# VII. PROCEDURES TO ESTIMATE AND PROJECT THE POPULATION OF URBAN AREAS AND URBAN AGGLOMERATIONS

The estimation and projection of the urban population is based on observed changes in the proportion of the population living in urban areas. Therefore, the quality of the estimates and projections made is highly dependent on the quality of the basic information permitting the calculation of the proportion urban. Such information consists normally of complete counts of both the total population in a country and the total population living in urban areas. Censuses or population registers are the most common sources of those counts. To be accurate, the proportion urban should be based on counts of the total and the urban population that achieve similar levels of coverage and that reflect properly the division of the territory into urban and rural areas. However, because of the complexity and variety of situations in which the urbanization process has taken place, it is not always straightforward to divide the inhabited territory into urban and rural areas. Indeed, the criteria used to identify urban areas vary from country to country and may not be consistent even between different data sources within the same country. Furthermore, as the process of urbanization proceeds, the number and extension of the areal units qualifying as urban generally expand, so that keeping an urban vs. rural division of the territory constant over time would be misleading and would likely result in a major underestimation of the actual proportion urban.

In preparing estimates and projections of the urban population, the United Nations relies on the data produced by national sources that reflect the definitions and criteria established by national authorities. It has long been recognized that, given the variety of situations in the countries of the world, it is not possible or desirable to adopt uniform criteria to distinguish urban areas from rural areas (see, for instance, United Nations, 1967 and 1969). Thus, stipulating that any areal unit with at least 5,000 inhabitants, for instance, is to be considered urban is not appropriate in populous countries such as China or India where rural settlements with none of the characteristics typical of urban areas often have large numbers of inhabitants. Clearly, national statistical offices are in the best position to establish the most appropriate criteria to characterize urban areas in their respective countries.

The urban and city projections presented in this report are based on the definitions used for statistical purposes by the countries and areas constituting the world. Those definitions have been compiled and appear in chapter VI. An analysis of the definitions used to distinguish urban areas from rural areas shows that 97 of the 228 countries or areas of the world use administrative criteria to make such a distinction. Thus, in 56 cases urban areas are equated with the capitals of provinces and in a further 41 they are defined as regions under the jurisdiction of certain types of local authority. However, among the latter, the definitions provided are often imprecise, referring to the generality of “urban centres”, “towns with proclaimed legal limits”, “localities designated” or “cities, urban agglomerations and urban communes”. In 96 cases, the criteria used to characterize urban areas include population size or population density. However, the lower limit above which a settlement is considered urban varies between 200 and 50,000 persons. This variation reflects the fact that in sparsely settled countries or in more developed countries, human settlements can have urban characteristics even if their number of inhabitants is lower than that of rural units in densely settled developing countries. Thus, there is little homogeneity in the identification of urban settlements in terms of population size.

Economic characteristics are used as the determining criteria to identify urban areas in 25 countries or areas, including all the successor States of the former Union of Soviet Socialist Republics. For instance, areal units where most of the labour force is employed in non-agricultural activities are considered urban. Criteria related to the functional nature of urban areas, such as the existence of paved streets, water-supply systems, sewerage systems or electric lighting, are taken into account in 15 cases, often in combination with other type of criteria. Lastly, in 22 cases no definition of “urban” has been supplied and in another 8 all of the population of a country or area was considered to be either urban or rural, depending on circumstances.

Despite the variety of criteria used to distinguish urban from rural areas and the resulting heterogeneity, no independent adjustment of national statistics is made unless it is clear that the definitions used by a given country have changed over time in ways that lead to inconsistencies in the data. Such adjustments eliminate the erratic peaks and troughs in urban growth resulting from changes in definition. However, despite efforts to avoid inconsistencies within countries, it is not always possible to adjust the data available in ways that ensure consistency. In some cases, inconsistencies remain precisely because the data needed to make the necessary adjustment are lacking. In cases where adjustment is possible, every effort is made to adjust earlier data so as to conform to the most recent definitions. Yet, in a few cases, it is necessary to use a definition different from all those used by a country in order to maximize comparability over time.

In the case of cities, population statistics are often reported in terms of the territory delimited by administrative boundaries that do not necessarily coincide with the extent of the urbanized territory as delimited by other standards. Thus, the city proper as defined by administrative boundaries may not include suburban areas where an important proportion of the population working or studying in the city lives. Furthermore, in some cases two or more adjacent cities may be separately administered, although they might form jointly a single urbanized region. Alternatively, in some cities administrative boundaries may cover large tracts of land devoted to agriculture, especially if the produce is intended for city consumption. Because of these problems it is advisable to base the measurement of a city’s population on territorial boundaries different from those established by the accidents of administrative history. Two auxiliary concepts have been used to improve the comparability of measurements of city populations across countries and over time, since they are not affected by changes in administrative boundaries. The first is that of urban agglomeration and it refers to the population contained within the contours of contiguous territory inhabited at urban levels of residential density. The second is that of metropolitan region, which entails a more extensive definition of the territory of interest. Thus, a metropolitan region includes both the contiguous territory inhabited at urban levels of residential density and additional surrounding areas of lower settlement density that are also under the direct influence of the city (e.g., through frequent transport, road linkages, commuting facilities etc.).

In compiling information on city population size, the Population Division has endeavoured to use data or estimates based on the concept of urban agglomeration. When those data are not available, population data relative to the city as defined by its administrative boundaries are used. It is recognized, however, that when the administrative boundaries of cities remain fixed for long periods of time, they are likely to misrepresent the actual growth of a city in both territorial and population terms. Only when administrative boundaries change with relative frequency can one assume that they are reflecting the actual territorial expansion of the urbanized area linked to the functioning of the city and inhabited at urban levels of population density. For a number of cities, the data available refer to both the city proper as defined by administrative boundaries and to its metropolitan area. In those instances, the data referring to the metropolitan area are usually preferred because they are thought to approximate better the territory associated with the urban agglomeration than the data based on administrative boundaries. However, the population of the metropolitan area is also likely to be larger than that of the urban agglomeration associated with it, so an upward bias is thus introduced.

For any given city, an effort is made to ensure that the time series of population estimates derived from national sources conforms to the same definition over time. Adjustments are made when necessary to achieve internal consistency. Often, the changes involved demand that the criterion on which the population of a city is based be changed. That is the case when data on a city in terms of the urban agglomeration are available for only one or two points in time and there is a longer and more consistent series of data on the population of the city proper. In those circumstances, the data on the city proper, based on administrative boundaries, are used instead of those on the urban agglomeration since a sufficiently long time series based on the latter concept is normally not possible to reconstruct from the data available. When such reconstruction is possible, it is undertaken.

In the *1999 Revision*, the city data for 106 of the 228 countries or areas considered was based on the concept of urban agglomeration. In a further 11, the data for the capital city was reported in terms of urban agglomeration or metropolitan area whereas for other cities in the same country the data conformed to the city proper definition based on administrative boundaries. For the remaining 107 countries or areas the city data available reflected the city proper definition. Adjustment of city data was carried out when information for a particular city has changed over time and, if at all possible, the urban agglomeration concept was used. However, when recent data were based on the concept of city proper and there was insufficient information to adjust it to reflect the population in the urban agglomeration, a time series based on the city proper definition was used.

### A. THE ESTIMATION OF URBAN INDICATORS OVER THE ESTIMATION PERIOD

Aside from varying in terms of underlying definitions, the data available for different countries vary in terms of their time references. Because census dates are not the same for all countries, estimates of the proportion urban or of city populations derived from census data refer to different points in time and are not directly comparable among countries. Nor is there consistency among countries in the reference dates of official estimates of urban or city populations. Consequently, to facilitate comparisons, estimates for specific points in time have to be made. Interpolation or extrapolation based on the data actually available is used to produce estimates of the proportion urban or of city populations referring to 1 July of the years 1950, 1955, 1960 etc. The most recent estimate derived in that way should refer to the year that is a multiple of five and immediately precedes the reference date of the most recent data available. From that point on, the projection procedure is used to complete the time series until 2030 for the proportion urban and until 2015 for city populations.

Given that a large majority of countries have data on the proportion urban referring to the 1990s, the numbers referring to 1990 or 1995 are usually estimates derived by interpolation between observed values. Consequently, 1950-1995 is considered to be the estimation period whereas 1996-2030 is the projection period since, for all countries or areas, the values for 2000-2030 are obtained by projecting the figures relative to 1950-1995. Clearly the more recent the latest information on the proportion urban available for a given country or area, the more likely that projections over the short-term future may approximate true trends. Among the 228 countries or areas considered in this *Revision*, for 190 (83 per cent) the most recent data available referred to 1985-1994 and, among them, 133 had data for 1990 or later. For a further 28 countries (12 per cent), the most recent data referred to 1975-1984.

The proportion of the population living in urban areas is estimated or projected, as the case may be, by country or area for the period 1950-2030 in five-year intervals. Once values of the proportion urban at the national level are established for the 1950-2030 period, they are applied to the estimates and projections of the total national population of each country or area derived from *World Population Prospects: The 1998 Revision* (United Nations, 1999) so as to obtain the corresponding urban population for 1950 to 2030. At a later stage, country level estimates and projections are aggregated to obtain the figures corresponding to regions, major areas and the world.

Calculation of the proportion urban during the estimation period involves interpolation between recorded figures and extrapolation back to 1 July 1950 when the earliest of recorded figures refer to a later date. Such interpolation or extrapolation to 1950 is based on the *urban-rural ratio (URR)*, defined as the ratio of the urban to the rural population, that is:

$$URR(t) = U(t)/R(t) \qquad (1)$$

where U(t) and R(t) denote the urban and the rural populations at time $t$, respectively. The urban-rural ratio at time $t$ is directly related to the percentage urban ($PU(t)$) since

$$PU(t) = URR(t)/[1+URR(t)] \qquad (2).$$

Letting $rur(t,n)$ denote the growth rate of the urban-rural ratio between time $t$ and $t+n$, we have that

$$rur(t,n) = \ln(URR(t+n)/URR(t))/n \qquad (3)$$

where, substituting $URR$ for its equivalent according to (1), we obtain

$$rur(t,n) = [\ln(U(t+n)/R(t+n)) - \ln(U(t)/R(t))]/n =$$
$$[\ln(U(t+n)) - \ln(R(t+n)) - \ln(U(t)) + \ln(R(t))]/n =$$
$$[\ln(U(t+n)/U(t)) - \ln(R(t+n)/R(t))]/n =$$
$$u(t,n) - r(t,n) \qquad (4)$$

where $u(t,n)$ denotes the growth rate of the urban population between $t$ and $t+n$, and $r(t,n)$ is the growth rate of the rural population between the same time points. That is, the growth rate of the urban-rural ratio is equivalent to the difference between the growth rates of the urban and the rural populations. Therefore, $rur(t,n)$ is known as the urban-rural growth difference and it is the basis for the interpolation and extrapolation of the proportion urban. Thus, if $T$ is any time point within the intercensal period ($t$, $t+n$),

$$URR(T) = URR(t)\exp[rur(t,n)(T-t)] \qquad (5).$$

The same equation can be applied to obtain extrapolated values of $URR$ when $T$ is outside the intercensal period and ($t,t+n$) is the intercensal period closest to it.

The use of (5) for interpolation and extrapolation purposes implies that $rur$ is assumed to remain constant during each intercensal period and during the period 1950 to the reference date of the second observation available. Once an estimate of $URR(T)$ is available, it can be converted to $PU(T)$ by using equation (2).

## B. PROJECTION OF THE PROPORTION URBAN AT THE NATIONAL LEVEL

The United Nations has developed a parsimonious and fairly straightforward method for the projection of the proportion urban. The United Nations projection method was first used in the 1970s (United Nations, 1974 and 1980) and, although it has undergone some revisions since then, the general estimation approach has not changed. Basically, the method projects the most recent urban-rural growth difference observed by assuming that the proportion urban follows a logistic path that attains a maximum growth rate when the proportion urban reaches 50 per cent and whose asymptotic value is 100 per cent.

Normally, an extrapolation based on a simple logistic curve would imply that the urban-rural growth difference remains constant over the projection period. Yet empirical evidence shows that the urban-rural growth difference declines as the proportion urban increases because the pool of potential rural-urban migrants decreases as a fraction of the urban population, while it increases as a fraction of the rural population. Consequently, a model for the evolution of the urban-rural growth difference was developed so that it would evolve over the projection period, passing from the last observed value to a universal norm consistent with general world-wide experience so far. The norm is expressed in terms of a hypothetical urban-rural growth difference, denoted by *hrur*, which has been obtained by regressing the initial observed percentage urban on the urban-rural growth difference for the 113 countries with more than 2 million inhabitants in 1995. The resulting regression equation is:

$$hrur = 0.037623 - 0.02604PU(t_0) \qquad (6)$$

where $PU(t_0)$ is the proportion urban at the time of the initial census.

Equation (6) implies that, as the initial level of urbanization increases, *hrur* decreases. When the initial proportion urban is zero, an urban-rural growth difference of 0.0376 can be expected; when the proportion urban is 0.5, an *hrur* of 0.0246 can be expected; and when the proportion urban is 1, an *hrur* of 0.0116 can be expected.

The projection of the proportion urban is carried out, based on a weighted average of the observed urban-rural growth difference for the most recent period available in a given country and the hypothetical urban-rural growth difference. The weights are such that the earlier the projection period, the greater the weight given to the observed *rur*. In this way, the empirical urban-rural growth difference for a country approaches the hypothetical value in a smooth way, with the country's current characteristics having a lower weight and the world norm having a higher weight the further into the future one projects.

Specifically, a weight ($W_1$) of 0.8 is assigned to the most recently observed *rur* and a weight ($W_2$) of 0.2 to *hrur* for the first projection period. With each subsequent projection period, the weight for *hrur* is incremented by 0.2 until $W_1$ becomes 0.0 and $W_2$ reaches 1.0; these weights are then maintained unchanged until 2030. The projected urban-rural growth difference, *rur**, is therefore calculated as follows:

$$rur^* = W_1 rur + W_2 hrur \qquad (7).$$

Then, the urban-rural ratio can be calculated as:

$$URR(t_2) = URR(t_1)\exp(rur^*(t_2 - t_1)) \qquad (8)$$

where $t_1$ is the last date with an estimate or a projected value of the proportion urban and $t_2$ is the next projection date. Each projected value of *URR* is converted into a proportion urban *PU* by using equation (*2*).

In order to derive the urban population at the national level, the proportion urban is multiplied by the total population of each country, obtained from the independent projections published in *World Population Prospects: The 1998 Revision* (United Nations, 1999). With respect to the estimates and projections of the urban population at the regional level, the urban populations of all the countries in the region are added up. Lastly, regional totals are aggregated to derive the estimates and projections at the world level.

## C. PAST ESTIMATES OF CITY POPULATIONS

Estimates and projections of the population of cities with an estimated population of 750,000 inhabitants or more in 1995 are calculated for the period 1950-2015 and presented for every year that is a multiple of five within that period. However, in order to carry out a more comprehensive monitoring of population growth in cities, all those reaching a population of 100,000 or more within the 1950-1995 period are considered, provided data on their population size is available from a census or population register. Furthermore, once a city has reached 100,000 inhabitants, its population size continues to be monitored even if it subsequently falls below that level, provided national statistical sources continue to report data on its population. For the *1999 Revision*, a total of 2,645 cities or urban agglomerations was considered, up from 2,361 considered in the *1996 Revision*. Because countries take population censuses at different times, the actual dates of observation vary from city to city, although they are usually identical for cities within a particular country. Consequently, just as with the estimates of the proportion urban, the first step in preparing estimates and projections of city populations consists in estimating the population size of all cities for the same dates in the past.

To estimate the population of cities on 1 July of the years 1950, 1955, 1960 and so on, the procedure used is similar to that described above for the proportion urban. However, in this case instead of using the urban-rural growth difference, the interpolation or extrapolation is based on the difference between the growth rate of a city minus the growth rate of the population of the rest of the country. Specifically, if we consider the ratio of the city population at time $t$, $C(t)$, to the population of the rest of the country, $RES(t)$, that is

$$CRR(t) = C(t)/RES(t) \qquad (9)$$

$$\text{where } RES(t) = P(t) - C(t) \qquad (10)$$

and $P(t)$ is the total population of the country at time $t$, then the growth rate of $CRR$ between $t$ and $t+n$, denoted by $rcr(t,n)$, is

$$rcr(t,n) = [\ln(CRR(t+n)) - \ln(CRR(t))]/n \qquad (11)$$

which is equivalent to

$$rcr(t,n) = c(t,n) - res(t,n) \qquad (12)$$

where $c(t,n)$ is the growth rate of the city's population between $t$ and $t$+n, and $res(t,n)$ is the growth rate of the rest of the country's population between $t$ and $t+n$. Then, the value of $CRR$ for any time $T$ within the period ($t$, $t+n$) is given by:

$$CRR(T) = CRR(t)\exp[rcr(t,n)(T-t)] \qquad (13)$$

The same equation can be applied to obtain extrapolated values of $CRR$ when $T$ is outside the intercensal period ($t$, $t+n$) and that period is the closest to $T$. Then, because the proportion of the total population living in the city at time $T$, $PC(T)$, is equivalent to:

$$PC(T) = CRR(T)/[1+ CRR(T)] \qquad (14)$$

that proportion can be calculated for time $T$ and multiplied by an independent estimate of the country's population to obtain the population of the city at time $T$. Such independent estimate is obtained from the country-level estimates published in *World Population Prospects: The 1998 Revision* (United Nations, 1999).

## D. The projection of city populations

The method used for projecting city populations is similar to that used for urban populations. The city growth rate over the most recent intercensal period is modified over the projection period so that it approaches linearly an expected value that is based on the city population and on the growth rate of the urban population as a whole. First, if (ô, ô+í) is the most recent intercensal period for a given country or, more specifically, the period between the two most recent sets of observed city populations, the city-urban growth difference, denoted by $rcu$, is calculated as:

$$rcu(ô,í) = c(ô,í) - u(ô,í) \qquad (15)$$

that is, it is the difference between the rate of population growth for the city and that for the total urban population. To project a city's population it is necessary to establish future values of $rcu$ using a model.

The model used to project $rcu$ was developed by regressing the observed values of $rcu$ for the most recent period for which data were available for each city on the logarithm of the city's population at the beginning of that period. The regression equation was fitted to the data relative to 1,982 cities located in the 113 countries that had at least 2 million inhabitants in 1995. Although the correlation between the city-urban growth difference and the logarithm of the initial population size of each city was a low 0.0077, taking account of the influence of population size on city growth dampens the growth of the largest cities in a manner that is realistic. The fitted model is the following:

$$rcu(ô,í) = 0.017089 - 0.00144\ln(C(ô)) \qquad (16)$$

where $C(\hat{o})$ is the population of the city at time ô. That is, as the population of the city increases, *rcu* Thus, if the projection period starts at time *T* and we denote by *hc*(*T*-*n*,*n*) the hypothetical growth rate of a city's population over the period (*T*-*n*,*T*), it can be calculated as follows:

$$hc(T\text{-}n,n) = u(T\text{-}n,n) + rcu(T\text{-}n,n) = u(T\text{-}n,n) + 0.017089 - 0.00144\ln(C(T\text{-}n)) \qquad (17).$$

Then, for the first projection period the city growth rate can be set to:

$$c(T,n) = W_1 c(T\text{-}n, n) + W_2 hc(T\text{-}n,n) \qquad (18)$$

where $W_1$ and $W_2$ are weights adding to 1. To start the process, $W_1$ is set to 0.8 and $W_2$ is set to 0.2. Then each is increased by 0.2 points per quinquennium until $W_1 = 0$ and $W_2 = 1$. For each city, the projection procedure begins to be applied starting at the end of the quinquennial period that contains the most recent observed data on city population size.

Projection calculations are carried out independently for each city within a country, but a further adjustment sometimes has to be made once the projected populations of all cities are available. If the aggregated projected values of the city populations of a country grow more rapidly than the total urban population of the country, a further dampening factor is imposed on the city growth rates. decreases. Equation (16) can be used recursively to calculate *rcu*(*t*,*n*) over the projection period. When this situation arises, the growth rate of each city is reduced by the following quantity:

$$\ddot{a}(t,n) = [rtc(t,n) - u(t,n)]\, TC(t)/U(t) \qquad (19)$$

where *TC*(*t*) is the aggregated population of cities whose populations are being projected at time *t*, *U*(*t*) is the total urban population, *rtc*(*t*,*n*) is the growth rate of the aggregated population of cities and *u*(*t*,*n*) is the growth rate of the urban population. That is, the growth rate of the city would be changed to:

$$c^*(T,n) = c(T,n) - \ddot{a}(T,n) \qquad (20)$$

This reduction assures that the total population of cities will not exceed the total urban population, while maintaining the differences in the growth rates among cities.

Adjustments are also made to the projected growth rates of cities when the most recent growth rate observed for a city or the hypothetical growth rate for a city is less than or equal to zero. If the hypothetical growth rate for a city is less than or equal to 0, it is set to 0. If the most recently observed growth rate for a city is less than or equal to 0, the city growth rate is set equal to the urban growth rate to start a city's projection. In all cases, however, equation (18) is used to project the city growth rate.