'rapid development' assumptions, respectively (see Table 4). Aging is the result of low mortality as well as low fertility. Strong population aging seems indicated, since a long term return to a fertility level as high as assumed under scenario 1 (TFR = 3.0) has so far never been experienced by any country that has completed the demographic transition. Depending on fertility assumptions, the proportion of children will decline significantly; even under 'no development' assumptions the proportion will always be below the 38% observed in 1990.

The development of the socio-economic dependency ratio is surprisingly robust with diverging scenario assumptions. As shown in Figure 7, it will never again reach a level as high as the 175 dependents per 100 actives observed in 1990. The SEDR will strongly decline during the next three decades under 'continued' and 'rapid development' assumptions, by 29% and 35% respectively, and it would still decline by 17% by the turn of the century under 'no development' assumptions. After a clearly diverging development between 2010 and 2040, the socio-economic dependency ratio converges to a level around 140-160 by the year 2050. Assumptions on migration affect the dependency ratio to a lesser extent than they affect the size of the total population and the labor force.

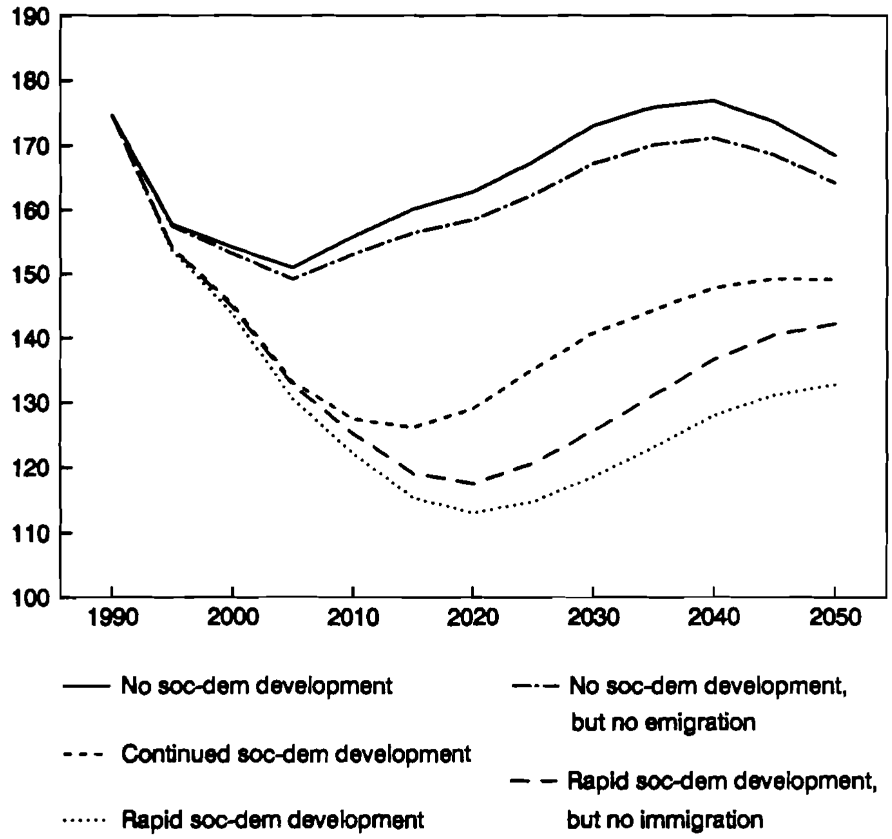

Figure 7. Projected socio-economic dependency ratio, 1990 to 2050.

If lower SEDRs have indeed a positive influence on the economy, then further economic development is strongly favored during the coming decades simply by changes in the socio-demographic composition of the population. This conclusion can only be derived from changes in the socio-economic dependency ratio, while the simple total dependency ratio does not indicate any room for development from the demographic side. The TDR, which is only influenced by the aging process, indicates an increase between 12% and 30% in the long run, depending on the scenario. A more precise explanation for the very different trends of the two dependency ratios can be found in Table 5, which gives additional sex-specific population developments concerning the size and the educational distribution of the labor force.

Among men, the share of the adult population in the labor force will decline depending on the speed of aging, for example from 82% in 1990 to only 62% by 2050 under 'rapid development', i.e. strong aging assumptions. Under the same scenario 3, the share of women in the labor force will increase significantly due to increasing labor force participation rates: from 35% in 1990 to 45% by 2020. Due to the increase in the proportion of elderly it will again decline somewhat thereafter. The share of the female labor force among the total labor force will increase from 30% in 1990 to between 32% and 42% by 2050 depending on socio-economic development.

Table 5. Labor force characteristics 1990-2050, by sex and scenario.

Year	Adults in the LF (in %)		Total labor force (1000)		Of which: primary educated		(in %) secondary educated		tertiary educated	
	fem	mal	fem	mal	fem	mal	fem	mal	fem	mal
1990	35	82	126	290	58	53	40	45	2	3
No socio-demographic development (scenario 1):										
2020	34	77	180	377	20	32	75	66	5	3
2050	34	77	212	448	14	29	81	69	6	2
Continued socio-demographic development (scenario 2):										
2020	41	75	221	383	24	33	65	60	11	7
2050	38	68	213	338	21	30	61	59	18	11
Rapid socio-demographic development (scenario 3):										
2020	45	75	264	422	20	30	62	58	18	12
2050	43	62	283	388	13	19	54	57	32	23

The educational distribution of the labor force (and of the population as a whole) is about to change remarkably. While in 1990 still a majority of the labor force had primary education only, this proportion will decline rapidly to about one-fourth or even one-fifth among the female and about one-third among the male population by 2020 (see Table 5). The higher proportion among women results from higher labor force participation rates among secondary and tertiary educated women as compared to primary educated women. In the total population the percentage with only primary education is slightly higher among women than among men, and it is for both sexes around one-third of the population by 2050 (only one-fourth in the case of rapid socio-economic development). Interestingly, especially among women there is little difference between 'no' and 'rapid development' as regards the proportion primary educated among the labor force, which is due to the combined effect of increasing labor force participation rates and increased educational attainment.

Most striking is the projected increase in the number and proportion of tertiary educated people. Taking both sexes together, the proportion tertiary educated will increase up to around 13% of the labor force by 2050 if 'continued development' is assumed and even up to 27% under 'rapid development' assumptions (see Table 5). Among the total population the respective figures are 8% and 17%. This huge increase, which is to a smaller extent due to the assumptions concerning immigration, would give tremendous room for changes in the structure of the Mauritian economy. On the other hand, it is questionable that in any economy such a development can be regarded as likely. Under 'no development' assumptions, the increase in the proportion tertiary educated would only be marginal.

3.3. Alternative Histories Between 1962 and 1990

Another way of using the model is to look at the past and run scenarios from 1962 on. This enables the user to compare the actually observed trends and developments over the past 30 years to hypothetical alternative trends. Mauritius experienced an extremely rapid fertility decline in the late 1960s and early 1970s and is now beyond the demographic transition. Because most other less developed countries are still in earlier phases of this process, it may be very instructive to simulate what impact continued high fertility would have had on Mauritius. Using this model it may be possible to disentangle the effects of fertility decline and of economic restructuring on the actual (economic) development of Mauritius. In this chapter only socio-demographic effects of different socio-demographic histories are discussed.

3.3.1. Arising problems

Data on the sex and age structure of migrants to and from Mauritius are missing. Since the total numbers showed that net emigration had been more than trivial in the past decades, reconstructing the population development between 1962 and today using observed fertility and mortality rates is difficult. While this is true for the sex and age structure of the population, it is even more so for the structure by educational and labor force status. Information on the educational and labor force distribution is lacking for both the 1962 population and the emigrants. Not only is information on the structure missing, but also information on dynamics. After reconstructing the 1962 population distribution we estimated the actual development during the last three decades. The main indicators could be estimated reasonably well. Then we tested alternative histories and compared the respective results with the estimated actual development.

3.3.2. What could have happened since 1962

It is not only of interest to investigate what could have happened during the period 1962 to 1990, but also what would have happened after 1990, if the socio-demographic development during the past three decades would have been different from what it actually was. That is why in the following analysis all variables and indicators will be discussed for the period 1962-2022.

Three basic scenarios plus one combined scenario were specified. To simplify the reconstruction of the population, net migration was considered to be zero.

Historical scenario 1: 'Observed development', using observed fertility and mortality rates and reconstructed transition rates between statuses for the period 1962-1987, thus trying to reconstruct the actual development during the past three decades, and keeping all rates constant after 1987.
Historical scenario 2: 'No development', keeping observed 1962 fertility and mortality rates and estimated 1962 transition rates constant throughout the whole period 1962-2022, thus evaluating what could have happened if nothing would have changed since 1962.
Historical scenario 3: 'Delayed development', keeping all rates constant at their 1962 level up until 1992, and shifting the socio-demographic development observed between 1962 and 1987 to the period 1992-2017, thus delaying the actual development by 30 years.
Historical scenario 4: 'Combined development', combining observed demographic with no socio-economic development, thus evaluating the impact of changes in socio-economic variables, namely education and labor force transitions.

The major results are shown in Table 6. From less than 700,000 inhabitants in 1962, the population of Mauritius would have more than doubled until 1992 if the demographic transition could not have been completed. By 2022, total population size could have reached 3.4 million. Delaying the demographic transition by 30 years would have brought the population size to almost 2.6 million by 2022, compared to only 1.45 million under the observed development scenario; i.e. in Mauritius, delaying the fertility decline by 30 years would have led to about twice as many inhabitants in the long run.

By 1992, the total labor force would have been around 450,000 under both the 'no' and the 'observed development' assumptions (see Table 6). This has two reasons: first, the labor force of the year 1992 is only to a smaller extent affected by fertility changes during the period 1962-1992. Second, until 1992 the increase in labor force participation rates of women since 1962 could actually offset the decline in fertility during the 1960s and 1970s. The difference between the two scenarios is that in 1992 in the 'observed development' scenario 60% of the adult working age population is part of the labor force, while under the 'no development' scenario the respective figure is only 50%. By the year 2022, 'observed development' results in a total labor force equal to 61% of the size of the labor force under 'no development', while the total population size is only 42% of the respective size under the 'no development' scenario. Delaying the increase in labor force participation rates by 30 years would have reduced the labor force by 7% by 1992 and by 15% by 2022, under otherwise identical fertility and mortality assumptions (compare scenarios 1 and 4). The remarkable impact of increased economic activity of women is also demonstrated by the fact that 'delayed development' gives the same size of the labor force by 2022 when compared to 'no development', with only 75% of the total population size.

Table 6. Hypothetical population developments, 1962-2022.

	Population size (1000)	Labor force (1000)	Adults in the LF (in %)	Of which primary educated	Socio-econ. dependency ratio
1962	687	191	51%	78%	337
Observed development:					
1977	937	299	53%	58%	250
1992	1157	452	61%	43%	173
2007	1338	583	66%	35%	140
2022	1450	620	69%	31%	149
No development:					
1977	1013	297	51%	60%	286
1992	1539	445	51%	51%	282
2007	2296	693	52%	47%	260
2022	3430	1015	52%	47%	269
Delayed development:					
1977	1013	297	51%	60%	286
1992	1539	445	51%	51%	282
2007	2124	696	54%	46%	228
2022	2595	1027	62%	40%	168
Combined development:					
1977	937	298	51%	60%	249
1992	1157	421	54%	51%	192
2007	1338	513	55%	47%	174
2022	1450	530	56%	46%	196

Since a strong increase in school enrolment ratios took place already before 1962, changes in the educational distribution are less influenced by our scenario assumptions. Even with no further development in that respect, the proportion of primary educated would decline from around three-quarters of the labor force in 1962 to only half of the labor force in the long run. With observed or delayed socio-economic development, the decline would be or would have been even stronger, down to 30% and 40% of the labor force, respectively, by 2022 (see Table 6).

Again, emphasis should be given to the development of the Socio-Economic Dependency Ratio. As discussed in Section 3.1, this ratio declined from 321 in 1962 to 175 in 1990 (see Section 3.1, Table 3), and it will decline further during the next decades. With no socio-economic development since 1962, the Socio-Economic Dependency Ratio would have declined only slightly to 280 by 1977 to fluctuate around that level thereafter (see Figure 8). Assuming a certain correlation between the development of the economy and the Socio-Economic Dependency Ratio, significant economic development would probably not have taken place.

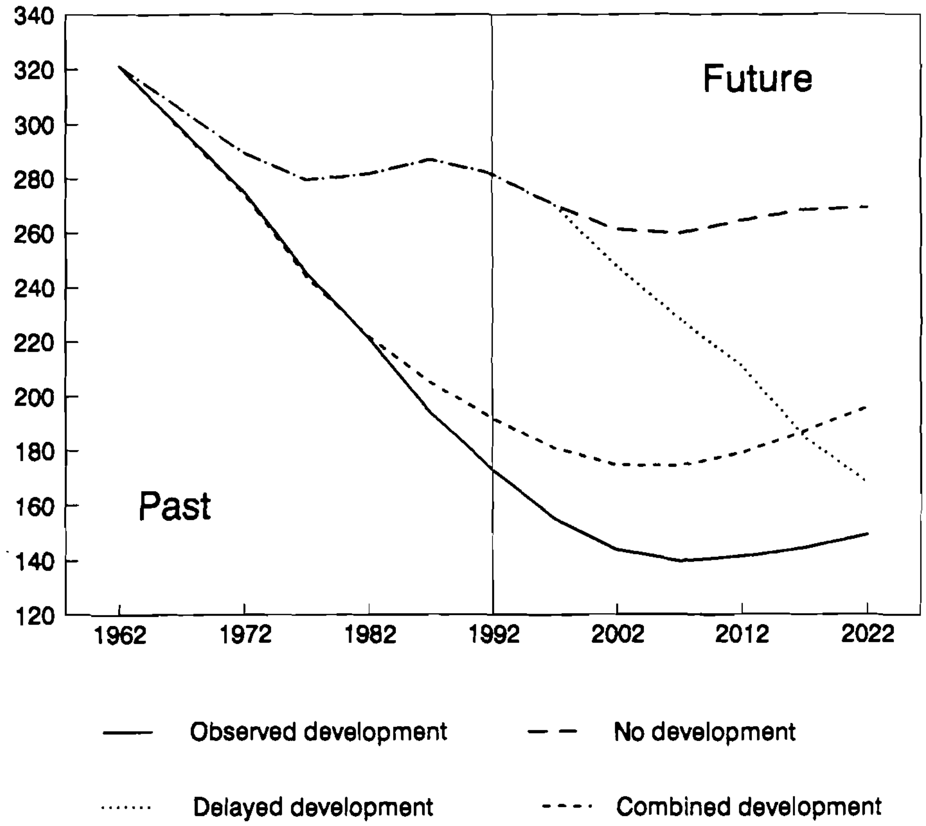

Figure 8. Projected socio-economic dependency ratio, 1962 to 2022.

Delaying the demographic transition and the observed socio-economic development by 30 years (scenario 3) would have delayed the decline of the Socio-Economic Dependency Ratio and thus possibly the economic boom by some 30 years.

Looking at the results for scenario 4, which combines observed demographic transition and no socio-economic development, one can conclude that during the period 1962-1982 the Socio-Economic Dependency Ratio was dominated by changes in the age structure of the population, while after 1982 socio-economic changes started to prevail. Comparing scenario 4 and scenario 1, the socio-economic dependency ratio would have been 11% higher by 1992 and even 32% higher by 2022 without changes in labor force participation rates and school enrolment ratios.

4. CONCLUSION

Whether alternative past and future developments of the Socio-Economic Dependency Ratio hinder or favor economic development can be tested by the full population-development-environment model. A general conclusion will be difficult since the relation depends on the economic strategy adopted. The full model will also be able to trigger the effects of alternative population developments on the environment, again mainly via economic development. To identify the role of population changes, like extreme aging or excessive growth, for both economic development and environmental degradation is the most important aim of the model; answers to those two questions will be given in forthcoming publications.

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APPENDIX

Data Estimation Procedure

a. School exit transition rates

Input data for estimating school exit transition rates were sex and age-specific school enrolment ratios, which give the proportion of the population in school in each age group. Four steps were required to estimate transition rates.

Given: Enrolment ratios x[i], i=1,...,6; i=1 for age group 0-4, i=2 for age group 5-9, ..., i=6 for age group 25-29. x[1] equals 1, x[6] equals 0.

Step 1: Estimate overall sex and age-specific transition probabilities y[i], i=1,...,5, using the following formula: y[i] = (x[i] - x[i+1]) / x[i].

Step 2: Distribute age-specific transition probabilities over educational levels according to the average age at which the different school levels are entered. The following distribution was used for both males and females: age group 0-4: 100% primary, age group 5-9: 100% primary, age group 10-14: 20% primary/80% secondary, age group 15-19: 90% secondary/10% tertiary, and age group 20-24: 100% tertiary.

Step 3: Distribute sex, age and education-specific transition probabilities over labor force status according to observed sex, age and education-specific labor force participation rates.

Step 4: Transfer the resulting sex, age, education and labor force status-specific school exit transition probabilities p[i] into school exit transition rates r[i] using the following formula: r[i] = -0.5 * ln (1 - 2*p[i]).

b. Labor force entrance/exit transition rates

Input data for estimating labor force entrance and exit transition rates were sex, age and education-specific labor force participation rates, which simply give the proportion of the population in the labor force at each age group. Again, four steps were required to estimate transition rates.

Given: Labor force participation rates x[i], i=1,...,18; i=1 for age group 0-4, i=2 for age group 5-9,..., i=18 for age group 85 and over. For i=1,...,3, x[i] equals 0.

Step 1: Calculate non-labor force participation rates y[i], i=1,...,18, by simply taking the differences y[i] = 1 - x[i].

Step 2: Calculate age and education-specific labor force entrance transition probabilities pen[i] by applying the following formula: pen[i] = (x[i+1] - x[i]) / y[i], provided (x[i+1] - x[i]) > 0, otherwise pen[i] equals 0.

Step 3: Calculate age and education-specific labor force exit transition probabilities pex[i] by applying the following formula: pex[i] = (x[i] - x[i+1]) / x[i], provided (x[i] - x[i+1]) > 0, otherwise pex[i] equals 0.

Step 4: Transfer the resulting sex, age and education-specific labor force entrance and labor force exit transition probabilities pen[i] and pex[i] into labor force entrance and labor force exit transition rates ren[i] and rex[i] using the following formulas: ren[i] = -0.5 * ln (1 - 2*pen[i]) and rex[i] = -0.5 * ln (1 - 2*pex[i]).

Note: In both cases, step 4 is automatically done by the model. The user has to implement transition probabilities.