



# Modifications of Traditional Formulas to Estimate and Project Dependency Ratios and Their Implications in a Developing Country, Bangladesh

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## Abstract

Traditional dependency ratios based on the United Nations' old age definition ( $\geq 65$  years) appear to be an inappropriate indicator for many developing countries, including Bangladesh. Bangladesh, with a retirement age of 59 in many sectors, defines old age as  $\geq 60$  years, whereas the United Nations documents 60–64 years as working age. This study offers two modifications to the traditional formulas of dependency ratios and compares the modified measures against the traditional measures from 1975 to 2100. Using data from the United Nations and the World Bank, (i) we moved the cut-off for 'old age' to 60 instead of 65 years, considering 15–59 years as 'potentially working', and (ii) we used the economically active population instead of the entire working-age population. Using our modified calculations, the growth rate of older adults ( $\geq 60$  years) will be at its peak (4.6%) between 2020 and 2030 and continue to increase until 2085, though we will observe a negative population growth after 2055, and 2020–2040 appears to be the best time for reaping the highest demographic dividend. Compared to our modification, the traditional formula undercounted the older adults substantially, predicting a much lower demographic and financial burden. The modifications and associated estimates are important in advancing our understanding of dependency ratios in Bangladesh and have policy and practical implications in preventing the inaccurate representation of demographic and financial issues, and they are useful for planning for geriatric care, social safety nets, and healthy aging. The modified formulas may also be applicable in other countries which adopt  $\geq 60$  years as an old-age threshold.

**Keywords** Dependency ratios · Dependents · Older adults · Working-age population · Economically active population · Developing country · Bangladesh

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## Introduction

Dependency ratios are established measures of age structure worldwide, generally used to predict healthcare and social support needs for the dependents (i.e., children and older adults). An accurate estimation of dependency ratio is of particular importance for older adults, who are in need of both hospice and long-term care owing to a high prevalence of comorbidities and a lack of aged care services, especially in developing countries like Bangladesh. Dependency estimation in developing countries often remains inaccurate due to differences in ‘old age’ definitions as compared to developed countries. The United Nations uses 65 years as a cut-off for “old” (United Nations, 2019), but in developing countries, such as Bangladesh, according to the National Policy on Older Persons 2013, the line is drawn at 60 years (Bangladesh Bureau of Statistics, 2015; Islam & Nath, 2012; Miyan, 2005; Rahman, 2010). As a result, it is likely that a measure of old-age dependency that uses the United Nations’ cut-off of 65 years could be an inappropriate indicator and thus likely yields misleading results for developing countries, such as Bangladesh. The usage of such inappropriate indicators has numerous negative implications. For instance, the number of older adults will be underestimated, working-age population will be overestimated, and consequential dependency ratios will be underestimated. Thus, any developmental policy and planning associated with working-age population and older adults, e.g., food, shelter, poverty, health and care services, social security program, will be misleading.

Across the globe, the number of older adults is increasing faster than any other age group, including Bangladesh. In 2019, there were 703 million older adults ( $\geq 65$  years) around the world, of whom 261 million resided in Eastern and South-Eastern Asia, and over 200 million resided in Europe and Northern America (United Nations, 2020). The total number of older adults is projected to be 1.5 billion by 2050 (United Nations, 2020). Globally, the number of older adults ( $\geq 65$  years) exceeded children below 5 years old in 2018. In Bangladesh, the older adults ( $\geq 60$  years) will surpass children below 5 years old in 2025 (United Nations, 2019). Bangladesh is experiencing epidemiological and demographic transitions, and life expectancy at birth is higher (73 years) than ever due to declines in fertility and early life mortality (World Bank, 2021). In 2020, the total population of Bangladesh was about 164.7 million, of whom 8% (i.e., 13.2 million) were older adults ( $\geq 60$  years), and the number of older adults is projected to be double in next 15 years (United Nations, 2019). This increasing trend in the number of older adults has numerous implications for the country’s socio-economic development and the structure of family caregivers.

Older Bangladeshis are susceptible to chronic gastritis or ulcer, arthritis, chronic heart disease, asthma, and paralysis. The increasing number of older adults is likely to amplify caregiving burden for the health system and family members. Filial piety, a virtue of respect for one’s parents, elders, and ancestors, is considered a key virtue in Bangladeshis, and family caregivers usually provide care for older adults. However, joint/extended family living is increasingly uncommon due to urbanization, prompting the need for more care providers for older adults in the near future.

One key metric to estimate these demographic and social shifts is the Dependency Ratio, which summarizes the number of dependents (children aged 0–14 years and/or older adults) for whom there is a potential worker who could provide economic support. A low dependency ratio indicates few dependents per potential worker, implying there is enough support for the dependent population. A high ratio indicates many dependents per potential worker, suggesting more financial and personal stress on the working-age population.

Traditionally, for the total dependency ratio (TDR), the dependent population includes children aged 0–14 years and the older adults ( $\geq 65$  years), whereas the working-age population includes individuals aged 15–64 years (United Nations, 2019). However, such a blanket definition of the dependency ratios, especially based on the developed countries' definition of older adults, could pose significant issues for developing countries, which adopt a lower age threshold for defining older adults and a retirement at age 59 years. Furthermore, early retirement is likely accompanied with earlier onset of elder poverty, depletion of savings, and earlier onset of disability. For instance, in the United States, complete retirement leads to an increase in difficulties associated with mobility and daily activities, an increase in illness conditions, and a decline in mental health, over an average post-retirement period of six years (Dave et al., 2006). As the individuals aged  $\geq 60$  years are considered as older adults in Bangladesh (Bangladesh Bureau of Statistics, 2015), the dependent population should comprise of the children aged 0–14 years and the older adults aged  $\geq 60$  years, instead of older adults aged  $\geq 65$  years. The retirement age of a service holder in the government job sectors, including most private industries, in Bangladesh, is 59 years (Financial Express, 2019; Trading Economics, 2020), and thus the working-age population should comprise of the individuals aged 15–59 years. Due to such discrepancies in the cut-offs for older adults, the traditional dependency ratios for Bangladesh need some modifications for more accurate estimation.

To address these issues, this study aims to construct a more accurate measure, offering modifications to the traditional formulas of dependency ratios and to compare these modified formulas against the traditional formulas in a developing country, Bangladesh, as a case study. We offer two modifications. In the Modified Formula-I, we move the cut-off for 'old' to 60 years instead of 65 years, while considering the 15–59 years age group as 'potentially working.' Based on Modified Formula-I, we build a Formula-II where, instead of the entire working-age population, we compare only the economically active population aged 15–59 years against the dependent population (children aged 0–14 years, economically inactive population aged 15–59 years and older adults aged  $\geq 60$  years). The rationale for building Formula-II is that, in reality, not all the individuals aged 15–59 years are economically active. Hence, considering this issue may further improve the precision of our estimation.

## Methods

### Data Sources

Data for this study came from the 2019 Revision of World Population Prospects (United Nations, 2019) and the World Bank (World Bank, 2020). The population estimates and projections by 5-year age group in Bangladesh from 1975 to 2100 were extracted in Excel files from the 2019 Revision of World Population Prospects, a secondary source maintained by the United Nations, Department of Economic and Social Affairs, Population Division (United Nations, 2019). The cohort-component method was utilized to project the total population by 5-year periods using future survival probabilities (United Nations, 2019). Additionally, the labor force participation rates—the proportion of the total population aged 15–64 years who are economically active (all people who supply labor for the production of goods and services during a specified period) (World Bank, 2020), in Bangladesh, from 1990 to 2019 were extracted in Excel files from the World Bank. For more details about the sources, see <https://population.un.org/wpp/> and <https://data.worldbank.org/indicator/SL.TLF.ACTI.ZS>.

### Analysis

Initially, the extracted population estimates and projections from 1975 to 2100 were divided into three broad age groups- (i) 0–14, economically active population aged 15–59, economically inactive population aged 15–59, 60–64, 65+, (ii) 0–14, 15–59, 20–59, 60+, and (iii) 0–14, 15–64, 20–64, 65+. Subsequently, the dependency ratios, potential support ratio, and old-age support ratio were computed according to traditional and modified formulas (detailed below). We compared the findings for traditional and modified formulas and studied the effects of modifying formulas from 1975 to 2100. Additionally, annual rate of growth for total population and for older adults was computed. Microsoft Excel 2016 was used to perform the analysis.

### Traditional and Modified Formulas

#### Total Dependency Ratio (TDR)

According to the United Nations (2019), the TDR is the ratio of the number of dependents to the number of working-age population. The dependents generally include the children aged 0–14 years and the older adults aged  $\geq 65$  years, and the working-age population includes the people aged 15–64 years. Mathematically, the formula (United Nations, 2019) of traditional TDR is:

$$\text{TDR}_{\text{Traditional}} = \frac{P_{0-14} + P_{65+}}{P_{15-64}} \times 100 \quad (1)$$

where  $P_{0-14}$  is the number of children aged 0–14 years,  $P_{15-64}$  is the number of working-age population aged 15–64 years, and  $P_{65+}$  is the number of older adults aged  $\geq 65$  years.

The  $TDR_{\text{Traditional}}$  is meant to indicate how many dependent people (children aged 0–14 and older adults aged 65+) a potential worker (population aged 15–64) has to support economically. As stated in the Introduction section, people retire at age 59 years, and those aged  $\geq 60$  years are considered as older adults in Bangladesh. We propose a modification to the  $TDR_{\text{Traditional}}$  formula, and we call it  $TDR_{\text{Modified-I}}$ . The modified formula is:

$$TDR_{\text{Modified-I}} = \frac{P_{0-14} + P_{60+}}{P_{15-59}} \times 100 \tag{2}$$

where  $P_{0-14}$  is the same as in the traditional formula,  $P_{15-59}$  is the number of working-age population aged 15–59 years, and  $P_{60+}$  is the number of older adults aged  $\geq 60$  years.

The  $TDR_{\text{Modified-I}}$  indicates how many dependent people (children aged 0–14 and older adults aged 60+) a potential worker (population aged 15–59) has to support economically. Without being economically active, the potential workers (population aged 15–59 years) will have limited capacity to support the dependent people financially. We, therefore, propose a further modification to the  $TDR_{\text{Modified-I}}$  formula, and we term it  $TDR_{\text{Modified-II}}$ . Here, we consider the economically active population as financially independent instead of the working-age population used in the other formulas, considering the economically inactive population, as well as children (0–14 years) and older adults ( $\geq 60$  years), as financially dependent. This is because all the working-age population does not earn. The further modified formula becomes:

$$TDR_{\text{Modified-II}} = \frac{P_{0-14} + \text{Economically inactive population of age } 15 - 59 + P_{60+}}{\text{Economically active population of age } 15 - 59} \times 100 \tag{3}$$

where  $P_{0-14}$  and  $P_{60+}$  are same as previous, economically active population of age 15–59 years is the product of population aged 15–59 years and labor force participation rate, and the economically inactive population results by subtracting economically active population from total population.

The traditional TDR has two parts, namely child dependency ratio (CDR) and old-age dependency ratio (OADR), which are as follows:

### Child Dependency Ratio (CDR)

According to the United Nations (2019), the CDR is the ratio of the number of children aged 0–14 years to the number of working-age population. It indicates how many children a potential worker has to support economically. It is defined as a percentage. Mathematically, the formula (United Nations, 2019) of CDR is:

$$CDR_{\text{Traditional}} = \frac{P_{0-14}}{P_{15-64}} \times 100 \quad (4)$$

where all notations are same as previous.

Similar to the TDR, we also propose two modifications to  $CDR_{\text{Traditional}}$  sequentially, and we call them  $CDR_{\text{Modified-I}}$  and  $CDR_{\text{Modified-II}}$ . The formulas are:

$$CDR_{\text{Modified-I}} = \frac{P_{0-14}}{P_{15-59}} \times 100 \quad (5)$$

$$CDR_{\text{Modified-II}} = \frac{P_{0-14}}{\text{Economically active population of age } 15 - 59} \times 100 \quad (6)$$

where all notations are same as previous.

### Old-Age Dependency Ratio (OADR)

According to the United Nations (2019), the OADR is the ratio of the number of older adults to the number of working-age population. Traditionally, it represents how many older adults a potential worker has to support economically. It is expressed as a percentage. Mathematically, the formula (United Nations, 2019) of OADR is:

$$OADR_{\text{Traditional}} = \frac{P_{65+}}{P_{15-64}} \times 100 \quad (7)$$

where all notations are same as previously described.

Similar to the TDR, we also propose two modifications to  $OADR_{\text{Traditional}}$  sequentially, and we call them  $OADR_{\text{Modified-I}}$  and  $OADR_{\text{Modified-II}}$ . The formulas are:

$$OADR_{\text{Modified-I}} = \frac{P_{60+}}{P_{15-59}} \times 100 \quad (8)$$

$$OADR_{\text{Modified-II}} = \frac{P_{60+}}{\text{Economically active population of age } 15 - 59} \times 100 \quad (9)$$

All notations are the same as used in the earlier presentation of the modified formulae.

### Potential Support Ratio (PSR)

The PSR, the reciprocal of OADR (2019), is the ratio of the number of working-age population to the number of older adults. Traditionally, it indicates how many working-age population are there to support an older adult. Mathematically, the formula of PSR (United Nations, 2019) is:

$$PSR_{\text{Traditional}} = \frac{P_{15-64}}{P_{65+}} \tag{10}$$

where all notations are the same as previous.

We also propose two modifications to the  $PSR_{\text{Traditional}}$  formula, and we call them  $PSR_{\text{Modified-I}}$  and  $PSR_{\text{Modified-II}}$ , respectively. The formulas are:

$$PSR_{\text{Modified-I}} = \frac{P_{15-59}}{P_{60+}} \tag{11}$$

$$PSR_{\text{Modified-II}} = \frac{\text{Economically active population of age 15 – 59}}{P_{60+}} \tag{12}$$

All notations are the same as previous.

A similar measure to PSR, old-age support ratio (OASR)—number of working-age population aged 20–64 years per older adults aged 65 years and above (United Nations, 2019), with two modifications are also measured. Relevant formulas and results are provided in Supplementary Materials.

**Annual Growth Rate of Population**

The annual rate of population change or the population growth rate is defined as the change in population over a given period of time. It is expressed as a percentage. The exponential growth formula (United Nations, 2019) is as follows:

$$\text{Annual growth rate of population (GR}_{\text{Total}}) = \frac{\ln\left(\frac{P_{t_2}}{P_{t_1}}\right)}{t} \times 100 \tag{13}$$

where  $P_{t_1}$  is the mid-year population in year  $t_1$ ,  $P_{t_2}$  is the mid-year population in year  $t_2$ , and  $t$  is the time duration between  $t_1$  and  $t_2$ .

**Annual Growth Rate of Older Adults**

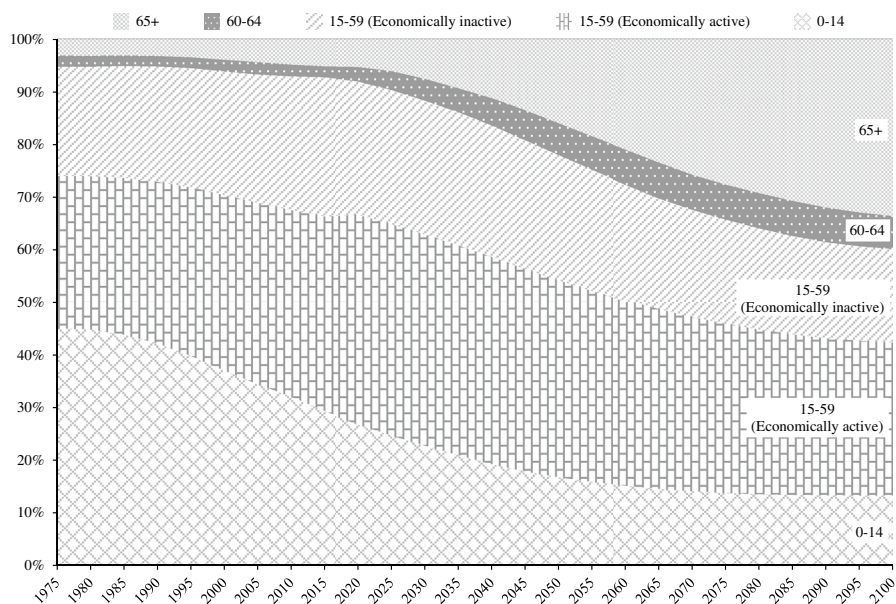
The annual growth rate of older adults ( $\geq 60$  years) is defined as the change in the number of older adults over a given period of time. It is expressed as a percentage. The exponential growth formula for older adults is as follows:

$$\text{Annual growth rate of older adults (GR}_{\text{Old}}) = \frac{\ln\left(\frac{P_{60t_2}}{P_{60t_1}}\right)}{t} \times 100 \tag{14}$$

where  $P_{60t_1}$  is the number of older adults ( $\geq 60$  years) in year  $t_1$ ,  $P_{60t_2}$  is the number of older adults ( $\geq 60$  years) in year  $t_2$ , and  $t$  is the time duration between  $t_1$  and  $t_2$ .

## Results

Figure 1 shows the trends in changes of age structure of Bangladeshis from 1975 to 2100. The total population, the percentage of total population by some selected age groups, and corresponding values are provided in Supplementary Table 1 and Supplementary Fig. 1. Four years after the 1971 Liberation war, the total population of Bangladesh was 70.1 million, with 49.8% working-age (15–59 years) population (29.3% economically active and 20.5% economically inactive), 2.2% older adults aged 60–64 years, 5.2% older adults aged  $\geq 60$  years, and 45% children aged 0–14 years (Fig. 1 and Supplementary Table 1). In 2005, the total population became almost double the starting point (139.0 million), with an increase in older adults aged 60–64 years by only 0.1% percentage points and older adults aged  $\geq 60$  years by 1.5% percentage points, an increase in economically active population aged 15–59 years by 5.4% percentage points and economically inactive population aged 15–59 years by 3.8% percentage points, and a decrease in children. It is evident that the population is aging slowly with the pace of time. In 2020, the total population became 164.7 million, with 65.3% working-age (15–59 years) population (40.1% economically active and 25.2% economically inactive), 8% older adults aged  $\geq 60$  years (2.7% older adults aged 60–64 years), and 26.8% children. The percentage of older adults aged 60–64 years was nearly stable (2.0–2.3%) till 2015, and then, it started increasing. The percentage of older adults aged 60–64 was 2.7% in 2020, and is projected to be 6.1% in 2050, with its peak (6.8%) in 2065. The working-age (15–59 years) population increased from 49.8 to 65.3% between 1975 and



**Fig. 1** Percentage of total population by broad age groups (0–14, 15–59, 60–64, 65+ years) in Bangladesh from 1975 to 2100. Proportion of economically active and inactive for 15–59 is measured from the proportion of 15–64



2020, and it will be of almost same percentage (64.5%) until 2040. That means that in the next 20 years, the country would add 20.0 million people to its total population, but there will be no change in the percentage of the working-age population and the dependents (sum of children and older adults; considering no unemployment among working-age population) due to declining fertility and mortality. Consequently, the period from 2020 to 2040 appears to be the high time for reaping the highest demographic dividend in Bangladesh.

The percentage of older adults aged  $\geq 60$  years will steadily increase after 2020, will crossover the declining percentage of children between 2040 and 2045, and will be close to the percentage of 20–59 years old people in 2100 (39.6% older adults versus 42.4% aged 20–59 years). The total population will peak at 192.6 million, with 61.3% working-age (15–59 years) population, 21.9% older adults ( $\geq 60$  years), and 16.8% children in 2050. The percentage of children will steadily decline until the end of this century, and the total population will eventually be 151.4 million in 2100 (Supplementary Fig. 1).

Figure 2 represents the trends in CDR in Bangladesh from 1975 to 2100. Despite having a big difference between traditional and modified-II CDR values, all CDR will be declining until 2070, and then will be nearly stable until the end of the century. In 1975, according to  $CDR_{\text{Traditional}}$ ,  $CDR_{\text{Modified-I}}$ , and  $CDR_{\text{Modified-II}}$ , respectively, 87, 90, and 154 children were supported economically by 100 potential workers. In 2020, according to  $CDR_{\text{Traditional}}$ ,  $CDR_{\text{Modified-I}}$ , and  $CDR_{\text{Modified-II}}$ , respectively, 39, 41, and 67 children are supported economically, and in 2050, 25, 27, and 45 children will be supported economically by 100 potential workers. Seemingly, economic pressure on the workers for child support is reducing over time. However, economic pressure measured by  $CDR_{\text{Modified-II}}$  is nearly double than that of  $CDR_{\text{Traditional}}$  (for more details, see Supplementary Table 2).

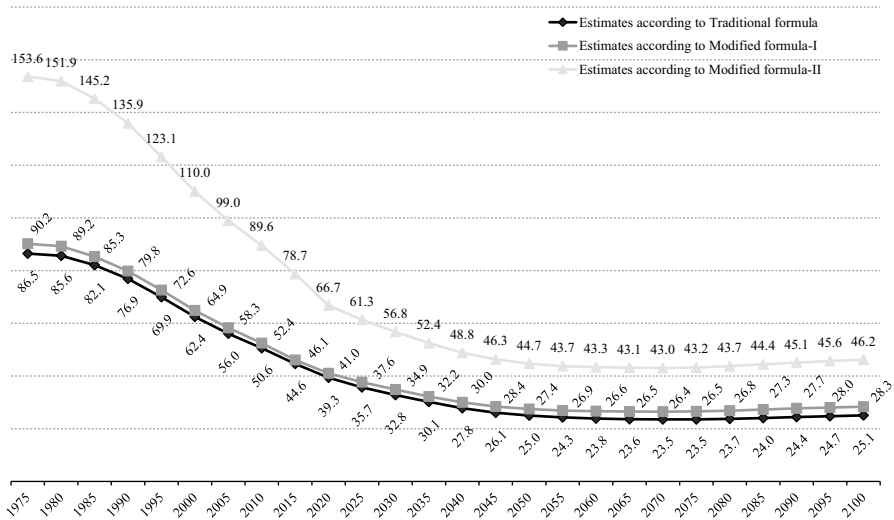


Fig. 2 Child dependency ratio (percentage) in Bangladesh from 1975 to 2100

Figure 3 illustrates the trends in OADR, PSR, and the number of older adults undercounted by  $OADR_{\text{Traditional}}$  in Bangladesh from 1975 to 2100. With a little heaping, all the OADR have been nearly stable up to 2020 and then started increasing incessantly until the end of the century. With a heaping,  $PSR_{\text{Traditional}}$  has been declining from the very beginning, whereas both  $PSR_{\text{Modified-I}}$  and  $PSR_{\text{Modified-II}}$  have been nearly stable up to 2020, and from 2020, all PSR started declining incessantly until the end of the century. In 1975, according to  $OADR_{\text{Traditional}}$ ,  $OADR_{\text{Modified-I}}$  and  $OADR_{\text{Modified-II}}$ , respectively, 6, 11, and 18 older adults were supported economically by 100 potential workers. Alternatively, 17, 10, and 6 workers, according to  $PSR_{\text{Traditional}}$ ,  $PSR_{\text{Modified-I}}$  and  $PSR_{\text{Modified-II}}$ , respectively, were available to support an older adult economically. Although  $OADR_{\text{Traditional}}$  and  $PSR_{\text{Traditional}}$  showed less burden (placed by the older adults) of support on the working-age population than  $OADR_{\text{Modified-II}}$  and  $PSR_{\text{Modified-II}}$ , they undercounted a total of 1.5 million older adults in 1975.  $PSR_{\text{Modified-II}}$  showed that, in 2020, 2050, and 2100, respectively, 5, 1.7, and 0.7 workers are to support an older adult, implying an increasing burden of support will be on shoulder of the working-age population over time. It is important to note that in 2020, 2050, and 2100, respectively,  $OADR_{\text{Traditional}}$  and  $PSR_{\text{Traditional}}$  undercount a total number of 4.5, 11.7, and 9.4 million older adults (for more details, see Supplementary Table 2).

Figure 4 shows the trends in TDR in Bangladesh from 1975 to 2100. All TDR has been declining until 2020, and will be nearly stable until 2035, and then will be increasing steadily and will reach at peak at the end of the century, with a big difference between traditional and modified-II TDR values. In 2020, according to  $TDR_{\text{Traditional}}$ ,  $TDR_{\text{Modified-I}}$  and  $TDR_{\text{Modified-II}}$ , respectively, 47, 53, and 149 dependents (sum of children, economically inactive population aged 15–59 years, and older adults) were supported economically, and in 2050, 48, 63, and 166 dependents will

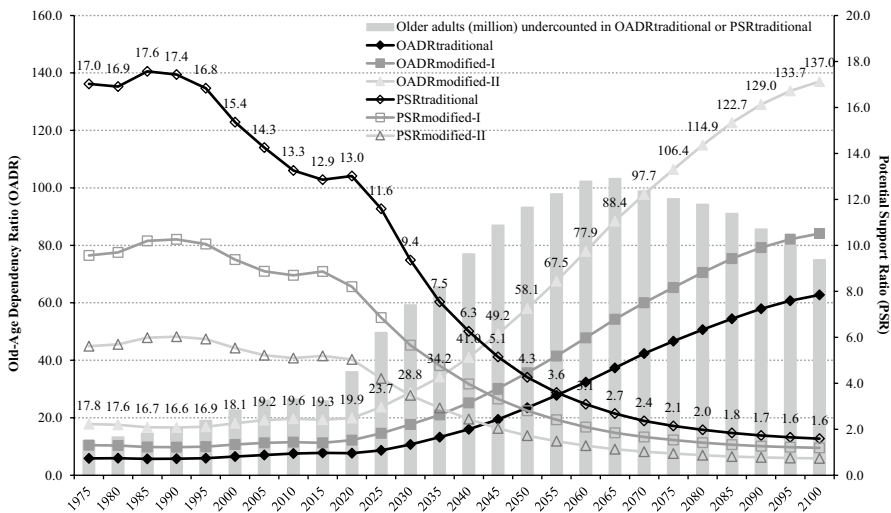


Fig. 3 Old-age dependency ratio (OADR), potential support ratio (PSR), and the older adults (million) undercounted in traditional formula of OADR in Bangladesh from 1975 to 2100

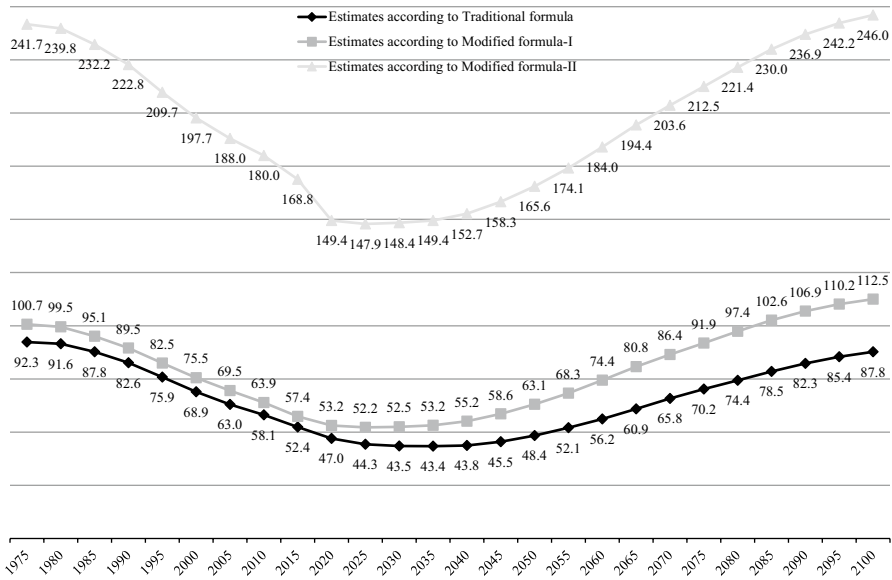


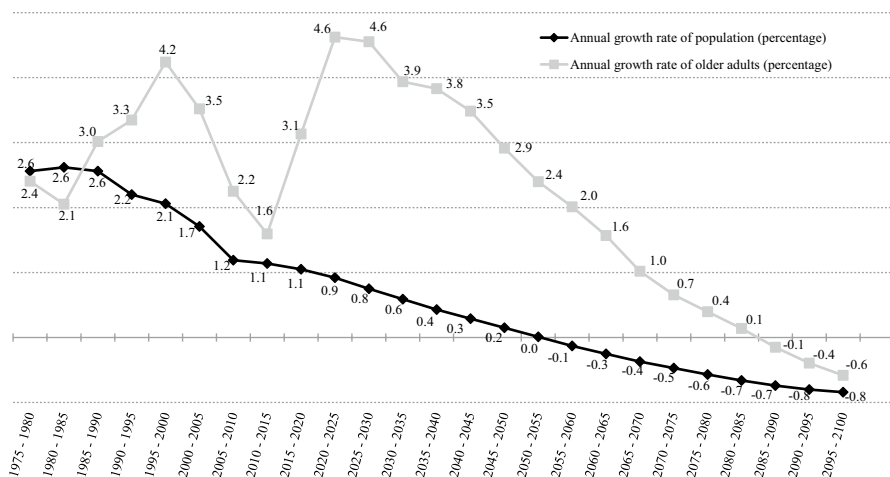
Fig. 4 Total dependency ratio (percentage) in Bangladesh from 1975 to 2100

be supported economically by 100 potential workers. Seemingly, economic pressure on the workers to support the dependents will be stable until 2035, and then will be increasing at a higher rate over time; however, economic pressure measured by  $TDR_{Modified-II}$  is around three times higher than that of  $TDR_{Traditional}$  (for more details, see Supplementary Table 2).

Figure 5 represents the trends in annual growth rate of population ( $GR_{Total}$ ) and annual growth rate of older adults ( $GR_{Old}$ ) in Bangladesh from 1975 to 2100. It can be seen that the  $GR_{Total}$  was very high in the post-Liberation War periods, and it has been declining gradually, and, now it is about 0.9%. Between 2050 and 2055, Bangladesh will observe a zero-growth rate for the first time in its history, implying no change in the size of total population at that time. Afterward, negative population growth rate will continue until the end of the century. On the other hand, the  $GR_{Old}$  will be at its apex between 2020 and 2030 and will have negative growth from 2085 to the end of the century. Apparently, number of older adults will continue to increase until 2085 with a declining total population since 2055 (for more details, see the Supplementary Table 3).

### Discussion

To our knowledge, this is the first study on the modifications of the traditional formulas of dependency ratios. Using Bangladesh as a case study, this study reveals several important insights, which have potentially significant implications for the demography, economy, health, and society for developing countries which similarly adopt the 60 years as the cut-off to define old age. The growth rate of older adults



**Fig. 5** Annual growth rate of population (percentage) and annual growth rate of older adults (percentage) in Bangladesh from 1975 to 2100

( $\geq 60$  years) will peak (4.6%) between 2020 and 2030, and continue to increase until 2085, though Bangladesh will observe a negative growth rate in population after 2055. The increasing number of older adults, 8% (13.2 million) of total population in 2020, 21.9% (42.1 million) in 2050, and 37.2% (63.4 million) in 2085, will put significant pressure on the socioeconomic development and nearly all sectors of society, including family structures and intergenerational ties. However, the next twenty years (2020–40) with working-age (15–59 years) population of 65.3% to 64.5% appears to be the best time for reaping the highest demographic dividend in Bangladesh. Economic pressure on the workers for children support alone is reducing over time, and for older adults support alone is increasing over time; however, economic pressure measured by all the modified-II formulas is nearly double (nearly triple in case of TDR) than that of traditional formulas. It is worth noting that the traditional formulas of OADR and PSR are found to undercount a huge number of older adults over time (specifically, 4.5, 11.7, and 9.4 million older adults in 2020, 2050, and 2100, respectively).

More than a century ago, Isaac Rubinow (1913) defined old-age threshold as—“Age 65 is generally set as the threshold of old age since it is at this period of life that the rates for sickness and death begin to show a marked increase over those of the earlier years.” However, holding chronological age constant to define older adults (e.g., defining a boundary to old age at 60 years or 65 years) over time represents a narrow view of population aging, as it does not consider the dynamic changes in life expectancy (Gietel-Basten et al., 2020; Scherbov & Sanderson, 2020). Thus, conventional measures of population aging are suggested to replace with the new measures—prospective age (i.e., remaining life expectancy below 15 years), prospective median age, prospective old-age dependency ratio, etc. (Coombs et al., 2019; Sanderson & Scherbov, 2005, 2010; Scherbov & Sanderson, 2020). However, adoption of these new measures was made in a limited number of studies till date

(Cuaresma et al., 2014; Gietel-Basten et al., 2020; Sanderson & Scherbov, 2015), and the chronological age cut-off ( $\geq 60$  or 65 years) is still core to define older adults, population aging, and healthy aging worldwide (United Nations, 2021; World Health Organization, 2015, 2018, 2021b). In accordance with the World Health Organization's and the United Nations' definition of "aging society (7% of total population is  $\geq 65$  years)," "aged society (14% of total population is  $\geq 65$  years)," and "super-aged society (21% of total population is  $\geq 65$  years)" (Tahara, 2016; World Health Organization, 2011), many developing countries are yet to be categorized as aging societies.

Bangladesh is progressively aging as a nation, and it will be an aging society in 2025–2030, an aged society in 2045–2050, and a super-aged society in 2060–2065. The corresponding percentage of the country's older adults ( $\geq 60$  years) to be an aging society is around 10%, 20% for an aged society, and 30% for a super-aged society (see Supplementary Table 1). As of present, having a less than 10% older adults ( $\geq 60$  years) discourages the policymakers to notice older adults' health and care needs related research, and apparently a national survey on Bangladeshi older adults' issues is missing. However, there are other small-scale surveys on older adults ( $\geq 60$  years) which have been addressing aging and health aspects in Bangladesh (Tareque et al., 2013a, 2013b; Tareque et al., 2014, 2015a, 2015b). These studies showed the prevalence of multimorbidity in older adults ranges from 56 to 80%, with hypertension, diabetes, ischemic heart disease, chronic obstructive pulmonary disease, and visual impairment being predominant (Rahman et al., 2021; Sara et al., 2018). Women (versus men) reported a higher disability, with 34.8% of women aged 60–64 years with at least one disability (Tareque et al., 2017, 2013a, 2013b). Women (versus men) are more likely to live a greater part of their remaining life with disability (Tareque, et al., 2013a, 2013b). Older adults from poor economic status experience abuse at a high rate (Tareque et al., 2015a, 2015b), when four factors (exercise, income, functional limitations, and abusive behavior) and active lifestyles and safety net dimensions of active aging framework may keep them healthy and protect from abuse (Tareque et al., 2014, 2015a, 2015b). All these aging-related issues could be aggravated during the peaks of the growth of older adults in Bangladesh in the coming years. Hence, policymakers and government should place emphasis on the periods where further strains are expected, investing in and changing policies to adapt to these changes.

Bangladesh is not yet considered an 'aging society,' but in 2020, it has 13.2 million older adults ( $\geq 60$  years), which is more than the total population of some countries, e.g., in 2020, Singapore's total population is 5.9 million, and China, Hong Kong SAR's total population is 7.5 million (United Nations, 2019). Bangladeshi older adults are also often regarded as "unproductive and people of poor health" (Rahman, 2020), and their growing number will pose significant burden to health-care system and society, unless having productive and healthy aging in near future. Similar to many other developing countries, the country's healthcare system is under-prepared (World Health Organization, 2021a, 2021b) and incompetent to provide geriatric care, with a lack of hospital beds, out-patients services, and medical staff, issues particularly prominent in the COVID-19 pandemic (Al-Zaman, 2020). Allocation of government funds for older adult support under the social safety nets

has been consistently inadequate (Rahman, 2020). The only visible policy is “Old Age Allowance Program”—monthly 500 BDT (i.e., 5.9 US\$; 1 US\$=85 BDT) per poor older adult in 2020–21; this monthly allowance is too small to meet their basic humanitarian needs. Beneficiaries are increased from 0.4 million in 1997–98 to 4.9 million in 2020–21, while many eligible older adults remained uncovered (Anwar et al., 2016; Begum & Wesumperuma, 2013; Department of Social Services, 2021). It is also important to note that the Bangladeshi government sets double standards in defining old-age threshold in the National Policy on Older Persons 2013 ( $\geq 60$  years) and the Old Age Allowance Program ( $\geq 65$  years for men and  $\geq 62$  years for women). Thus, setting a single standard (i.e., defining the boundary to old age at 60 years), especially on the basis of existing retirement age (59 years) and persisting disability at ages 60–64, for studying and addressing older adults’ dependency is warranted.

Apart from the issues posed by growing patterns of older adults, there are considerable differences between developed countries, which the cut-off for old age and all the traditional measures based on, and other countries. The persisting disability at ages 60–64 years and the current retirement age (59 years) in most sectors make people aged 60–64 years financially and physically dependent. Thus, excluding people aged 60–64 years from the dependent population and employing them as working-age population in the calculation by traditional OADR are inappropriate. By doing so, it does not only underestimate OADR, but also undercount a significant number of older adults, who may need intensive and often continuing health care and social support. These subgroup of older adults, without being appropriately categorized and thus under-considered in policymaking, likely create challenges for the country’s economy, labor and financial markets, tax division, government spending on health care, social protection, housing, transportation, etc. (Pettinger, 2019; Yoshino et al., 2019). Increase in the number of older adults and decrease in the number of working-age people will create burden of high tax rates on wage earners (Pettinger, 2019). More spending on health care and social protection for the excessive older adults may reduce government’s savings from more productive investment, and consequently, the economic growth of Bangladesh may lead to a slow-down in the coming decades, despite the older adult population growth, perpetuating an ever-growing discrepancy.

Increase in the number of older adults until 2085, coupled with a declining total population after 2055, will generate significant demographic and financial burden of support on shoulder of the working-age population over time. Traditional formulas (i.e., considering people aged 60–64 years as working-age population) than modified-II formulas (i.e., considering people aged 60–64 years as older adults) estimate a way lower demographic and financial burden on the economically active population. For instance, in 2020, there were 13 (versus 5) working-age people by  $PSR_{\text{Traditional}}$  (versus  $PSR_{\text{Modified-II}}$ ) to support an older adult. Apparently, any developmental policy based on the estimations made by traditional formulas will be misleading, and Bangladesh may face dire consequences owing to the overestimation of the working-age population. Conversely, accurate quantifications of dependency ratios can play critical roles in preventing further exaggerations or worsening of the issues in Bangladesh, e.g., the demographic and financial issues, scarcity of resources, food and shelter insecurity, poverty, insufficient health facilities and

social services, and absence of a strong social security program. Thus, the current study advocated not adopting the traditional dependency ratios and the standards of the developed countries (i.e., considering people aged 60–64 years as working-age population) for Bangladesh. For developing countries which adopt a different old-age cut-off of 60 years, we suggest adopting more accurate formulas (i.e., modified-I and modified-II formulas) and associated estimations instead.

Given its rapidly aging population, inaccurately quantifying the dependency ratios risks policymakers not being well informed of the actual demographics of Bangladesh, hindering their ability to craft timely solutions. In addition to the estimates of dependency ratios, the current study apprises the twenty years (2020–40) as the opportunity to reap the highest demographic dividend in Bangladesh. Making Bangladesh able to reap the dividend in coming years may offset the upcoming demographic and financial burden of support on shoulder of the working-age population.

We acknowledge several limitations of this study. Due to the lack of labor force participation rate for ages 15–59, the labor force participation rate of ages 15–64 was used for the ages 15–59 years. In practical, the labor force participation rate of ages 15–59 may appear to be a little higher than that of ages 15–64, mainly due to mandatory retirement at age 59 in government services in Bangladesh. In addition, due to unavailability of the labor force participation rates for 2020 onwards, the labor force participation rates of the year 2019 were used for 2020 to 2100. Industrial expansion, informal and formal work or employment generation, labor market expansion, and increase of women's participation in the work force are likely to expand the volume of labor force in coming decades, and thus the current projections of dependency ratios based on the modified-II might appear to be slightly overestimated. These warrant recalculation of dependency ratios (based on the availability of new rates of labor force participation) in coming decades. Future change in retirement age and working age should also be adjusted in recalculation of dependency ratio in coming decades, and our study provided the basis for such adjustments. There are children (aged 12–14) who supply labor for the production of goods and services in Bangladesh, mainly due to several minimum ages for admission to work or employment (e.g., 12 years for shops and commercial establishments or tea plantations, 18 for road transport services, etc.) (International Labour Office, 2007). Inclusion and adjustment for the children aged 12–14 in the computation were beyond the scope of this study, due to lack of labor force participation rates for the children aged 12–14 years and 5-year age group data utilization. Future studies should explore whether the current findings differ if single-year data, adjusted for child labor aged 12–14, are utilized.

## Conclusion

In all, our study advances the knowledge in old-age dependency measures by advocating two modifications to the traditional dependency ratio formulas for the developing countries which define  $\geq 60$  years as old age and adopt retirement at the age 59 years. Using blanket formulas as devised for developed countries without modifications leads

to inappropriate dependency ratio estimates and projections. The application of these inappropriate dependency ratio estimates and projections for policy and planning in Bangladesh will undoubtedly be misleading. Adopting our proposed modifications and associated estimations could not only prevent exaggeration of the demographic and financial issues but also help inform policymakers to plan for healthcare, social support system, and productive and healthy aging. Due to a large number of older adults ( $\geq 60$  years), existing retirement age (59 years), double standards in defining old-age threshold and persisting disability at ages 60–64, a single standard (i.e., defining the boundary to old age at 60 years) for studying and addressing older adults' issues and dependency ratios is also urgently needed. Finally, reaping the highest demographic dividend in coming years (2020–40) is pondered to offset the upcoming demographic and financial burden of support on shoulder of the working-age population.

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**Data Availability** Data for this study came from the 2019 Revision of World Population Prospects and the World Bank, which are publicly available at <https://population.un.org/wpp/> and <https://data.worldbank.org/indicator/SL.TLF.ACTI.ZS>.

**Code Availability** Not applicable.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical Approval** This study does not require ethical approval, as it uses de-identified data from secondary sources.

**Consent to Participate** Not applicable.

**Consent for Publication** Not applicable.

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