I. GENERAL CONSIDERATIONS

A. Purpose and scope of the manual

1. There is little need to emphasize the importance of future population estimates for countries attempting to plan their economic and social development. The primary needs of the people, which the development programmes aim to satisfy, cannot be gauged rationally without regard to the expected size and composition of the population, nor can the national resources be appraised adequately without considering labour, the supply of which depends primarily on population size and structure. If no estimates based on systematic analysis of population trends are available, the planners can only proceed with more or less vague assumptions or notions concerning the magnitude of needs and resources.

2. In spite of their importance, future population projections are rarely attempted in countries that do not have well-developed statistical apparatus furnishing detailed current information on population changes. One reason is that these countries generally also lack statisticians with much training and experience in the analysis of population trends, but there is also a mistaken idea that projections can only be useful if they are based on very detailed and accurate vital statistics and census materials. This idea reflects a misconception of the practical role of estimates as guides to action. Better statistics undoubtedly make better estimates possible, but any estimate, and especially one relating to the future, contains an element of uncertainty which cannot be overcome, no matter how abundant the statistical information on which it is based. A careful appraisal of the available statistics, even though they are fragmentary and defective, can yield future population estimates that have practical utility for planners, just as weather forecasts, fallible as they are, have a practical value for farmers even in areas where the most modern meteorological services have not been developed.

3. The making of future population estimates for countries with deficient statistics has been hindered also by the fact that rather little attention has so far been paid to the development of methods that are suitable for this purpose. The aim of this manual is to help in overcoming this difficulty, primarily by explaining the methods which have been developed by the United Nations staff for calculating future population estimates for various countries of the world, including those where demographic statistics are scanty and imperfect.

4. The estimates prepared by the United Nations staff are being published in a series of reports for the countries in various regions, two of which have been issued to date.[1] The methods employed for these projections have a wide range of usefulness, but many problems arise in their application to any particular country. In this manual, the methods are described in detail and their application under various conditions is illustrated. A specific example is presented and carried through all the successive steps in the making of a population projection.

5. As a preliminary to the detailed description of these methods, to be set forth in the subsequent chapters, a brief summary of the general principles of future population estimates, and alternative methods of computing them, will now be presented.

B. Principles and methods in the calculation of future population estimates

1. *General principles*

6. It should be explained to begin with that not all calculations concerning possible future population trends are intended to provide estimates of the most probable future numbers. It is sometimes useful, for example, to calculate the growth of population that would result from the continuation during a specified future period of the current fertility or mortality rates, or from the admission of a stated number of immigrants; or to determine the rates of fertility, mortality, and migration that would be required to achieve a population of a stated size within a given length of time. Such calculations, made without regard to the probability that the stipulated conditions of fertility, mortality, or migration will actually materialize, may be very helpful in evaluating the merits of various proposals relating to population policy. This manual is not concerned with calculations of this variety, but with efforts to make the best possible estimates, in the light of available information, as to the size and composition of the population to be expected at a given future date.

7. Formerly, many scholars believed that a relatively simple "law" of population growth might be found which would suffice to predict future changes in almost any circumstances. The attempt to find such a formula has now been generally abandoned, since the accumulation of observations has shown that experience generally conflicts with any such theoretical expectations. As recently as the 1930's and early 1940's, it was nevertheless believed that future trends in any given area could be fairly reliably predicted on the basis of a careful study of detailed statistics relating to the current situation and past experience in that area. Unforeseen changes in the birth rates of many countries during the 1940's greatly undermined this confidence, and for a time caused many persons to question the utility of any future population estimates. It is now more generally realized that, while there can be no certainty in estimates of future population trends, they can serve a useful practical purpose by indicating the approximate numbers that appear most likely to be attained, in view of the information available.

[1] *The Population of Central America (including Mexico), 1950-1980,* and *The Population of South America, 1950-1980.* (Population Studies, No. 16 and No. 21.)

8. It is common to present two or more alternative estimates representing "high" and "low" expectations of future population growth. Of course, the purpose of any estimate would be defeated if it were attempted to make the alternatives embrace the entire range of possible future events. For practical purposes, the possibility of catastrophic events, such as a war or natural calamity, or the sudden appearance of important new factors without parallel in the current situation or past experience, has to be neglected, although it must always be recognized that such possibilities exist and that the trend of population growth may consequently be very different from anything which could have been foreseen. Within the framework of present and past experience, it is desirable to choose the upper and lower limits in such a way that the future trend will more probably lie between these limits than outside them. The limits may be revised from time to time in the light of changes being observed in the current situation.

9. There are numerous possible methods of calculating future population estimates in accordance with the principles stated above. Some of these are briefly cited in the following pages. Detailed description of them would be outside the scope of this manual, but a brief discussion will help to make clear in what situations the methods developed by the United Nations staff can be used with advantage.

2. *"Mathematical" methods*

10. The simplest method of estimating the future size of a population is to take the number of individuals as determined at a more or less recent date in the past and to apply to it an assumed rate of increase, as a function of time.[2] The rate may be derived from observations on the past growth of the population itself or by analogy with rates observed in other populations in similar circumstances. The calculations can be carried out directly with reference to the net rate of population growth, or the assumed birth rates, death rates, and rates of immigration and emigration may be calculated separately and added to obtain the rate of growth for each future period. Methods of this type are called "mathematical" because emphasis is placed upon the formulation of equations as expressing the rates as functions of time, instead of on particular factors which may influence the trend during any specific time period. However, all population projections embody this same principle at least in some degree. The really distinguishing feature of a "mathematical" projection lies in the fact that calculations are applied to the figure of total population only, rather than to population segments, or relations between the population and its environment. Nevertheless, subsidiary estimating techniques have been devised for dividing "mathematically" projected figures of total population according to sex, age, or other characteristics.

11. Not all "mathematical" projections are simple. Very elaborate methods have been invented for specific purposes. It is often assumed that population growth does not proceed at a constant rate but at varying rates, determined by a curve of regular form. The curve most widely use is the logistic growth curve. This curve represents a trend of growth with increasing annual increments until a point is reached where growth is at a maximum; beyond that point, growth diminishes until it becomes negligible. The logistic and other curves can be computed on the basis of population totals observed at various dates in the past.

12. At one time, certain scholars believed that the logistic curve expressed a universal biological law of growth. In fact, various biological phenomena, including the past growth of several human populations, have been found to follow a trend more or less closely resembling that of the logistic. However, since human behaviour changes constantly as a result of deliberate action, it should not ordinarily be expected that the growth of a human population will conform to a precise mathematical formula. Though no longer accepted as a universal law, the logistic curve is still employed in some population projections, since it usually portrays a trend which is at least within reason. Various adjustments have also been devised for modifying the shape of the logistic curve to achieve greater conformity with observed past trends.

3. *"Economic" methods*

13. Population growth can seldom, if ever, be expected to be completely independent of changing economic circumstances. Within limits, mortality and fertility are responsive to economic conditions. The same is true of migration; immigrants are attracted to areas of economic opportunity, while emigrants depart from areas where opportunities are more restricted. Within limits, a government may be able, by means of economic incentives and deterrents, to relate migratory movements and even the natural growth of the population to an economic plan.

14. A projection by "economic" methods is most obviously appropriate for an area subject to easy, unrestricted in-migration and out-migration, where an important new industry is being established which will dominate the economy of the area. The assumed future capacity of this industry to absorb labour is then the primary determinant of population growth. To this amount of labour, a certain multiple must be added to represent dependants, as well as the additional workers in subsidiary industries (trade, service, etc.) who will be required in the expanding community. The "economic" method can likewise be applied to an industrial area of free inward and outward movement where industrial employment opportunities are expected to change greatly. Under certain conditions, anticipated housing development may be regarded as a primary factor of expected population change. Expected changes in income, education or social status may also be listed among the factors influencing future population growth.

4. *"Component" projections*

15. The "component" method of population projections is usually understood to consist in the separate projection of numbers of males and females in each age group of the population. Separate projections for each of several ethnic or linguistic groups, of urban and rural

[2] This method is most frequently used in making current, or post-censal, estimates of total population. Its uses are discussed in *Methods of Estimating Total Population for Current Dates* (Manuals on methods of estimating population, No. I), ST/SOA/Ser. A, No. 10, United Nations, New York, 1952.

populations, or any other segments into which the population can be divided, might also be regarded as "component" projections.

16. It is most convenient to project the population by time-intervals equal to the age-intervals into which it has been divided. Thus, if the population is subdivided by five-year groups of ages, the projection can most easily be made for five-year intervals of time: at the end of a five-year period, all surviving members of one age group will have moved into the next subsequent age group.

17. The number of survivors from one date to another is calculated separately for each sex-age group by specific mortality rates selected for this purpose. Hence, the assumptions regarding mortality must be detailed enough to permit the derivation of survival ratios separately for each sex and age. Future mortality may be assumed either to be constant or to conform to some assumed trends. If the projection is made for five-year intervals of time, multiplication of original numbers in each sex-age group with the five-year survival ratios for each of these groups results in estimated numbers of persons five years older at a date which is five years later. Repetition of the procedure yields the estimated population aged ten years more than at the base date which should be expected ten years hence, and so forth.

18. An additional procedure is required to estimate the future numbers of persons not yet born at the base date. Fertility can be defined in several different ways and its probable future trend can be estimated under a variety of assumptions. Usually, the number of children to be born in the future is conceived as a function of the number of women of various ages, but there are situations in which a different relation of births to women appears more pertinent. The number of children surviving to the end of a given time-interval is determined by multiplying the number of births expected during the interval with the appropriate survival ratio.

19. The effects of immigration and emigration can also be calculated, on the assumption of a certain volume of future migration, divided according to sex and age, with the use of appropriate survival ratios and assumptions as regards the fertility of the migrants.

20. Sex-age projections like these can also be made by single years of age and for various intervals of time. The procedure is reversible, permitting an estimation of the population in the past, by sex and age. Many theoretical applications of this method are possible, since it permits calculation of changes in age structure of the population which result from any combination of hypothetical assumptions as regards the initial age structure, mortality, fertility and migration.

21. "Component" projections of a population with respect to characteristics other than sex and age do not require any departure in basic method. The procedures for the projection of any one population segment can very well be identical with those for projecting the combined population, except where transfers and interactions between one segment and another must be taken into account, as in the case of changes of religion on the part of individuals, mixed marriages between ethnic groups, or migration between the rural and the urban habitat.

5. *Relevance of various methods to different situations*

22. Each of the three types of methods reviewed involves some basic assumption without which its use would not be justifiable. The implicit conditions might be stated as follows.

(*a*) The use of a "mathematical" method presupposes that the trend of total population growth is fairly regular and that relevant features of the economic and social setting of the future will be the same as those of the past, or will represent the result of a gradual evolution. Consistent trends of change can reasonably be expected in populations with fairly regular age composition where the social and economic environment exerts a steady or only gradually changing influence. "Mathematical" methods are not appropriate for use where the present age structure of the population exhibits marked peculiarities. Moreover, where important and rapid changes in social and economic conditions relevant to population growth can be expected on grounds of current indications or the previous experience of other populations similarly situated, it is not appropriate to use a "mathematical" method that implies the continuation, without modification, of the growth tendencies observed in the past. In such cases, it may be possible to devise a "mathematical" method which takes account of the expected changes in conditions—for example, with a future arithmetic or geometric rate of growth assumed to be higher or lower, in a certain ratio, than the rates observed in a past period. The logistic curve, however, does not readily lend itself to such modifications.

(*b*) The use of an "economic" method is justified where some major economic variable, such as the rise or decline of an industry, can exert an overriding influence on population change, particularly through migration. Birth rates and death rates are only moderately responsive to economic change, since they depend also on a variety of other factors in the cultural and social environment, some of which are statistically imponderable. The "economic" method is most pertinent where migration is sufficiently free of legal barriers or other impediments to become a major element in the trend of population.

(*c*) The "component" method is superior to "mathematical" methods in that it involves a separate analysis of the changes affecting each component of the population.

23. If plausible assumptions can be made with respect to each of a number of population segments, the risk of error in the resulting total is thereby decreased. Furthermore, useful information is then obtained with regard to expected future changes in population composition. Unfortunately, statistical information is often not sufficiently detailed or accurate to permit the formulation of the specific assumptions needed in the projection of each component. Some populations are not large enough to permit the expectation of regularity of trends in each of their components. Accurate and detailed statistics relating to sex-age composition, mortality and fertility of migrants are particularly scarce; this is an impediment to "component" projections, particularly where migration is likely to have substantial effects; trends of migration, moreover, are notorious for their irregularity.

24. It follows that a "component" method is generally preferable to others except where there are important obstacles to its application (inaccuracy or lack of detailed statistics, smallness of the population), or where an economic or other factor in the environment assumes an overriding importance, with its influence exerted primarily through migration. If one or more of these reasons prejudice the use of a "component" projection, then a "mathematical" or "economic" method is to be preferred, depending on the conditions of the particular case. Sometimes a combination of two or more methods yields the best results.

C. Principles underlying the methods developed by the United Nations staff

25. The methods developed by the United Nations staff have as their main objective to facilitate the making of "component" projections for as many countries as possible, including those where the available statistics are defective in several respects. In the latter instances, the procedures include the use of certain general schemes by which the missing figures can be approximated. Since the projections themselves are in the nature of estimates, they are still justified where a part of their statistical basis is likewise estimated. The latter estimates should, of course, be realistic.

1. *Brief summary of the methods*

26. Two types of procedures are involved in these methods. One set of procedures has been devised for the purpose of estimating those elements in the *current,* or recent, sex-age distribution of the population, or its rates of fertility and mortality, for which the available statistical documentation is not adequate. Another set of procedures consists in the evaluation of probable *future* trends in fertility and mortality and the calculation of their effects on the size and composition of the population.

27. The current structure of a population is the result of past rates of fertility, mortality and migration; these same factors will also determine the future size and structure of the population. The three elements of population change, however, cannot all be evaluated with the same degree of confidence. Comparatively speaking, future mortality trends can be treated with the greatest and future trends in migration with the least assurance, while the degree of confidence with which fertility can be predicted is of an intermediate order. The difficulties of statistical analysis of these three factors also vary in the same order. Mortality is readily represented by death rates according to sex and age,[3] which have usually exhibited fairly stable trends.[4] Birth rates according to age of mother are easy to compute where the data required are available, but are not in all instances the most pertinent indicators of fertility.[5] The volume of a migratory movement and its distribution by sex and age can often vary abruptly; the available statistics of migration are very deficient in many cases; moreover, there is very little knowledge concerning the rates of fertility and mortality among migrants.

28. The numerical importance of the three factors of population change is also different. Disregarding some of the more extreme cases, we find that the birth rates in most populations now lie between 18 and 50 per 1,000 inhabitants; death rates of most countries range between 8 and 25; and there are now few countries where the annual rate of net immigration or emigration even approaches 10 per 1,000 inhabitants. By and large—though not in every single instance—fertility is most important, mortality is second in importance, and migration is the least important factor of population change. Trends in fertility, however, cannot usually be estimated with as much assurance as trends in mortality.

29. Because of these considerations, different principles had to be adopted in the treatment of each of the three demographic factors.

30. The comparative stability observed in mortality trends makes it possible to estimate future mortality rates with the smallest risk of error. Such errors as may be made, moreover, do not have a very great effect on the future population estimates, since the magnitude of mortality is generally of less importance than that of fertility. It was therefore found sufficient to base the estimates of mortality, current and future, on some generalized scheme in which various patterns of mortality rates and changes therein are reflected. This scheme, which has been elaborated on the basis of actual past experience in death rates, constitutes the backbone of the methods, as will be shown later.

31. The greater instability of fertility trends and difficulties in their measurement involve more serious risk of error, especially in view of the fact that fertility is usually the most important element of population change. Some procedures have been developed which permit the computation of a fairly simple yet sensitive index of fertility even in the absence of accurate, detailed statistics. As regards its possible future trend, reasoned judgement must be exercised in each individual instance. Moreover, it is considered necessary to make more than one assumption as to future changes in birth rates in each country, and to compute the effects of plausible "high" and "low" expectations of future fertility.

32. In the case of a population which has not been subjected to major changes in its vital rates or to large changes through migration, the sex-age structure, the rates of mortality and the rates of fertility constitute a system in which a measure of any two factors is sufficient to determine the third. If the rates of mortality and fertility are known, the resulting age structure can be computed. Given a certain age structure, a certain level of mortality corresponds to a certain level of fertility, and *vice versa.* Various factors such as irregularity of past trends, migration, and inaccuracies in the data usually interfere so that the system cannot be reconstructed perfectly. Nevertheless, these relationships often permit the estimation of certain factors given the remaining factors, or fairly reliable estimates of the latter. The scheme of mortality rates already referred

[3] Mortality of different social groups, and according to causes of deaths, though relevant, would introduce an unwarranted degree of refinement for the purposes here contemplated.

[4] A sudden rise or sharp fall in mortality may sometimes occur in connexion with rather extraordinary events. Such events, however, are not within the sphere of projections.

[5] Other relevant indicators are birth rates by duration of marriage and/or by number of children already born to the same woman. The relevance of these and other fertility measures varies in different situations.

to, in combination with statistics of the population by sex and age, often permits a fairly reasonable estimate of the level of fertility.

33. The combination of one assumption as to future mortality trends (derived from the general scheme) with two or more assumptions as to future fertility results in population projections which differ only in respect of those future age groups whose members were still unborn at the base date from which the calculation proceeds. Thus, if the computation departs from the year 1950, alternative projections for the year 1960 are obtained for children less than 10 years old; persons aged 10 years or more, however, are estimated uniformly, irrespective of fertility.

34. Because of the great uncertainty attached to future migration, it is advisable in any case to compute first a population projection in which the possible effects of international movement are not taken into account. Such a projection will suffice for a country in which migration is not expected to have much importance. For other countries, separate treatment of the migration factor is useful because the expected effects of migration can then be singled out and assessed separately from the natural growth of the resident population.

35. Since comparatively little is known concerning the composition and vital rates of migratory contingents, the effects of only one characteristic type of international movements have been worked out in detail for the United Nations estimates. These calculations constitute a model which, with suitable modifications, can be applied in certain analogous situations.

2. *Relevance of generalized assumptions to actual situations*

36. It is plausible to assume, where there is no specific indication to the contrary, that the trend of a given demographic factor in a certain instance will correspond to a general pattern which has been observed in other instances. For example, unless there is some reason to suppose otherwise, the mortality rates of a particular population may reasonably be assumed to decline in the future at a rate representing estimated average expectations of mortality decline throughout the world, according to recent experience. This assumption is probably better than one of constant mortality, in view of the almost universal experience of decreasing mortality in modern times. Likewise, where it is not possible to assess specific factors which might affect the trend in fertility, the best that can be done is to roughly evaluate the type of situation that exists in the given country and to assume that future developments will be like those observed elsewhere in similar situations in the past.

37. The procedures suggested here would be misused if they were applied as a rule of thumb in every situation, without regard to such pertinent information as could be obtained with regard to each case. In each instance, before the application of these procedures is considered, all available information relevant to the situation and prospects in the given area should be studied. Very often the result of such a study will be a departure from or modification of the generalized assumptions.

D. Arrangements of the detailed description of the United Nations methods

38. The calculation of a population projection by the "component" method requires, first, the establishment of base figures for the population, classified by sex and age groups, at the date from which the projection departs. The problem of establishing these base figures is discussed in chapter II. With these figures as the starting point, projections are carried out by means of estimates of current fertility and mortality rates and assumptions as to their future trends. Chapters III, IV, and V deal with the techniques of estimation and assumptions concerning these factors of population change, and chapter VI describes the method of computing a projection when these factors have been established.

39. In most situations, the treatment of the mortality factor involves the use of certain life-table functions. Model life-tables containing these functions are tabulated in appendix A, and the concepts involved are explained in chapter III. Chapter IV deals with the application of these and other functions in estimates and assumptions relevant to the mortality factor. Estimates and assumptions pertaining to fertility are taken up in chapter V.

40. Chapter VII describes how the effects of international migration can be taken into account in a population projection. A model, representing characteristic effects of transoceanic movements, is tabulated in appendix B. Methods for developing an alternative model, when needed, are also described.

41. Chapter VIII deals with efficient modes of presentation and with provisions for quick revision of figures, which should be considered when the results of a projection are being published.

42. Various illustrative examples are presented in the text of each of the chapters. In each case, the examples were selected to illustrate the use of a particular procedure that is pertinent if the statistics or demographic trends are of a certain kind. In addition, in order to give a concrete illustration of the entire series of operations required for an estimate of future population, at the end of each chapter one example is carried through all the stages. For this example, a projection of the population of Costa Rica was chosen. Many other national populations for which at least a certain minimum of statistics exists could reasonably be projected by the methods applied to Costa Rica, though not always by the same detailed procedures.

43. An examination of the statistics of Costa Rica indicates that they are of an intermediate order of detail and quality. The data are not as accurate or abundant as the statistics of some countries of Western Europe, Northern America, Australia and New Zealand. On the other hand, especially since the taking of the 1950 census, statistics on the population of Costa Rica are considerably more advanced than the data for many populations to which the methods described here are also applicable. The example selected may be regarded as one which illustrates the "average" conditions under which the present methods can be used with advantage.