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Population Forecasting in Canada: Conceptual and Methodological Developments

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Abstract

After introducing the value and interest in population forecasting, the thrust of the paper is on conceptual issues and methodological developments in population forecasting. It provides an historical overview of population projections by Statistics Canada and is presented for the periods before and after the 1970s, covering a seventy-year history. The evolution of the current regional cohort component projection model is articulated by describing the methodological developments by components in each of the six sets of population projections from the 1970s to the beginning of the new century. Also presented is a brief account of the main special/customized projections prepared. Finally, the paper provides a brief evaluation of the accuracy of selected past projections.

Key words: projections, time span, forecasting, projection model, simulation, components, assumptions

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Résumé

Après avoir souligné l'importance et l'intérêt que présentent les projections de population, l'article consacre une attention particulière à l'examen des concepts et des méthodes dans le développement des perspectives démographiques. Une revue des projections démographiques au Canada dans une perspective historique avant et après 1970, couvrant une période de 70 ans, y est entreprise. L'approche cohorte-composante, en vigueur au Canada dans les travaux des projections depuis 1970 et jusqu'à présent, est analysée dans le cadre de chacune de six séries de projection, élaborées durant cette période de temps. Un bref compte-rendu est fourni du programme de projections sur demande. L'article se termine par une évaluation de quelques projections sélectionnées quant à leur précision.

Mots clés - projection, unité de temps, perspective, modèle de projection, simulation, composants, hypothèse

Introduction

Population projection, for which a more widely used term in practice is forecasting, constitutes an essential part of the statistical apparatus of modern government and society. National statistical and planning agencies in both developed and developing countries and international agencies produce and routinely publish population projections using the latest available demographic data. Statistics Canada, for instance, has been publishing routinely projections for Canada and provinces since the 1970s (George, 1999). The U.S. Bureau of the Census has been publishing projections for the United States since the 1940s (Shryock and Siegel, 1971). The United Nations Population Division has so far published 16 rounds of population projections for all countries, areas and regions of the World (United Nations, 1999). Almost all the countries of Europe, as well as Australia, and New Zealand have a population projection program and are producing projections at regular intervals. In a recent Work Session on Demographic Projections, organised jointly by the U.N. Economic Commission for Europe (ECE) and EUROSTAT, participants from ECE countries, U.S.A. and Canada reported and discussed the various aspects of demographic projections carried out by these countries (U.N.E.C.E, 1999).

The empirical and theoretical foundations for population projections are strengthened by progress in census-taking, improvement in vital statistics data, and other avenues of demographic data collection. The improvement in techniques for estimating basic demographic indicators, the ongoing research on patterns and determinants of the demographic components, and methodological developments have also contributed to the production of more reliable projections than in the past. Further, the application of computer technology has cut the cost and time required for producing projections and has widened the scope and refinements in the application of complex statistical and modelling operations.

If we consider other disciplines as well, it can be seen that the field of futures studies itself has grown enormously. As an indicator of this trend, the paid-up membership of the World Future Society (WFS) has increased to over 30,000 members and subscribers from 200 in 1967, when it started. It is represented in more than 20 developed and developing countries (Solem, 1994).

Despite the dismal past records in population projections, especially those prepared following World War II, there is an increasing interest in and use of demographic projections. People today are more anxious than ever to make population projections and to devise new and improved techniques which will provide more accurate projections than those in the past.

Who are the users, and what are the data used for? Population projections as a quantitative basis for social and economic planning and policy making have been recognised by governments at all levels and private enterprises (United Nations, 1981). Further, the increasing attention to the links between demographic and socio-economic changes creates growing demands for projections of population by sex, age, and other characteristics, at the national, regional, and other subnational levels. Population projections by age and sex are also used for developing specialised demographic projections or 'derived projections' such as those covering the labour force, households and families, the population by marital status categories, the school age population and school enrolments, the rural-urban population, etc. In addition, projections are used for demographic analysis and other related impact studies such as the quantitative evaluation of the anticipated impact of programmes and policies. The need to foresee future population trends has been intensified by concern over the consequences of the upsurge in population growth in developing countries, and with the consequences for industrialised countries of the recent declines of fertility to levels far below replacement. Demographic projections have served as guides to the formulation of policies to boost the fertility level in certain countries. The linguistic demographic projections of Quebec, for instance, have contributed to the adoption of provincial government policies to avert the decline in the number of francophones. Thus, while the true course of the demographic future cannot be known, projections can at least indicate the proper direction, or alert us to some "undesirable" situations. As Romaniuc has observed, what is far more important is whether and how projections are used in the decisions that affect our future as individuals and as a collectively. "Clearly, the acceptance of a projection and the likelihood of its utilisation depends a great deal on the quality of the work and the professional credibility its makers enjoy among peers and users. Projections thus acquire the features of a working tool and take a proactive stance rather than that of a passive contemplation of the future. They are turned into an instrument for creating rather than discovering the future" (Romaniuc, 1994, p. 175).

Having stated the value and interest in population forecasting, the thrust of this paper will be on conceptual issues and methodological developments in forecasting of population in Canada. The paper begins with an attempt to explain and clarify some conceptual and definitional issues relating to forecasting. This is followed by a description of the occasional forecasting studies carried out prior to the 1970s. It then describes the methodological developments in population projections in Statistics Canada since the 1970s, as well as the current approach. This discussion does not include other specialised demographic projections such as those covering households and families, school enrolments, labour force, etc. Finally, it touches upon the evaluation and accuracy aspects in forecasting; special customised projections; and concludes with some summary remarks.

Conceptual Issues

Definition of Forecast/Projection

'Estimate', 'projection', 'forecast', 'prediction' - these are all terms used to denote future population, but all these do not stand for one and the same thing. The term estimate is used to refer to both past, current, and future population, and it may refer, in the case of future population, to a 'projection', 'forecast' or 'prediction'. The distinction between a forecast and a prediction is not always clear, but they are generally taken to mean the same thing. Most statistical agencies, including Statistics Canada, claim to produce 'projections'. These are calculations of future population based on a starting population and a certain assumed future growth rate, or components of growth. By definition, a projection is therefore conditional, and must be correct unless arithmetical errors have been made. A projection, however, becomes a forecast or prediction if it is asserted that the assumed fertility, mortality and migration will in fact take place. Thus, according to Keyfitz (1972, p. 347 and 353), population forecasts are unconditional statements of what the population of a given area will be, preferably in the form of a probability distribution. He also states, "a demographer makes a projection, and the reader uses it as a forecast". This is especially true since a large number of agencies generally prepare "high", "medium", and "low" projections and label the "medium" variant as most plausible while considering the "high" and "low" variants as the approximate range within which future population would fall.

Anatole Romaniuc makes the distinction between population projection as future-oriented simulation, and as prospective analysis.

Projection as Future-Oriented Simulation

Prospective demographic simulations have broadened the program in population projections. They are useful as analytical tools in governmental decision making and in the evaluation of population related issues. They are, by definition, "conditional" projections, and the operation involves transforming one set of input parameters into another set of output parameters appropriate to the analysis of the problem at hand. They vary widely with regard to their scope, purpose and technical complexity.

In elaborating the projection-related concepts and definitions, Romaniuc has made a distinction between "process-oriented" and "goal-oriented" single-purpose simulation models (Romaniuc, 1990 and 1994). In the first type, simulations are designed to generate outcome. For example, the population size and age structure implied in an assumed level of fertility, mortality and migration, over the stipulated time period. One concrete application of this type of simulation will be to examine the implications of various levels of immigration on population size, age structure and distribution. Two examples of such simulations pertaining to Canada are the studies by Basavarajappa and George (1981); and George, Nault, and Romaniuc (1991). The former study examined the impact of immigration as a tuning mechanism for achieving a desired rate of population growth under different assumptions of fertility level. The latter focussed on the effects of fertility and international migration on changing age composition of the population in Canada. In the second case, a demographic 'goal' is set by the analyst; then a simulation is performed to determine the optimum combination of demographic factors leading to the goal. An example of 'goal oriented' simulations is the research by Thomas Frejka (1973) for the purpose of demonstrating the demographic conditions necessary to attain a stationary population in various parts of the world at different future points in time.

"Multi-purpose" models are another type of prospective simulation. They involve highly complex computer operations inputting a multitude of socio-economic and demographic factors. They are designed to demonstrate the long-term implications of the interaction of these factors (see the model built by Meadows (1974) and his associates at the Massachusetts Institute of Technology).

Projections as Prospective Analysis

The purpose of this type of projection is to produce plausible scenarios of the future population by sex age, territorial distribution etc.. Its production involves often elaborate analysis of the population growth components (mortality, fertility, international migration, and internal migration). It does not claim to predict future population. As Romaniuc (1990, p. 23) puts it, “The hallmarks of this type of projection are "potentiality" rather than "inevitability", and "plausibility" rather than "certainty" or "probability"”. The notion of analytical credibility is at the very heart of this conception of projection, according to him. These are the kind of projections that are generally done by Statistics Canada. Their programmation involves a number of analytical and policy decisions, such as frequency, time span, base population to be used, and range of projections as well as input parameters to generate future population by sex and age.

The Frequency of Projections

How often should population projections be revised? There is no uniform practice among agencies which produce projections on a regular basis. Some are of the view that they should be revised every year; others hold a flexible view that the projections should be revised when notable changes in demographic trends have occurred. Romaniuc (1990) has suggested that the frequency of updating may be based on pragmatic considerations. “Much depends on the extent of demographic change that has occurred and the amount of work required (affordable) to generate new projections grounded on solid analysis”. There is, thus, general agreement that projections should be revised periodically and kept as closely updated as possible as new data become available.

A survey conducted on this question among 30 industrialised countries in 1988 shows that no fewer than 15 countries produce their forecasts at intervals of 4 years or longer (Cruijsen and Keilman, 1988). As regards the practice of revising projections in some specific countries: the U.S.A. every three years; the United Kingdom every two years; Australia every four years; and the United Nations every two years. Statistics Canada revises long-term population projections for Canada, provinces and territories by age and sex every five years following the census, and prepares short-term (five-year) updates every year.

Time-span of Projections

There is no uniform practice in the time horizon used for population projections. However, projections prepared are either for a short-term period, or for a long-term period. A period of 5 to 10 years is considered a short-term forecast in demography (Keyfitz, 1979). The main criterion rests on the length of period for which the factors affecting population change can be projected with reasonable accuracy. A reasonable time period for long-term projections is 20 to 30 years, or roughly the mean length of a generation. Producing projections exceeding this period is meaningless, especially for population affected by international and internal migration, and should be regarded as an exercise in simulation. The shorter the time period, the more reliable the projection is likely to be. However, long-range demographic projections for longer periods both at the national and international level have been adopted by the United Nations (1999) and other agencies to serve as a basis for long-term development plans and investment strategies, and for assessing long-term implications of population size and age structure of current or assumed levels in mortality, fertility and migration.

According to a recent survey of projection methods in 31 industrialised countries, sixteen of them project their national population 30-49 years ahead; eight 50-74 years; and three 75 years or more (Cruijsen and Keilman, 1988). The period of the 1999-based population projections of the United States was extended to 100 years for the first time to 2100. (Hollmann, 2000) Also, the 1998 revision of the United Nations population projections extended the long-term projections of the world and its major areas for a period of 150 years from 2000 to 2150 (United Nations, 1999). The time period for Statistics Canada's long-term projections has been 25 to 30 years for Canada and provinces/territories, and about 50 years for Canada, depending upon the year of the population estimate used as the base after the census, around which new projections are prepared.

Number of Projections

The combination of component assumptions yields numerous projections. From these, a set of projections are generally selected to provide plausible maximum, medium, and minimum population growth levels. The range of the projections provides a sense of likely margins of error for the user. If the series contains an odd number of projections, often three, with labels such as "high", "medium", and "low", the user decision is obvious: pick the "medium", treating the others as outside possibilities. In many cases, the middle projection is presented in more detail, perhaps recognising that most users will select it in any event. If the number of projections issued is an even number, selecting a single projection becomes more problematic.

Keyfitz (1977) has suggested a new procedural doctrine for projections by official agencies. Instead of the agency providing a neutral series of projections for the users to choose, it should choose a realistic medium series, straddled by low and high variants as defining a kind of confidence interval, perhaps of two-thirds probability, with about 1 chance in 3 between medium and high and 1 in 3 of being between low and medium.

Statistics Canada stipulates: "There should be several estimates for each reference date. These alternatives should be the product of different but clearly stated assumptions or else the product of alternative specifications of the model. No single set of estimates should be labelled as most probable". (Statistics Canada, 1986). Following this policy, Statistics Canada issues, for each round of projections, four or five projection series for Canada and provinces.

Population Forecasting Before the 1970s

Forecasting of population in Canada started as a regular activity in the 1970s with the publication of population projections for Canada, 1969-1984 by the Dominion Bureau of Statistics (1970). Prior to this year, several occasional demographic projections were prepared and published by government departments, or by individuals/private consultants for planning, policy-making and analysis purposes. A brief review of these projections by M.V. George (1967) lists 19 demographic projections at the national and subnational level. Although a number of such ad hoc population projections were prepared by Statistics Canada, the stand of the bureau during this period was rather mixed or not favourable for developing projections. This can be seen from statements by the then Chief Statisticians.

In 1938, in connection with a request from the Rowell-Sirois Commission, R.H. Coats, the Dominion Statistician, expressed the view that... "we think it unwise to issue any statement regarding the future population of Canada". In 1946, however, the bureau published *The Future Population of Canada*, Bulletin F-4 in the 1941 census monograph series. Its introduction made it quite clear that there were no longer any concerns on the bureau's part about the validity or propriety of such an undertaking: "The value of population projections lies, not in their prophetic qualities, for it cannot be too strongly emphasised that no attempt is made to predict what the total population of a community will be at some future date, but in the examination of what consequences must ensue if no unforeseen agencies intervene to affect drastically past trends" (Worton, 1998, p. 243).

But the bureau's assurances did not satisfy the Department of Trade and Commerce. On March 6, 1946, the deputy minister, M.W. Mackenzie, wrote to the assistant deputy minister, Oliver Master, commenting on discussions stemming from the release of Bulletin F-4: "The Minister is concerned, and I think rightly, as to the propriety of … engaging in this field of crystal gazing. I was under the impression that the Bureau restricted its releases to factual material, from which others are quite at liberty to draw predictions or conclusions".

Herbert Marshall, the then Dominion Statistician wrote a long memorandum defending the practice, stressing that... "in many countries population trends are giving great concern to statesmen, economists, sociologists" and noting that the projections... "were prepared initially because information was required by the Dominion-Provincial Committee on Reconstruction to assist them in their deliberations on old age pensions and on provincial subsidies". He argued that "the contents of our bulletins are purely statistical. Naturally it suggests nothing as to policy concerning population... There have been many estimates of Canada's future population, many based on wishful thinking. It seems desirable that there should be an official estimate based on carefully stated unbiased assumptions".

Towards the end of the Marshall regime, Nathan Keyfitz's office compiled a "Memorandum on the Projection of Population Statistics, 1954", with an even stronger cautionary statement: "Despite… improved procedures, the fact remains that there are no methods at present available to forecast with reasonable accuracy the forces… determining population magnitudes and movements". It went on to say that, "for this reason, and because this calculation has not the same factual basis as other Bureau publications, this memorandum, like its predecessor, will not be given general distribution. It will be available only on request and for their own use to those interested in the subject". (Worton, 1998, p. 243-244). In any case, the bureau continued to maintain a low profile in preparing population projections until the late 1960s when the Population Estimates and Projections Division was established with the mandate to develop population projections for Canada and provinces. The projection work was started under the stewardship of Anatole Romaniuc, who then became Director of the new Population Estimates and Projections Division.

The first known population projection for Canada, 1931-1971, prepared using a component approach, was published in 1936 (Maclean and Hurd, 1936). They also prepared another projection for Canada for the same period using a logistic curve (Pearl and Read technique) on the census populations of 1911, 1921 and 1931 for comparison. The two projections were compared and analysed by Hurd (1939). Since the publication of these projections, Statistics Canada has published five population projections for Canada only, using a component approach. The main characteristics of these five and the two earlier projections, including the one using the logistic curve method, are presented in Table 1.

Table 1. Main Characteristics of Population Projections in Canada, 1936-1970

Title and Year of Publication	Author / Method	Base Population (year)	Period of Projection	Mortality Assumptions	Fertility Assumptions	Migration Assumptions	Number of Projections Selected/Published
1a. Projection of Canada's Population on the Basis of Current Birth and Death Rates, 1936	Macleans & Hurd / Component Method	1931	1931-1971	One	Two	Nil	One
1b. Projection of Canada's Population on the Basis of Current Birth and Death Rates, 1936	Hurd / Logistic Method	1911, 1921, 1931 Census Population	1931-1971	Nil	Nil	Nil	N.A.[3]
2. The Future Population of Canada, 1946[1]	DBS Component Method	1940 1944	1941-1971 1944-1971	One	Two	None	Two
3. Memorandum on the Projection of Population Statistics, 1950[2]	DBS Component Method	1946	1946-1971	One	Two	One	Two
4. Memorandum on the Projection of Population Statistics, 1954	DBS Component Method	1951	1951-1971	One	Three	Two	Six
5. Population, Family, Household and Labour Force Growth to 1980, 1967	DBS Component Method	1966	1966-1980	One	Three	Three	Three
6. The Population Projections for Canada, 1969-1984, 1970	Statistics Canada Component Method	1969	1969-1984	One	Four	Four	Four

(1) There are four projection series: A, B, C, D. A and B used 1941, C and D 1944 – base population. A and B are based on one set of assumptions, C and D on another.

(2) Including Newfoundland, but excluding Yukon and Northwest Territories.

(3) Only one projection possible by this method.

The first two projections (1a and 1b) in Table 1 were prepared using entirely different methods. A "component" method was used in the first, whereas the second applied a logistic mathematical method. Thus, while the first is a "conditional" projection by age and sex, the second is a forecast of total population using a logistic method. It was a coincidence that the latter method yielded a projected population in 1971 almost identical with that obtained by the component method.

As shown in Table 1, the six earlier projections share some basic common characteristics: they are all conditional projections; the projection horizon is 15 to 25 years; and they use a component method with single or alternative assumptions on mortality, fertility and international migration.

Although the basic methodology adopted for these projections was a component approach, there were differences in the specific methods being used for projecting particular population components. This was especially true with regard to fertility, the most crucial variable in population forecasting.

The earlier projections relied exclusively on the so-called period fertility method. According to this method, analysis and projection of fertility is carried out using calendar-year, age-specific fertility rates. It is a straightforward procedure, with limited analytical capabilities. Projections using period rates rely heavily on the extrapolation of historical trends. Realising the limitations of fertility projections based on period fertility rates, the cohort approach was introduced for the first time in Canada with the 1969 Statistics Canada population projections. Anatole Romaniuc took the lead in this work and contributed greatly to the analysis and development of fertility projections using this method (Romaniuc, 1970; Statistics Canada, 1970).

A relatively simple procedure has been followed in migration projections. Four alternative assumptions on migration were made on the basis of past trends, and were stated in annual numbers.

Mortality has been considered as a minor factor in population projections. There was only one assumption based on the consideration that mortality would follow the monotonic decline but at an increasingly slower pace in view of the low levels already reached and the resistance to medical progress of such causes of death as heart and degenerative diseases. The projections were made in terms of either the age-specific mortality rates or survival ratios at successive ages. However, greater importance was given to mortality in the 1969 projections. Based on the potential for an increase in the expectation of life among elderly people, mortality projections were made through analysis of data by cause of death for the first time (Dominion Bureau of Statistics, 1970).

Population Forecasting Since the 1970s

As a part of its program to produce population projections by age and sex for Canada, provinces and territories, altogether six generations or sets of projections have been developed/published by Statistics Canada (1974: 1972-2001; 1979: 1976-2001; 1985: 1984-2006; 1990: 1989-2011; 1994: 1993-2016; 2001: 2000-2026).

When national and subnational projections are prepared by different agencies, one of the main problems from the point of view of the user is the lack of numerical and methodological consistency between national and subnational projections and the resulting lack of comparability between them. Statistics Canada's issuing of population projections for Canada and the provinces on a regular basis has ensured methodologically and numerically consistent and comparable projections from the 1970s to the present. The general methodology used, the methodological changes and developments in the component projections over the years, and the current approach, are briefly discussed here.

General Methodology: The Regional Cohort-Component Method

The cohort component approach, originally developed by P.K. Whelpton in 1928, has become the preferred analytical method for preparing national and sub-national projections. In order to serve the users of both national and provincial population projections more satisfactorily a regional cohort-component approach was used in these projections (see Table 2 for projection inputs). The term "region" is used here in a generic sense to refer to a province or a group of provinces, such as the Atlantic Region, or to economic/geographic subdivisions of the country. The method is basically a demographic accounting system. Specifically, the calculations start with the base year population distributed by sex and age, applying assumed sex/age/specific survival ratios and age-specific fertility rates for females, and making allowance for international migration (immigration and emigration) and interprovincial migration (in-migration and out-migration) for each province by age and sex.

In order to produce consistent and comparable projections for Canada and provinces simultaneously, a "hybrid bottom up" projection model, incorporating internal migration projections, is used for Statistics Canada projections. In this model component assumptions on fertility, mortality, immigration, emigration and non-permanent residents are first developed at the national level and the corresponding provincial assumptions are derived consistent with those of Canada as a whole. Thus, the model allows separate projection of each component at the provincial/territorial level taking into account regional differences, and attempts to combine the advantages of the "top down" and "bottom up" approaches (for further details, see George and Loh, 2000).

Table 2. Basic Projection Inputs for Statistics Canada's Projection Model

Base Year Population	Fertility[1]	Mortality	Immigration; Emigration; and Returning Canadians (RC)	Interprovincial Migration	Non Permanent[3] Residents (NPR)
Population by single years of age and sex	• Total fertility rate (TFR)	• Life expectancy at birth by sex	• Total number of annual immigrants for Canada	• Origin destination matrix of interprovincial migration	Annual net change in NPR
		• Age-specific death rate (mx)			
	• Mean age of fertility	• Survival ratios by age and sex	• Provincial annual distribution of immigrants	• In-migration	
	• Modal age of fertility		• Provincial age-sex distribution	• Out-migration	
	• The variance		• Annual number of emigrants/emigration rate by age and sex	• Age-sex distribution	
	• The third moment of the fertility distribution		• Annual number of returning Canadians by age and sex[2]		
	• Sex ratio at birth				

Notes: (1) See text for the difference in the inputs/parameters used for the Pearsonian Type 1 and Type 3 models.

(2) Only 1994 projections had used Returning Canadians (RC) as a separate component.

(3) Non Permanent Residents (RPR) are applicable for 1994 and 2001 projections.

Source: Based on Population Projections, 1974, 1979, 1985, 1990, 1994 and 2001.

There are two basic steps in this approach. First, a separate analysis and projection of each component of population growth - fertility, mortality and migration (interprovincial and international) - is made for Canada and the regions by using appropriate demographic parameters. These parameters (generally in the form of absolute values, rates and ratios) are added or applied to the population of the base year to obtain separately the future population by age and sex for each province and territory ($P_{t+\Delta t}$) as shown in the following equation. Second, the national projections are derived by aggregating the projections for provinces and territories. Unlike most other statistical agencies, which develop projections separately at the national and subnational level (for e.g., the U.S.A., the U.K. and most countries of the European Union), the Statistics Canada model produces projections for provinces and Canada simultaneously. The projection model employed permits the choice of a wide range and combination of assumptions and projection series to encompass plausible future population growth with its components for Canada, provinces and territories.

Thus:

$$P_{t+\Delta t} = \sum_{i=1}^{13} (P_{i,t} + B_{i,\Delta t} - D_{i,\Delta t} + I_{i,\Delta t} - E_{i,\Delta t} + NPR_{i,\Delta t} + NM_{i,\Delta t})$$

where: $P_{t+\Delta t}$ = projected population at the end of the time interval Δt; $P_{i,t}$ = the population of province i at time t; $B_{i,\Delta t}$ = the number of births in i during the time interval Δt; $D_{i,\Delta t}$ = the number of deaths in i during the time interval Δt; $I_{i,\Delta t}$ = the number of immigrants in i during the time interval Δt; $E_{i,\Delta t}$ = the number of emigrants in i during the time interval Δt; and $NM_{i,\Delta t}$ = the net interprovincial migration in i during the time interval Δt; $NPR_{i,\Delta t}$ = net change in the number of non permanent residents in i during the time interval Δt.

It should be noted that the above formula is applied on a cohort basis for each sex by single years of age. Thus, the procedure yields future population by single years of age and sex for Canada and each province and territory. Since the projections are developed for each single year of age, the results are available for each year of the projection. This ensures maximum flexibility for analysis of results.

Two new components: returning Canadians (RC) and non-permanent residents (NPR) were introduced into the population estimation system in 1991. These two new components were added to the projection model for the 1994 set of population projections. However, as modified in the population estimation system (Statistics Canada, 2001b), the component of returning Canadians became one of the constituents of emigration component for the latest set of population projections (Statistics Canada, 2001a).

The development of population projections for Canada, provinces and territories using the regional cohort-component method is a complex operation involving several networks of tasks as follows: (1) establishment of a base population; (2) conducting analytical studies on each component (fertility, mortality, interprovincial migration (in- and out-migration) and international migration (immigration and emigration); (3) methodological research and modelling related to each component; (4) development of assumptions on each component with rationale; (5) integration of assumptions into the projection model, test runs and sensitivity analysis; (6) a consultation process with provincial and territorial statistical focal points with a projection package; (7) production of final projections and evaluation of the results; (8) selection of projection series for publication; and (9) the preparation of projection report.

Each of these tasks from (1) to (7) has extremely important effects on the quality of the projections produced. In what follows, the discussion centres on these various tasks in terms of the methodological developments over the years, with emphasis on component projections.

Projection Inputs

The required basic projection inputs for Statistics Canada's current projection model, modified since the 1993-based projections, are presented in Table 2.

Base Year Population

Every projection has a starting point. The last date for which the benchmark data are available is generally the criterion for selecting the starting point for the Statistics Canada projection model. The base year population used is the latest census population, or the latest postcensal population estimates for Canada, provinces and territories by single years of age and sex, by Demography Division of Statistics Canada. For the first time, the 1993-based projections used the population estimates adjusted for net census undercoverage as its base, and included two new components, non permanent residents and returning Canadians. However, as stated above, the 2000-based population projections did not include returning Canadians as a separate component, but included them as a constituent of emigration component. Due to these changes, the 1993-based and 2000-based population projections cannot be directly compared with the previous projections.

Projection of Demographic Components of Population Change

As mentioned earlier, the component method of projection consists of analysing past trends of each component and the associated sociodemographic and economic factors and their interrelations, developing plausible assumptions based on this analysis, and separately projecting each component. From an analytical point of view, a major advantage of this approach is that each component of population growth can be studied much more thoroughly than with any other method. Romaniuc (1994, p. 174) calls this aspect the "analytical credibility" of the projection work. In practical terms, this implies... "making use of all professional skills available, within the confines of cost-effectiveness, to come up with analytically credible assumptions about the key parameters of the projection". Further, the component method permits a variety of approaches to project each component on the basis of available data and methodology suited to embody different assumptions. The development of assumptions on future trends in the components of population change and the projection of each component are the most difficult. The more distant the future, the more difficult is the task of determining realistic assumptions on the future course of the components of growth. The following describes the evolution of the current method(s) used for projecting each component, from 1972 to the present, with greater emphasis on the current practice.

Fertility Projection

The application of the projection model requires a set of projected age-specific fertility rates. By applying the projected age-specific fertility rates to the females of corresponding childbearing ages (15-44), the annual number of births for each province and territory are derived for each year of the projected period. Births are then distributed by sex on the basis of the sex ratio at birth. The calculation of the projected births (column 1) is carried out by multiplying age-specific fertility rate (column 2) with the corresponding female population by age (column 1) as follows:

PROJECTED FEMALE POPULATION AT AGE X		PROJECTED FERTILITY RATE FOR AGE X		PROJECTED BIRTHS FOR FEMALES OF AGE X
FP_{15}		FR_{15}		B_{15}
FP_{16}		FR_{16}		B_{16}
FP_{17}	X	FR_{17}	=	B_{17}
.		.		.
.		.		.
.		.		.
.		.		.
FP_{44}		FR_{44}		B_{44}

$$\sum_{15}^{44} = \text{Total number of births}$$

The conventional approach for birth projection is to project age-specific fertility rates by calendar years. These rates can be projected either directly, or derived indirectly by first projecting cohort fertility rates and then converting them to period rates. As in the 1970 projections (see Romaniuc, 1970), a cohort approach was used in the 1974 projections. The chief merit of this approach is that fertility can be analysed and projected separately in terms of (a) completed fertility or family size, and (b) the age pattern of fertility for the real cohorts. The cohort method is, however, more complex to apply operationally than is the period approach. The extra level of complexity was, however, justified by noting that fertility had by far the largest effect on the future population level of all components and historically had been one of the most volatile. Because of the complexity of this method and the problems sometimes in getting the required data, there is limited application of this approach in projecting fertility. According to the survey on forecasting process in 30 industrialised countries referred to earlier, only the United Kingdom used a cohort approach for fertility projections (Cruijsen and Keilman, 1988). In Canada, the only other known projection in which a cohort method is used is the population and labour force projections for Alberta, 1970-1985 (George and Gnanasekaran, 1972). It also contains a detailed description of the cohort approach and its application.

In addition to the use of the cohort approach, a three-parameter model (Pearsonian Type 1 curve) was used for the first time, to derive age-specific fertility rates. The three period-fertility parameters consisted of (1) the total fertility rate, which measures the level of fertility; (2) the mean age; and (3) the model age of fertility. The latter two measure the timing of births. The application of this model rests on an analysis of each of these parameters, and the formulation of assumptions on their future course over the projection period (for a complete description of the model see Romaniuc, 1973). Further, the reduction in the number of fertility parameters offers appreciable operational and analytical advantages. One significant advantage is that statistical operation is confined to only three fertility measures which are most appropriate for in-depth analysis required to provide rationales for assumptions of future fertility (Statistics Canada, 1974).

The work in this complex operation involved the following: (a) development of cohort fertility data tables and their in-depth analysis; (b) the formulation of assumptions regarding the future trends of the three parameters involved; and (c) the conversion of the completed cohort fertility rate (family size) into period total fertility rate; and (d) the application of the three parameter model to derive age-specific fertility rates from the projected (assumed) total fertility rate. Detailed analysis of cohort fertility data by birth order (i.e., parity distribution) was carried out to make assumptions about cohort fertility levels. An adaptation of the translation model by Ryder was applied to translate the projected completed cohort fertility rate into the period total fertility rate (Vanasse-Duhamel, 1975). There were three assumptions on fertility. These projected (assumed) total fertility rates (TFR) for the last year of the projection period are shown in Table 3.

Fertility parameters used to project births by provinces/territories were derived from corresponding parameters projected for Canada by applying a "ratio" method. The ratio method consisted of calculating ratios of provincial to national values, for a given parameter, which were then projected forward. Finally, values of provincial parameters for future years were obtained by applying the projected ratios to the corresponding parameters at the Canada level. The decision to use the ratio method was made after a careful study of the patterns of interprovincial variations in the time series of both cohort and period fertility measures. On the basis of this analysis, it was assumed that fertility trends in the provinces will continue to evolve in the same manner as national fertility trends and that there will be a tendency toward convergence for the total fertility rate over time.

The cohort approach to fertility projections, used in the 1970 and 1974, sets of projections, was discontinued in the 1979 projections for the following reasons. First, it is a complex approach, especially when cohort fertility data have to be prepared and analysed at the regional and national level. Second, despite the apparent robustness of this approach, the projection of fertility for cohorts who have not completed their fertility is problematic as there is no empirically verifiable method to do it. Third, period fertility rates are ultimately needed for deriving annual births for projection purposes. Therefore, by using appropriate procedure(s), the cohort rates must be converted into period rates. It is possible that the resulting total fertility rate for the first projection year may depart from the previous year's observed total fertility rate by an amount that is not acceptable by any empirical standard (Romaniuc, 1970). Considering these problems in the cohort approach, it was abandoned in the 1979 projections in favour of the simpler period-fertility approach in combination with the three-parameter model for projecting births (Statistics Canada, 1979). Furthermore, it was observed that the gap between cohort and period fertility trends, especially the bulge in the total fertility curve during the baby-boom period had disappeared by the middle of the sixties. This weakened the case for greater reliance on cohort fertility rates.

The methodology followed for fertility projections in the 1985 and 1990 sets of projections was identical to that of 1979 with a three-parameter model to derive age-specific fertility rates from projected total fertility rates (TFR). The only difference was that, unlike in 1979 when only two assumptions were developed, there were three fertility assumptions ("high", "constant", and "low").

The tri-parametric model (the Pearsonian Type I) hitherto used for obtaining age-specific fertility rates was replaced in the 1994 and 2001 sets of projections by a new version of the parametric model known as the Pearsonian Type III curve. Indeed as fertility fell to low levels, about or even below-replacement,

Table 3. Assumptions on Each Component in Statistics Canada's Six Sets (Rounds) of Population Projections, 1974, 1979, 1985, 1990, 1994 and 2000

Set Title and Year of Publication	Base Population Year	Period of Projection	Mortality Assumptions and Horizon Value (e_o)	Fertility Assumptions and Horizon Value (TFR)	Immigration Assumptions and Horizon Value (number)	Emigration Assumptions and Horizon Value (number)	RC, NPR (number)[4]	Interprovincial Migration Assumptions (scenario)	Series Published
First **Population Projections for Canada and the Provinces, 1972-2001:1974**	1972[1] (estimate)	1972-2001	One[2]: M: 70.2 F: 78.4	Three: L: 1.80 M: 2.20 H: 2.60	Five: 1: 200,000 2: 160,000 3: 120,000 4: 80,000 5: zero	One: 60,000		Four (A,B,C,D)	Four
Second **Population Projections for Canada and the Provinces, 1976-2001: 1979**	1976 (census)	1976-2001	One: M: 70.2 F: 78.7	Two: M: 1.71 H: 2.06	Four: L: 75,000 M: 120,000 M: 150,000 H: 175,000	One: 75,000		Four (A,B,C,D)	Four
Third **Population Projections for Canada, Provinces and Territories, 1984-2006: 1985**	1983[1] (estimate)	1983-2006	One: M: 74.9 F: 81.6	Three: L: 1.4 M: 1.7 H: 2.2	Two: L: 100,000 H: 150,000	One: 50,000		Three (A,B,C)	Five
Fourth **Population Projections for Canada, Provinces and Territories, 1989-2011: 1990**	1989[1] (estimate)	1989-2011	One: M: 77.2 F: 84.0	Three: L: 1.20 M: 1.67 H: 2.10	Two: L: 140,000 H: 200,000	One: 81,000		Three (A,B,C)	Four
Fifth **Population Projections for Canada, Provinces and Territories, 1993-2016: 1994**	1993[1] (estimate)	1993-2016	Three: M: F: L: 77.0 L: 83.0 M: 78.5 M: 84.0 H: 81.0 H: 86.0	Three: L: 1.50 M: 1.70 H: 1.90	Three: L: 150,000 M: 250,000 H: 330,000	One[3]: 49,600 to 58,000	One[4] RC: 25,600 NPR: 150,000	Three (Medium, Central, West)	Four
Sixth **Population Projections for Canada, Provinces and Territories, 2000-2026(5): 2001**	1991[1] (estimate)	1999-2026	Three: M: F: L: 78.5 L: 83.0 M: 80.0 M: 84.0 H: 81.5 H: 85.0	Three: L: 1.30 M: 1.48 H: 1.80	Three: L: 180,000 M: 225,000 H: 270,000	One[3]: 63,000 to 74,000	One: NPR: 240,000	Three (Medium, Central, West)	Four

1. Postcensal population estimate of June 1 for the First, Third and Fourth Sets, and July 1 for the Fifth and Sixth Sets.
2. Developed based on cause-specific death rates.
3. Obtained by applying the emigration rate to the respective projected population according to "low", "medium", and "high" scenarios.
4. "Returning Canadians" was used as a constituent of emigration component in the sixth set.

e_o Life expectancy at birth.
RC Returning Canadians.
NPR Non Permanent Residents.
TFR Total Fertility Rate.

Source: The reports listed above (see references).

and the childbearing spread over longer age span, the Pearsonian Type I no longer provided a good fit. A better fit was, therefore, obtained by applying the Pearsonian Type III curve (see Figure 1). The latter model requires four parameters to project the age-specific fertility rates: (1) the total fertility rate (TFR); (2) the mean age and fertility; (3) the variance; and (4) the third moment or skewness of the fertility distribution. The first parameter provides the level of fertility, while the other three provide a measure of the age pattern of childbearing. Like the Type I model used previously, the application of the Type III version rests on an analysis of each of these parameters, and the formulation of assumptions on their future course over the projection period. (For further details, see Verma, Loh, Dai and Ford, 1996).

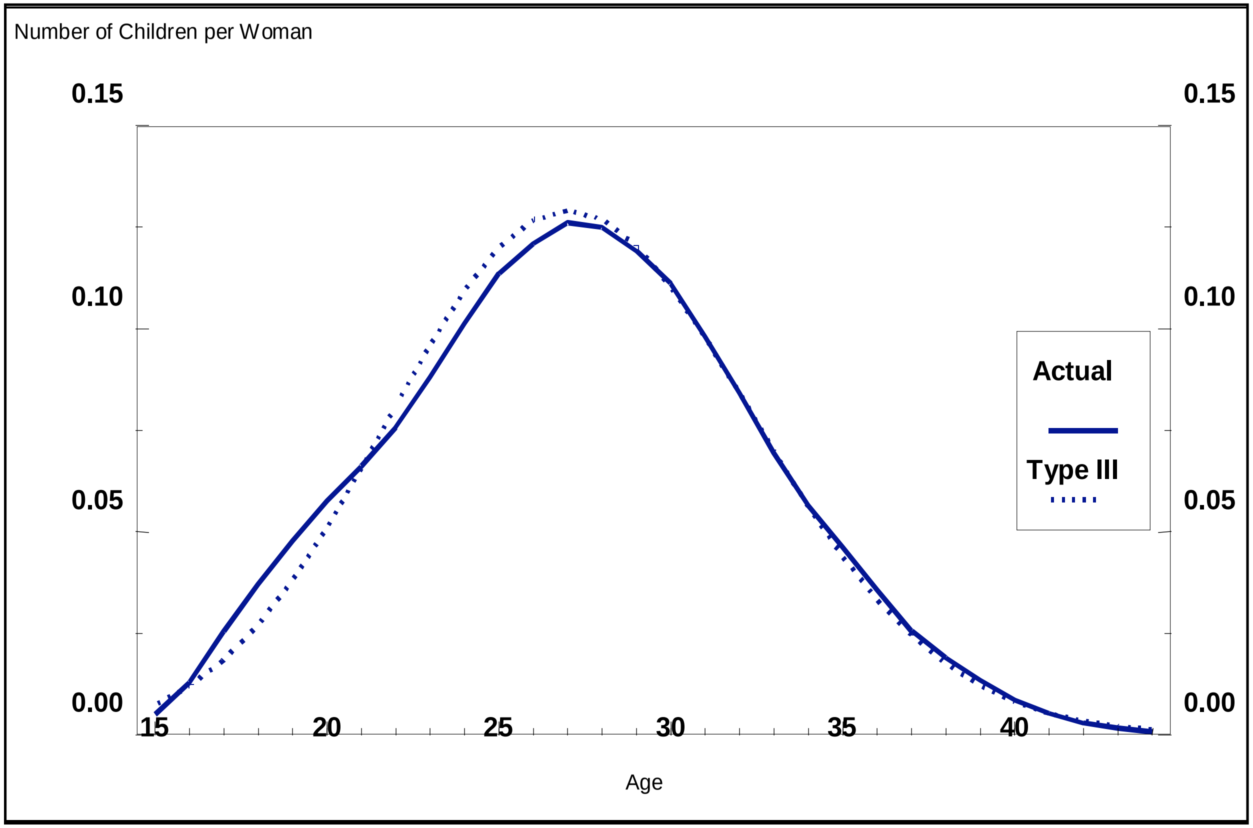
The assumptions regarding the fertility parameters were made at the national level. The projected values for the provinces and territories were then derived using an index method based on the observed provincial/national ratios. As shown in Table 3, while three assumptions were developed for the first two parameters (TFR and mean age of fertility), only one assumption was developed for the variance and skewness. Another methodological change was in the interpolation of rates between the starting value and the horizon value. Instead of a linear interpolation used in the previous rounds of projections, a decreasing slope method was applied in the 1994 projections to interpolate the TFR (for further details, see Verma, Loh, Dai and Ford, 1996). This procedure provided a wider range between the projected values of the high and low assumptions.

The method followed for projecting fertility in the 6^{th} set of population projections is basically the same as in the 5^{th} set. The assumed fertility levels are presented in Table 3. There are, however, a few minor refinements in the procedure, as follows: First, although on the whole the fertility rates of the provinces/territories are not assumed to converge to the national level, a slight reduction of disparity in Manitoba and Saskatchewan is considered plausible. Second, based on recent trends, it is assumed that the mean age at fertility will increase in both the high and low assumptions of fertility. In the 1994 projections, the low fertility assumption was combined with a high variant of the mean age of fertility rate, and the high fertility assumption was paired with a low variant of the mean age of fertility. Further, a simpler linear approach was used for interpolating the projected total fertility rates (TFR) between the initial and final years.

Mortality Projection

As discussed earlier, given the slower pace of mortality decline in Canada (the death rate declined from 7.8 in 1960 to about 7.4 per thousand population), simpler techniques were used for projecting mortality prior to the 1970s. Projection of the mortality component for the 1970 projections for example, was

Figure 1. Comparison of Actual and Pearson Type III Distribution of Age-Specific Fertility Rates for Canada: 1991



Source: Statistics Canada, Demography Division, Population Projections Section.

done on the basis of graphical extrapolation of past trends in the age-sex specific survival ratios (S_x values) .

The subsequent analysis of mortality trends in Canada and the comparison of its mortality level with low mortality countries suggested that there was scope for further gains in life expectancy at birth with a widening gap between the two sexes (Gnanasekaran, 1975). Forecasting of the future level and pattern of mortality was therefore, developed by examining past trends in terms of age, sex and cause of death. This process yielded projected death rates by age and sex, from which life tables were calculated for Canada for 1975-1979 and 1985-1989. Second, the probabilities of survivorship for the projection period were derived from these life tables (for details of the method, see Statistics Canada, 1974; and Gnanasekaran, 1975).

The technique of preparing mortality projections for the provinces involved a ratio method. For the purpose of projections, the ratio of life expectancy for each province to that of Canada for the period 1968-1970 was assumed to continue in the future. These ratios were then applied to the projected expectation of life at birth for each province. The survival ratios that corresponded to these life expectancy values were then obtained by reference to the projected life tables for Canada, 1975-1979, and 1985-1989. In the final step, using the official life table values for 1965-1967 as the base, the survival ratios between the initial year and the final year of the projection were obtained by linear interpolation.

For the second set of projections (1979), an evaluation of the 1974 mortality projections was made in light of actual mortality trends during the subsequent years, i.e., 1971-1976. This evaluation compared actual to projected life expectancies in 1971 and the actual to projected number of deaths during the period 1972-1976. Over all, the projections showed only slight deviations from the observed trends. Consequently, it was decided to adopt the original mortality projections for Canada and the provinces and to revise them, where needed, in light of the trends proceeding the base year of the projection. As shown in Table 3, a single assumption was made for mortality projection.

Despite its inherent merit, the method based on trends in cause-specific mortality rates is rather complex, especially for developing assumptions in terms of trends in cause of death by age and sex at the national and sub-national level. Users generally prefer to express their assumptions regarding mortality change in terms of life expectancy at birth (e_o). In the 1985 projections, the cause-specific projection method was, therefore, replaced by a simpler and relatively more flexible method which facilitated faster updating and the accommodation of user-specified assumptions.

In this method, assumptions were made in terms of changes in life expectancy at birth. These changes were then translated into changes in age-specific survival ratios in a manner consistent with the age pattern of change in mortality observed between 1976 and 1981. Thus, the new procedure followed is similar to what is done for projecting fertility based on the total fertility rate (TFR). The age-specific mortality pattern is obtained on the basis of an analysis of mortality trends by age as measured by the L_x vector of the 1976 and 1981 life tables. Assumptions were made on the pace of mortality decline at each age (for details see Statistics Canada, 1985).

Between 1976 and 1981, male and female life expectancies at birth increased by 1.7 and 1.5 years, respectively. This increase for males was almost double that of the previous quinquennial period (Statistics Canada, 1985). As a result, the difference between male and female life expectancy narrowed slightly for the first time between 1976 and 1981.

On the basis of the observed mortality changes by age and sex between 1976 and 1981, a single assumption on mortality was developed as shown in Table 3. As in the 1979 projections, a ratio approach was used for projecting mortality at the provincial level. The provincial/national ratios of mortality for the period 1976-1981 were held constant over the projection period.

The method applied for projecting mortality in the 1990 projections was the same as the one developed for the 1985 projections. A single mortality assumption (see Table 3) was adopted as in previous projections, and as adopted by most industrialised countries (Hämälaïnen, 1988). It was assumed that the gains in life expectancy among males would be slightly larger than those among females. The age-specific mortality pattern was obtained on the basis of an analysis of mortality trends by age as measured by the life tables in 1981 and 1986. Assumptions were formulated as to the pace of mortality decline at each age. By and large, the regional differences in mortality according to the 1986 life table were assumed to continue in the future (for details see Statistics Canada, 1990).

The method used for the 1994 projections was analogous to that of the 1985 and 1990 projections. The main difference was in the translation of projected life expectancy at birth (e_o) into age-specific mortality rates.

In this new approach, first assumptions were made in terms of changes in life expectancy at birth (e_o). The assumptions of mortality in terms of life expectancy were developed based on three extrapolated values of e_o using the following techniques: (1) an extrapolation using a linear regression on the logarithm of the central death rate by 5 year-age groups $l_n({}_5m_x)$ for 15 and 30 years; (ii) the Brass Logit model applied for 15 and 30 years; and (iii) the Lee-Carter model for 70 years (for details, see Statistics Canada, 1994).

For the first time three mortality assumptions in terms of e_o were developed (see Table 3). The provincial assumptions were derived from the national assumptions, by holding the average provincial/national e_o ratios observed over the 1988-1991 period constant throughout the projection period.

The Lee-Carter model which was used for extrapolating e_o was used to distribute the projected gains in e_o by ages. It involves the following equation:

$$l_n(m_x) = a_x + b_x k_t$$

where:

$l_n(m_x)$ = the logarithm of the central death rates by age (x);

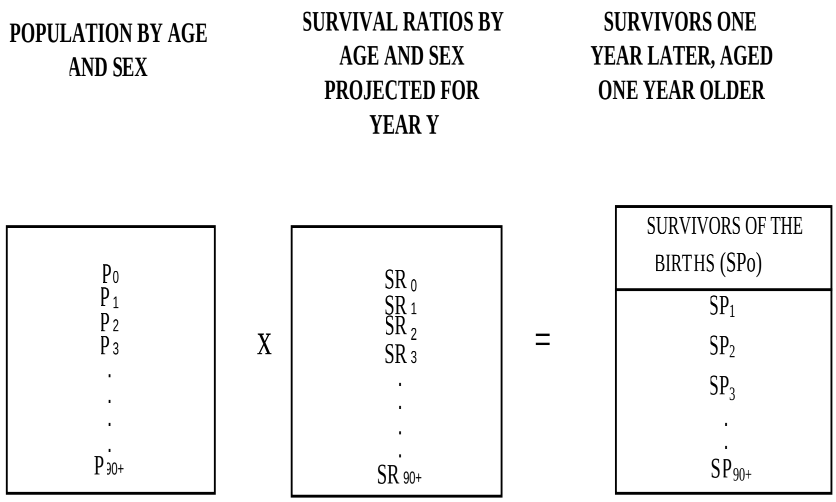
a_x and b_x = the age specific constants;

k_t = the level or time (t) parameter.

To ensure a smooth transition from the last year of observation to the first year of projections, a_x is set equal to the logarithm of the 1991 age-specific central death rates (m_x) for each sex and province/territory, so that when k_t equals 0, the equation produces the 1991 central death rates. The b_x series determines the rate of mortality change at each age. It is set to distribute the projected gains in e_o by age, according to the age-specific rates of change observed over the 1971-1990 period for both sexes at the Canada level. The same b_x series is used for both sexes and in each province/territory. Finally, the k_t are calculated to yield the exact e_os assumed by sex and province/territory.

The forecasting of mortality in the 2001 projections (6th set) was done using the same method as in the 1994 projections. There are three assumptions ("high", "medium", and "low") in terms of life expectancy at birth (see Table 3). The projections assume a greater increase in the e_o of males and a reduction in the gap between males and females in $e_{o.}$ Projected e_o for the provinces/territories are derived from the values at the national level by applying the assumed provincial/national ratios in e_o.

For population projection purposes, what is required is a schedule of survivorship probabilities at different ages by sex (S_x values). These are calculated from the projected L_x values of the life tables for Canada, provinces and territories. The projected survival ratios by age and sex (SR_s in Column 2) are applied to the corresponding population by age at the beginning of each year (P0, P1, ------ in column 1) to obtain the annual number of survivors as illustrated below:



The survivors of the births (SP_o) in column 3 are obtained by multiplying the total number of births during the time interval (Δt) with the survival probability from birth to population under age 1.

International Migration

Historically, international migration has been an important source of population growth in Canada. It affects the population growth, structure and distribution at both the national and subnational levels. Traditionally, there are two components of international migration: immigration and emigration. However, a new component called ‘returning Canadians’ was added to the population estimation process as a part of international migration from 1991 onwards. They are incorporated into the 1994 projection model and projected separately. The forecasting procedure followed, is different for each of these three components.

Immigration Projection

While annual fertility and mortality levels tend to change slowly, and are largely determined by demographic factors such as age, sex, and marital status, the time series of immigration data shows some rather volatile fluctuations (see Figure 2). They reflect the effect of a more complex set of both demographic and diverse socio-economic factors including political factors. Changes in immigration regulations and the administration of these regulations have played a role. For example, the extremely high levels of immigration during 1966-1968 and 1973-1975 were in some part due to special efforts to clear a backlog of applications before the new regulations came into effect. The announcement of an annual immigration target level by the government is the most important factor from the 1980s. Given the state of knowledge and available data on the phenomenon, an analytical method has been adopted for immigration in the past and recent projections (Statistics Canada, 1974, 1979 and 1985, 1990, 1994). The analytical method rests upon analysis of past trends. This method is highly subjective and weak, especially when adequate historical data are limited and the migration phenomenon is highly volatile over time. Within the analytical framework, different strategies are possible for migration projections. The usual strategy is to examine past trends in the number of immigrants by calculating the average immigration over different periods and to develop plausible alternative assumptions encompassing the future volume of immigration.

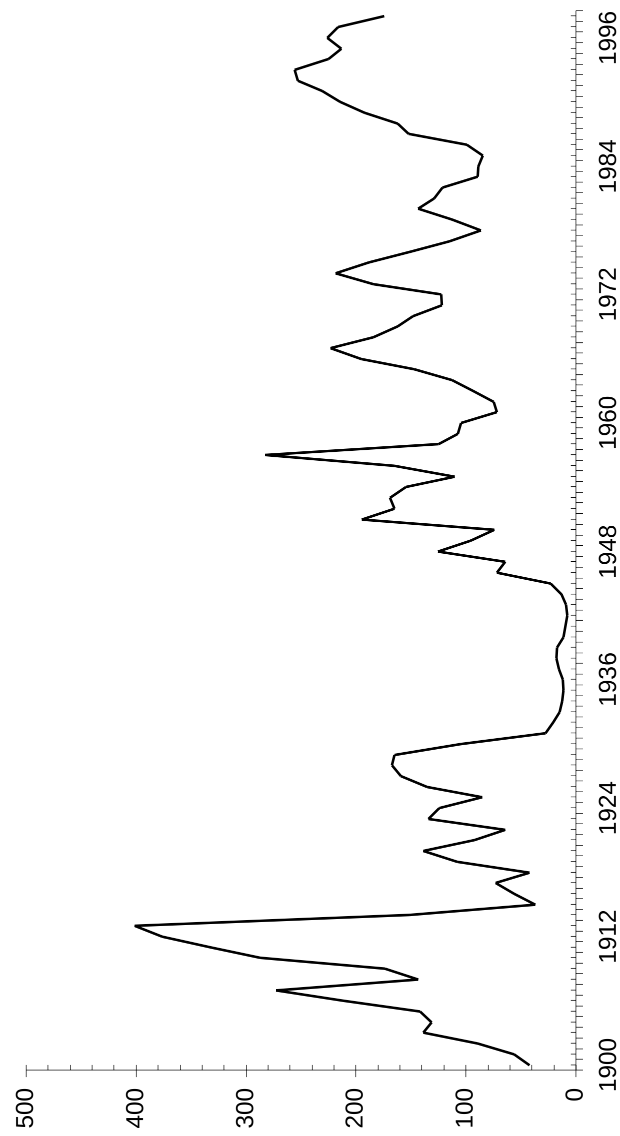
Considering the volatile nature of immigration, four assumptions within the range of 80,000 to 200,000 a year were developed in the first generation of projections (see Table 3). An average percentage distribution of immigrants by province during the three years proceeding the base year was applied to distribute these projected numbers at the national level by province.

A similar analytical method for forecasting immigration has been adopted in all the projections. However, the number of immigration assumptions varied from four in 1974 to two in 1979, 1985 and 1990, and to three in 1994 and 2001 (see Table 3). There are two basic steps. First assumptions are formulated regarding future annual levels for Canada as a whole. Second, the assumed national levels are distributed on the basis of an assumed proportional distribution established through an examination of the sex and age structure of intended immigration for each province, generally an average for the last-three years.

The formulation of immigration assumptions is dictated to a great extent by the fact that immigration falls under government control. The Canadian Parliament establishes each year, the target levels of immigration deemed desirable for the following year along with targets for a longer-time horizon. In 1990, for example, an increased target level in the order of 250,000 a year was announced for the following five years, up to 1995. In establishing the target levels, various considerations are taken into account: economic (levels of unemployment, manpower requirements, anticipated shortages of workers in certain sectors), humanitarian (reunification of family members, refugees, etc.), and demographic (in respect of the size, rate of growth, structure and demographic distribution of the Canadian population).

Figure 2 shows wide fluctuations in annual levels, with extreme values and turning points. The immigration assumptions have, therefore, primarily been based on the announced annual levels of immigration by the government (for more details on international migration projections, see George and Perreault, 1992). The underlying premise of this approach is that immigration assumptions tend to be more accurate when based on policy decisions already or about to be

Figure 2 Number of Immigrants, Canada, 1990 to 1998



Sources : Emploi et immigration Canada, ***Statistiques sur l'immigration*** et après 1993, Citoyenneté et immigration Canada, données non publiées.

taken by the government than when based solely on the statistical analysis of past trends. Immigration is expected to play an increasing role as a major component of demographic growth in Canada in future years. With fertility much below the replacement level, and the faster ageing of the population, the prospect of negative natural increase is imminent. In this context, the maintenance of a stable population size will depend very much on the immigration size. Furthermore, the government's annual target level has also increased substantially to around 250,000 in the 1990s. In view of these developments, three assumptions have been made in the 1994 and 2000 projections (see Table 3).

Emigration Projection

In view of the paucity of data on emigration, a fixed number, the estimate of annual emigration used for Statistics Canada's post-censal estimates, was assumed for population projections before the 1990 projections. Further, a single assumption has been adopted in all the generations of population projections. For the first time in the 1990 population projections, emigration was set at a fixed share of the Canadian population based on the assumed total number of emigrants. This proportion was set at 0.25%. The number of emigrants therefore rises with the size of the population. The projected number of emigrants thus obtained at the national level is then distributed by an assumed age-sex distribution for each province/territory. This procedure had two limitations. First, it produced inflated emigration levels which were not consistent with official estimates. Second, the use of this crude emigration rate may have generated some inconsistencies in the projection results (Rémillard, 1994). The solution to these inconsistencies was to calculate emigration rates by age and sex based on official estimates of emigration and apply them to the population at risk of emigrating.

In the 1994 projections, emigration was projected using age-specific emigration rates (ASER). Emigration rates by single years of age and sex up to 90+ were calculated annually for each province/territory over the period 1976-1993 and summed to produce an index labelled the global emigration rate (GER). This is analogous to total fertility rate (TFR). Five-year averages of the GER were then computed by sex, and province/territory (for a detailed description of the method, see Rémillard, 1994).

Annual estimates of emigration have been revised upward since 1996 (see Statistics Canada, 2001b). The GER average by sex calculated based on the revised estimates was held constant over the projection period for both the 1994 and 2001 projections. The provincial age-specific rates were derived by applying the national age-sex pattern to the projected GER of each province/territory. The projected number of emigrants was calculated by multiplying the projected population with these assumed emigration rates. The

2001 projections show that the number of emigrants increased over the projection period between 63,000 and 74,000 by the year 2025-2026, under the low-growth and high-growth scenarios respectively (Table 3).

Non-Permanent Residents (NPR) Projection

The 1991 Census population universe was expanded to include the following persons and their dependents: (1) student authorisation holders; (2) employment authorisation holders; (3) Minister's permit holders; and (4) refugee status claimants in Canada. They form the non-permanent resident population for which the population estimates have been adjusted. It became a new component of population growth for projection purposes in the 1994 population projections. In the current methodology a single assumption is set in terms of the number of non-permanent residents (NPRs) by year. Since NPRs are a depleting stock, only the effect of NPRs in year t on the fertility and mortality is taken into account for projection purposes without surviving them to the year $t+1$. The new stock of NPRs in year $t+1$ (net change) is then added to the surviving population in year $t+1$. The process continues until the end of the projection period.

In the 2001 projections, the NPRs are distributed by age, sex, province/territory according to the 4-years sum of the NPRs in 1996 to 1999 (Statistics Canada, 2001a).

Projection of Returning Canadians

Returning Canadians are Canadian citizens who emigrated from the country in a given year and who subsequently returned. As a new component of population growth, they were incorporated for the first time in the 1994 population projections (Statistics Canada, 1994).

As there is no direct data on the total number of returning Canadians, they are estimated as a percentage of the number of emigrants. In the 1994 projections, it was assumed that 50% of emigrants would return to Canada over a 10-year period. This number was proportionally distributed based on the length-of-stay information derived from the Customs and Excise records from 1988 to 1992 (Declos, 1993).

Only one assumption was developed, based on both the estimated (past ten years), and projected numbers of emigrants (Table 3). The provincial and territorial age-sex distributions of the returning Canadian population were based on the one-year mobility data from the 1991 Census. This age-sex distribution was assumed to be constant for the projection period.

As stated earlier (see Tables 2 and 3), following the change in the post-censal population estimation procedure (Statistics Canada, 2001b), returning Canadians were not used as a separate component in the 2001 projections. They were included as one of the constituents of emigration projection (see Statistics Canada, 2001a).

Interprovincial Migration Projection

Internal migration is the most unstable component of population growth in Canada. The contribution of interprovincial migration to provincial growth is bound to become more critical as natural increase diminishes in importance. With the increasing influence of migration on population growth and the high uncertainty associated with its trends, the degree of error in population forecasts is likely to increase at the subnational level (Statistics Canada, 1985). An examination of trends in net migration over the past three decades (1966-1999) illustrates the volatile nature of interprovincial migration and the consequent difficulty in developing assumptions based on such trends. The fluctuations that have occurred "… are abrupt, of large amplitude, and are often in reverse direction" (Statistics Canada, 1990). Thus, in developing interprovincial migration assumptions, it is important to provide a range that can reasonably encompass future levels of net migration flows for each of the provinces and territories.

Given the most volatile nature of interprovincial migration and its importance in provincial population growth, the evolution of the current method has been the result of intense research at each round of projections, involving several changes/refinements. The present method is based on the multiregional approach, taking into account interprovincial migration volume and patterns with respect to origin and destination or each migration flow. The projections are developed from an analysis of past and recent trends in annual estimates of interprovincial migration. The analysis is done using three main measures: net migration levels, out-migration rates, and origin-destination proportions.

Multiregional Migration Model

The multiregional migration model requires as input assumed age-sex specific out-migration rates and origin-destination proportions. The rate and proportion method has four basic steps. First, projected crude out-migration rates and origin-destination proportions are developed according to a selected migration scenario. Second, corresponding age-specific rates are derived by sex from the extrapolated crude out-migration rates using the Rogers-Castro parametric model (Bélanger, 1992). Third, these age-specific out-migration rates are applied to the corresponding provincial or territorial population to yield out-migrants by age and sex. Fourth, these out-migrants, derived by age and sex for each province and territory, are distributed as in-migrants to other provincial or territorial destinations using the projected origin-destination proportions. (In this last step it is assumed that the destination proportions do not vary by age or sex.) The application of the projected rates and proportions is illustrated by the following equations:

$$M_{xi} = m_{xi} \text{ x } P_{xi}$$

where:

M_{xi} = the total number of out-migrants from origin i by age and sex, x;

P_{xi} = the population of age and sex, x,at origin i; and

m_{xi} = the annual out-migration rates of persons of age and sex, x, from origin i.

The number of out-migrants from each area of origin is distributed by area of destination on the basis of in-migration proportions by:

$$M_{xij} = M_{xi} \text{ x } P_{ij}$$

where:

M_{xij} = the number of annual out-migrants of age and sex, x, moving from area i to area j (origin-destinations flows);

M_{xi} = the number of annual out-migrants of age and sex, x, from area i; and
P_{ij} = origin-destination proportions, from area i to area j, where Pij = 1 for any i.

In the previous projections, migrants by age and sex were derived after the total number of out-migrants was obtained, based on age-sex distributions that reflect current, not projected, age-sex specific migration rates (Statistics Canada, 1985 and 1990). The direct use of projected age-sex specific rates in the 1994 projections is an improvement over the earlier approach (Bélanger, 1992; Norris, 1994).

Because of the large degree of uncertainty with the levels of net internal migration, the practice has been to develop three scenarios or assumptions of interprovincial migration (e.g. “east/central”, “west” or “average” scenarios). Both subjective and statistical guidelines were used in the development of the migration assumptions. In addition to the analysis of past trends, along with the use of forecasts and confidence intervals, Statistics Canada also consults the statistical focal points of each provincial and territorial government, which supply their preferred range of net migration. Thus, the forecasting procedure is basically a combination of time-series analysis, and subjective procedures. For the 1994 projections, the ARIMA-based long-term forecast and 68% confidence intervals of net migration, although not directly implemented, served as useful statistical guidelines, in combination with inputs from the statistical focal points (Statistics Canada, 1994).

Except for the 1979 projections which had four assumptions, three assumptions have been developed in all the projection sets in order to provide a range of net migration for each province or territory. Of the three scenarios of net migration provided for each province/territory, one provides the high scenario, a second the low scenario, corresponding to either the “central” or “west” scenario depending on the province, and a third, generally an average of the two, provides the medium scenario (for further details, see Statistics Canada, 1994; and 2001a).

Choice of Projection Series

Following the policy stipulated by Statistics Canada, more than three series of projections have been selected for publication purposes in all the six generations of projections. The number of series varied between four and five (see Table 3).

The combinations of three fertility, three mortality, three immigration and three interprovincial migration assumptions in the 1994 and 2001 projections yield 81 possible projection series for each set. Four projection series were finally selected from these subsets for publication purposes in 1994 and 2001 (Statistics Canada, 1994 and 2001a).

The combination of the four selected projections consists of: two high-growth scenarios, using the highest or maximum growth possible for each province and territory; the medium-growth scenario; and the low-growth scenario with medium internal migration for all provinces and territories.

The selection was made on the basis of a variety of considerations, the primary one being the need for a combination of assumptions that would reflect a continuation of current trends. With this objective, the medium scenario which incorporates the most recent course of events (Projection 2) was first selected. The other scenarios are intended to reflect possible deviations from the medium scenario. They were selected to provide a plausible range of growth possibilities in each province and for Canada as a whole.

At the national level, Projection 1 is a low-growth scenario, Projection 2 is a medium-growth scenario, whereas Projections 3 and 4 are high growth scenarios. For each province/territory, there is a low-, medium-, and high-growth scenario, with an additional one usually close to either the medium- or high-growth scenario (Statistics Canada, 1994 and 2001a).

Special/Customised Projections

In addition to the population projections by age and sex for Canada, and the provinces/territories, Demography Division of Statistics Canada has been developing special/customised population projections on a cost-recovery basis. From a methodological point of view, the main projections prepared under this program are Registered Indian population projections for the Department of Indian and Northern Affairs and Development (DIAND); projections of Employment Equity Groups (women, aboriginal population; visible minorities; and disabled population); population projections for sub-provincial areas such as census metropolitan areas (CMAs); provincial counties/regions, etc. (see George, 1999).

Although the cohort component approach is the principal forecasting approach used in these projections, several supplementary methods have been employed in adjusting the data used, and in the component projections. These include the ratio method and a variety of extrapolation and interpolation techniques.

The first CMA short-term (5-year horizon) total population projections for the 25 CMAs were prepared using a ratio method. This method was replaced by a cohort-component approach for the next round of CMA projections, analogous to the one used for population projections for Canada and the provinces.

The most comprehensive special population projections series for population groups developed are the four generations of projections for Registered Indians (1985; 1990; 1993; and 1998), which use the unique data source provided by the Indian Register System. The Indian Register is a continuous registration system where all vital events affecting the population are recorded. The data, however, have limitations (i.e., late reporting and underreporting of events) that seriously distort the demographic indices directly calculated from them. Hence, the data need to be evaluated and adjusted using appropriate demographic techniques before using them for projection purposes (for details see Loh, Verma, et.al, 1998).

For the Employment Equity Data Program, projections have been prepared for three groups for a period of 25 years by age and sex: The Aboriginal Population (Statistics Canada, 1995); Visible Minorities (Statistics Canada, 1996); and Persons with Disabilities at Work (Statistics Canada, 1996). Except for the projections with disabilities at work, a cohort-component approach has been used with a variety of techniques for projecting the components of growth. For the projections of persons with disabilities at work, by sex and age (15-64) for Canada, provinces/territories, the method used is a "derived projection approach". This involves applying projected age-specific disability prevalence rates to the corresponding projected population of working ages (for details see Michaud, George and Loh, 1996).

The other ad hoc special population projections for sub-provincial areas were prepared using a combination of the cohort-component approach and the ratio method (for details of these projections, see George, 1999).

Accuracy in Population Forecasting

The dismal record of population projections, especially those made in the 1940s by eminent demographers had made the evaluation of projection accuracy an unpleasant exercise. However, as Grauman (1954) states, "publicised failure frankly discussed carries the seeds of eventually greater success". Such positive thinking may have prompted the recommendations made in projection-related meetings to make projection evaluation an integral part of the projection programs of national statistical agencies (United Nations, 1981 and 1999).

Before discussing the design and type of evaluation studies, it is important to note the following basic rules which apply to all forecasts: (1) the shorter the projection period, the more reliable the projection is likely to prove; (2) the larger the geographic area being projected, the more reliable the projection is likely to be; (3) the lower the current fertility rate and the higher the prevailing life expectancy, the greater will be the reduction in the projection's likely margin of error. This is based on the idea that future change in vital rates in such situations is likely to be much less than the situations with high fertility and high mortality.

Keeping these basic rules in mind, one can consider three kinds of evaluation of projection results (Inoue, 1980): external examination; internal examination; and ex post facto evaluation. External examination means comparison of the projection results with the benchmark data and independent estimates in order to verify consistency of the projection with the demographic situation of the country based on available information. Internal examination involves closer scrutiny of details of the projection results such as sex ratios, growth of numbers by age groups, etc. Ex post facto examination consists of checking the performance of projections with observed actual trends in total population by components and by age.

Evaluation of projections generally means ex post evaluation of results. To measure export accuracy, it is important to: (1) establish which scenario(s) to evaluate (medium, high, low, or all of them); (2) select an appropriate method; and (3) determine which demographic variable or component is to be evaluated (fertility, mortality, migration, etc.; age groups).

The most common measures of accuracy used for projection evaluation are the mean percentage error (MPE), and the root mean square percentage error (RMSPE). These measures have been used in a number of recent studies (Keilman, 1990, Long, 1988; Keyfitz, 1981, George and Nault, 1991).

As shown in Table 1, several occasional population projections at the Canada level were published before 1972. Five of these were evaluated for their accuracy in terms of population size, age and sex, and components of growth. The evaluation results show that the root mean square of total population size varied between 0.1% and 10% over a 15-year period, and that the errors varied widely over the age spectrum. Errors in the projections are unevenly distributed over a 15-year projection period (for more details see George and Nault, 1991). Further, the recent projections are more accurate than earlier ones. The greater inaccuracy in the earlier projections could be attributed to their failure to anticipate the post-war baby boom, the understatement of fertility assumptions during the forties, and overstatement during the declining phase of fertility since 1959.

The reports of 1994 and 2001 projections provide an ex-post evaluation of the accuracy of four population projections in Canada prepared since the 1970s (1974, 1979, 1985 and 1990). The two analyses show that the actual population size falls within the projected range of the four sets. The results by age and sex show that the projected figures over a 15-year period are close to the “actual” population (Statistics Canada, 1994 and 2001a).

Given the poor record of past performance in general and the uncertainty associated with the underlying components of demographic change in particular, inaccuracy is unavoidable in population projections. One common way of handling this uncertainty is to publish more than one series of projections. The concept of inaccuracy becomes less meaningful when several series of projections are offered. They are designed to encompass plausible future trends in the components of growth. The high and low projection series can be considered a kind of confidence interval, perhaps of two-thirds probability, one in three between “Medium” and “High”, and one in three between “Medium’ and “Low” (see Keyfitz, 1977).

Conclusion

This overview of the state of the art in population forecasting in Canada shows its long history of seventy years. However, systematic projection work on a regular basis has been advanced since 1970. Overall, great strides have been accomplished in the population projection field by the Canada's Federal Bureau of Statistics.

The population projection programme is now established as part of the wide range of the Bureau's statistical activities. Unlike in the earlier days, when forecasting by the Bureau was regarded with some misgiving as an exercise in "crystal gazing", projections are now viewed by the governments, both federal and provincial, and by the public at large as legitimate, and a desirable statistical function of the Bureau.

There is now a much better understanding of what population projections are, their purpose and their nature, their potentials but also their limitations. We no longer claim to *predict* the future, even though users may take it as such. What we strive is to produce *analytically credible* assumptions about the future course of the population growth components and derive plausible numerical scenarios of the future population. This does not at all devalue their usefulness. Their usefulness as aids in *managing* the future is increasingly recognised by the government agencies and business corporations alike, and this translates itself into a growing market for projection products. In addition to the regular projection, at national and sub-national levels, there has been in recent years a growing market for custom-made projections to meet users' specific needs.

It is in the projection methodology and modelling that great progress has been achieved. While cohort-component approach has been the mainstream method used historically and is currently used for producing projections, significant methodological innovations have taken place in recent years. The traditional cohort-component method has evolved into a multiregional hybrid bottom-up approach for simultaneously developing population projections by age and sex for the provinces/territories and Canada. It also incorporates multiregional migration method for internal migration projections. Further, there has been substantial methodological modification and refinement in the component projections over the years, especially with the parametric approach, in mortality and fertility projections. The current parametric approaches for these two components use a limited number of parameters, and have enhanced the operational and analytical capabilities of the model. The outcome of the parametric modelling along with the computerisation of the operations was the improved timeliness, lower cost, and above all the Bureau's capacity to respond effectively to growing demand for regular national and subnational, and custom-made projections. The Bureau's projection products, which are scientifically reproducible, enjoy public trust, the users' community acceptance for its highly professional craftsmanship.

Population forecasting continue, however, to have its shortcomings and limitations. One of the principal deficiencies of forecasting in general is its judgmental aspect whether in the selection of the appropriate time series, in the choice of component assumptions, or in the choice of independent variables for any explanatory analysis. The elaboration of well-founded demographic projections incorporating the existing demographic theories is not an easy task due to their limited predictive power (U.N., 1979). Research has not sufficiently advanced to incorporate into projection models complex interrelations of demographic, economic, and social factors, both because of their complex nature and difficulties of measurement. As Keyfitz (1991) states “the best one can say of most projections is that they are made by conventions to which we are habituated, that at least are not self contradictory, and to which demographers and their clients typically raise no objections”.

On a more general note, as Romaniuc (1999, p. 9) concludes it: " With all the progress made in the arts of forecasting we may not be closer, it must be conceded, to predict the future. The future remains as opaque and elusive to the forecaster's eye as ever. But we succeeded in having greatly enhanced the wherewithal designed to *manage* the future. Today we have a wide range of tools of various degree of sophistication to chose from, depending on particular future-oriented task at hand" (1999).

As we are about to enter a new century, with all its great potential for human development, what are the challenges we face in the field of population forecasting? Life itself will bring about new issues and problems that one cannot yet anticipate. But we are already witnessing important demographic developments emerging on the horizon which will challenge analysts' and forecasters' skill and foresight. As in many western countries, Canada's fertility rate has settled at the below-replacement level with the ageing of population and demographic deceleration as its corollaries. The country will have to rely increasingly on immigration for its growth. With the increasing ethnic and cultural diversity of Canada’s population and its social and economic regional disparities, the demand for sub-population projections - ethnic, linguistic, elderly etc. - is expected to escalate. A variety of cost-effective, user-oriented projections will be a priority to meet this potential demand. And there is more to expect. Despite the inability in the past to integrate explanatory theories into the projection model to forecast with greater plausibility the components of population growth, research in this area must continue with the help of fast advancing computer technology. This will entail increased projection-focussed in-depth analytical research and modelling.

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