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# A polio transition investment case for the WHO Eastern Mediterranean Region

World Health Organization

Eastern Mediterranean Region

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## Executive summary

The objective of this study is to present an investment case to support investments in polio assets beyond polio eradication that would continue to support routine immunization, disease surveillance and outbreak response in the Eastern Mediterranean Region of the World Health Organization (WHO). The report is not only intended for donors, but also to convince the governments of polio transition countries to invest in these functions.

The report covers six polio transition fragile countries in the Eastern Mediterranean Region. These are Iraq, Libya, Somalia, Syrian Arab Republic, Sudan and Yemen, which have been certified as polio free, in addition to Afghanistan and Pakistan which are yet to be certified.

Most of these countries suffer from:

- weak health systems;
- high mortality rates for children aged under 5 from vaccine-preventable diseases (VPDs);
- low vaccination coverage compared with the Eastern Mediterranean Region as a whole;
- high levels of political instability and violence/terrorism; and
- generally low human development rankings.

For all of these reasons, the countries need continuing support for their immunization, surveillance and emergency response programmes.

The study employs projections of ongoing costs, and estimates of lives saved through the immunization and surveillance and emergency response programmes, to develop benefit-cost ratios (BCRs) to demonstrate the value of continuing funding for the programmes in these countries.

The results of the benefit-cost analysis show that the investment returns to both expanded routine immunization and to surveillance and emergency response programmes in the eight countries are very high. Based on our projections, the BCRs are described below and shown in Table ES1.

- Expanding national immunization programmes to achieve Immunization Agenda 2030 targets by 2030 provides an estimated BCR of 38.7 (meaning that for each dollar invested, US$ 38.7 are returned).
- Strengthening the surveillance and emergency response programme by repurposing the polio programme assets yields an estimated BCR of 36.4 (meaning that for each dollar invested, US$ 36.4 are returned).
- Overall, the combined programme yields total estimated benefits in present value terms of US$ 289.2 billion at a present value cost of US$ 7.5 billion, providing an estimated BCR of 38.5.

While the national vaccination and surveillance and emergency response programmes are separately estimated from the period 2021 to 2030, the results are interdependent. The relatively low cost and benefits of the surveillance and emergency response programme is a product of the assumed success

**Table ES1. Benefit and cost results for immunization, surveillance and emergency response, in selected countries of the Eastern Mediterranean Region**

| | Economic benefit US$ million | Social benefit US$ million | Economic and social benefits US$ million | Cost US$ million | BCR economic | BCR economic and social |
|---|---|---|---|---|---|---|
| **Routine vaccination** | US$ 158 069.6 | US$ 104 657.0 | US$ 262 726.6 | US$ 6 783.1 | 23.3 | 38.7 |
| **Surveillance and emergency response** | US$ 13 454.0 | US$ 12 995.9 | US$ 26 449.8 | US$ 726.5 | 18.5 | 36.4 |
| **Overall result** | US$ 171 523.6 | US$ 117 652.9 | US$ 289 176.4 | US$ 7 509.6 | 22.8 | 38.5 |

BCR: benefit-cost ratio.
*Source*: Authors' estimates.

of the national vaccination programmes in reducing infectious disease prevalence. These results mean that investing in these programmes will deliver benefits of almost US$ 39 for every dollar invested. They confirm, despite the limitations of such analyses, the substantial economic benefits, as well as the social returns in the form of lives saved, of the investment programme.

# 1. Introduction

As the final stage of eradication of polio from most parts of the world is reached, the funding for the Global Polio Eradication Initiative (GPEI) has been wound down, except in two endemic countries (Afghanistan and Pakistan) and one high-risk country (Somalia) in the Eastern Mediterranean Region of the World Health Organization (WHO).[1] For other countries in the Region, much or all of the funding has been withdrawn. There are eight fragile countries in the Eastern Mediterranean Region – Iraq, Libya, Somalia, Syrian Arab Republic, Sudan and Yemen – which have been certified as polio-free, together with Afghanistan and Pakistan which are yet to be certified.

The polio eradication programme has invested significantly in polio assets (staff, laboratories and equipment) to establish surveillance, response and immunization programmes to identify and respond to polio outbreaks. For many countries, these assets represented the best funded resources for surveillance and emergency response in the country, and were frequently used to address other health emergencies, such as supporting the response to the COVID-19 pandemic. Rather than allow these assets to be lost, WHO, in the interest of countries, is seeking funding to sustain these assets and to transition them for integration into the national health systems. The progress of the development of national polio transition plans has proven to be challenging, with limited funding commitments (Euro Health Group, 2022).

## 1.1 Situation of health systems in the study countries

The health systems in the eight study countries, which are affected by various chronic emergencies, are under duress. One way of gaining an overview of the performance of a health system is through the universal health coverage (UHC) service coverage index, an indicator of the accessibility of essential health services without facing financial hardship (World Bank, 2023b). Table 1 shows the values of the UHC index for the eight countries. This suggests that while each of the countries has made some improvement in access to essential health services since 2010, all are below even the average for the Middle East and North Africa region. Somalia (29), Afghanistan (42) and Yemen (42), in particular, are well below the average for the Middle East and North Africa region of 69 (World Bank, 2023c).

The low level of the UHC index is a product of low expenditure levels by governments and high out-of-pocket expenses. For Afghanistan, Government expenditure was just 0.6% of gross domestic product (GDP) in 2021 and out-of-pocket expenses accounted for 77% of current health expenditure. Out-of-pocket expenditure was 55.4% in Pakistan and 53% in Sudan in 2020. Averages for low- and middle-income countries and low-income countries were 47% and 42%, respectively, for 2020 (World Bank, 2023c). In resource-poor settings, high out-of-pocket expenses place a high burden on public hospitals. Conflict has made this considerably worse.

**Table 1. UHC service coverage index in selected countries**

| | 2010 | 2015 | 2021 |
|---|---|---|---|
| **Afghanistan** | 29 | 36 | 41 |
| **Iraq** | 53 | 56 | 59 |
| **Libya** | 62 | 61 | 62 |
| **Somalia** | 17 | 21 | 27 |
| **Sudan** | 36 | 43 | 44 |
| **Syrian Arab Republic** | 58 | 60 | 64 |
| **Yemen** | 39 | 39 | 42 |
| **Middle East and North Africa** | 60 | 65 | 69 |

*Source*: World Bank (2023c).

[1] The WHO Eastern Mediterranean Region comprises 22 countries and territories in the Middle East, North Africa, the Horn of Africa and Central Asia.

In the Syrian Arab Republic, the Public Health Situation Analysis (WHO, 2022) reports that the fragile health system is overstretched with only 50% of the 113 assessed public hospitals fully functioning, 26% partially functioning and 24% (27) not functioning at all. Of the 1790 assessed public health centres, 47% were fully functioning, 21% partially functioning and 32% not functioning. Up to 50% of the health workforce was estimated to have left the country due to displacement, attacks and low salary (WHO, 2022).

In Somalia, as a result of the ongoing conflict, less than 30% of the population have access to health services and only 11% of children receive basic vaccinations (Osman, 2022). There is only one government hospital in the capital, Mogadishu, and people often have to seek health care services at a private health facility and pay very high amounts out of their own pocket for their treatment. Only a few people can afford these services, thereby leading to high child and maternal mortality (United Nations, 2022a).

In Yemen, diseases such as cholera, diphtheria, dengue, measles and malaria, as well as a circulating vaccine-derived poliovirus outbreak, have been rampant in recent years (Devi, 2021). One major problem in continuing vaccinations is the lack of electricity and fuel, which affects vaccines cold storage and therefore availability (Lorenzen, 2019). In addition, there is resistance to vaccination among political leadership in control of parts of the country.

On 15 April 2023, fighting between the Sudanese Armed Forces and the Rapid Support Forces erupted in Khartoum and other parts of Sudan. WHO (2023a) reports that there have been severe shortages of doctors, blood, transfusion equipment, intravenous fluids, medical supplies and other life-saving commodities due to exhaustion of the remaining supplies distributed by WHO to health care facilities before the escalation of the conflict. Power outages, blocking of internet access and fuel shortages, which are all associated with conflict, will impair the functionality of the already burdened health care service (WHO, 2023a). In 2023, dengue fever reached Khartoum for the first time; the effects of this disease have been worsened by the faltering health care system, which has lost a great deal of international funding since the 2021 military coup (Saied, 2023).

In Iraq, both COVID-19 and non-COVID-19 infectious diseases are at high levels. Al-Saiedi & Hassad (2021) estimated that by March 2021, more than 844 000 Iraqis had contracted the coronavirus, i.e. almost 22 per 1000 persons, a rate that makes it one of the highest in the Middle East. In addition, Iraq faced outbreaks of many other communicable diseases, including measles, tuberculosis and, recently, a large outbreak of Crimean-Congo haemorrhagic fever.

## 1.2 Communicable disease deaths in children aged under 5

Deaths from communicable diseases remain high in children aged under 5 in most of the eight countries (Afghanistan, Iraq, Libya, Pakistan, Somalia, Sudan, Syrian Arab Republic and Yemen). In 2019, the total number of under-5 deaths was almost 700 000 in the selected countries, out of which 31.7% died from communicable diseases. In Somalia, deaths from communicable diseases accounted for 57% of total deaths of children aged under 5 in 2019. For most of the other countries (Afghanistan, Pakistan and Sudan), deaths from communicable diseases were about a quarter of total under-5 deaths. For the other three countries (Iraq, Libya and Syrian Arab Republic), deaths from communicable diseases were less than 20%, with the lowest in Libya at 10.4% (Table 2). This is often further compounded by the severe malnutrition that affects children in many of these countries, especially in Somalia, Sudan, Yemen, Afghanistan and Pakistan.

**Table 2. Composition of deaths, under 5-year-olds, in selected countries, 2019**

| | Afghanistan | Iraq | Libya | Pakistan | Somalia | Sudan | Syrian Arab Republic | Yemen | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Communicable diseases** | 31.5% | 17.4% | 10.4% | 29.0% | 57.0% | 25.5% | 18.0% | 25.5% | 31.7% |
| **Maternal and neonatal disorders** | 29.1% | 48.4% | 31.5% | 59.4% | 24.5% | 42.2% | 33.8% | 42.9% | 49.1% |
| **NCDs and injuries** | 39.4% | 34.2% | 58.2% | 11.6% | 18.5% | 32.3% | 48.2% | 31.6% | 19.2% |
| **Total** | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

*Source*: IHME (2019).

Despite the importance of communicable diseases, for the eight countries combined, maternal and neonatal disorders were the greatest cause of death, responsible for more than 340 000 deaths (49.1% of total deaths). In Pakistan, maternal and neonatal disorders represented 59.4% of under-5 deaths. For war-torn Afghanistan, Libya and Syrian Arab Republic, the share of deaths due to noncommunicable diseases (NCDs) and injuries was relatively high, largely due to the high levels of deaths attributable to interpersonal violence.

The impact of routine immunization programmes is dependent on a number of factors such as the typical course of infection within the individual patient, the biology of the infectious agent, and the social and demographic makeup of the community, as well as on the type of mass vaccination policy implemented to control the spread of infection. Hence, despite falling death rates across the eight study countries (as indicated in Table 3), 220 792 children aged under 5 died from communicable diseases in 2019. Twenty-eight per cent, or 62 625, of these deaths arose from VPDs, only for some of which vaccines have been included in the national immunization programme. Almost half of these, 30 053 deaths, were from Pakistan, and almost 20 000 were from Somalia, representing together 79% of the total. The Syrian Arab Republic, with only 225 deaths from VPDs, appears low.

The top three diseases by number of under-5 deaths – whooping cough, meningitis and measles – accounted for 41 100 of these deaths. Tuberculosis, tetanus and malaria together claimed about 16 000 lives. Other than malaria, each of these diseases has well-accepted vaccines, and the failure to fully vaccinate young children costs tens of thousands of lives each year.

**Table 3. Deaths from communicable diseases in selected countries, under-5 years, 2019**

| | Afghanistan | Iraq | Libya | Pakistan | Somalia | Sudan | Syrian Arab Republic | Yemen | Total |
|---|---|---|---|---|---|---|---|---|---|
| VPDs | | | | | | | | | |
| Whooping cough | 3 104 | 531 | 26 | 5 804 | 3 916 | 941 | 152 | 901 | 15 375 |
| Meningitis | 953 | 143 | 5 | 10 635 | 2 413 | 333 | 49 | 196 | 14 727 |
| Measles | 1 061 | 130 | 0 | 2 277 | 6 569 | 592 | 4 | 366 | 10 999 |
| Tuberculosis | 344 | 19 | 1 | 5 014 | 2 090 | 89 | 2 | 65 | 7 624 |
| Tetanus | 513 | 15 | 0 | 2 055 | 1 656 | 23 | 2 | 37 | 4 301 |
| Malaria | 92 | 0 | 0 | 529 | 2 411 | 975 | 0 | 64 | 4 071 |
| Encephalitis | 201 | 147 | 2 | 1 619 | 36 | 97 | 11 | 75 | 2 188 |
| Acute hepatitis | 307 | 12 | 1 | 1 298 | 100 | 140 | 1 | 53 | 1 912 |
| Varicella and herpes zoster | 118 | 10 | 1 | 333 | 124 | 30 | 3 | 24 | 643 |
| Dengue | 0 | 0 | 0 | 298 | 0 | 0 | 0 | 22 | 320 |
| Diphtheria | 14 | 1 | 0 | 41 | 173 | 4 | 1 | 5 | 239 |
| Rabies | 0 | 1 | 0 | 152 | 33 | 0 | 0 | 0 | 186 |
| Yellow fever | 0 | 0 | 0 | 0 | 15 | 25 | 0 | 0 | 40 |
| Total VPDs | 6 707 | 1 010 | 36 | 30 053 | 19 536 | 3 250 | 225 | 1 808 | 62 625 |
| Other communicable disease deaths | 18 921 | 1 600 | 79 | 91 637 | 26 432 | 9 675 | 352 | 9 471 | 158 167 |
| Total communicable disease deaths | 25 628 | 2 610 | 115 | 121 690 | 45 968 | 12 926 | 578 | 11 279 | 220 792 |
| Proportion of VPD deaths | 26.2% | 38.7% | 31.0% | 24.7% | 42.5% | 25.1% | 39.0% | 16.0% | 28.4% |

*Source*: Institute for Health Metrics and Evaluation (2019).

## 1.3 Vaccination coverage in the study countries

Countries affected by conflict – Afghanistan, Syrian Arab Republic, Somalia (partial data) and Yemen – have low vaccination coverage rates compared with the Eastern Mediterranean Region as a whole. This is especially the case for measles and polio. For Somalia, the vaccination rate for most diseases is in the low 40s (Table 4).

COVID-19 had a marked impact on vaccination coverage. According to WHO (2023b), global coverage for first-dose measles vaccines dropped from 86% in 2019 to 81% in 2021, with an estimated 25 million children aged under-1 not receiving basic vaccines (Centers for Disease Control and Prevention, 2023a). The number of completely unvaccinated children increased by 5 million between 2019 and 2021 (WHO, 2023b). The main reason for the decline in coverage was attributed to the disruption to health systems caused by the COVID-19 pandemic. However, by 2022, overall coverage rates recovered to pre-pandemic rates, and the number of children missing out on any vaccination – so-called zero-dose children – improved from 18.1 million in 2021 to 14.3 million in 2022, nearly back to the pre-pandemic 2019 level of 12.9 million (WHO, 2023b).

The data for Table 4 are drawn from the WHO site for WHO/UNICEF Estimates of National Immunization Coverage 2022 (WHO, 2023c).

**Table 4. Vaccine coverage in selected countries, 2022 and total 2019 for comparison**

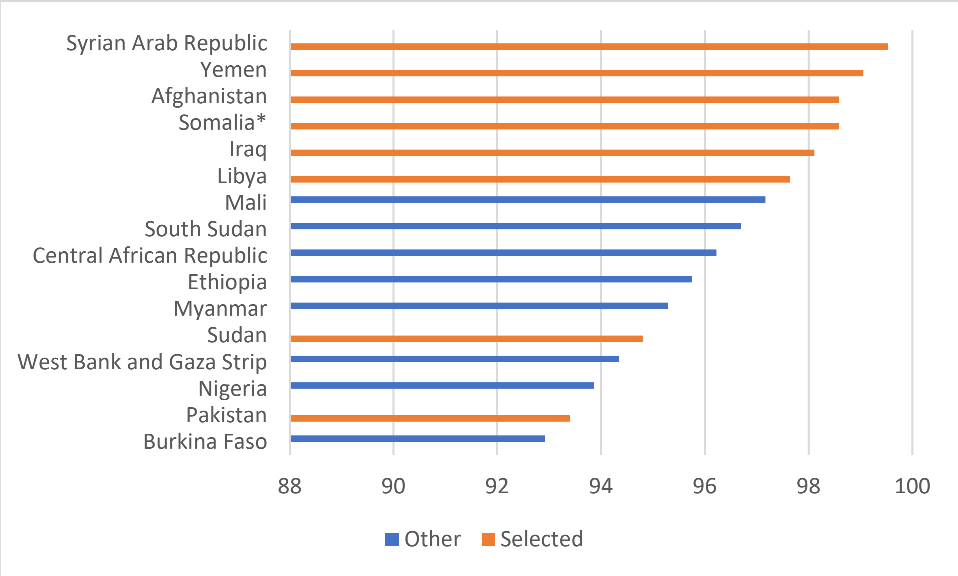
| Vaccine<br>Disease | BCG<br>Tuberculosis | DTP3<br>DTP | HepB3<br>Hepatitis B | Hib3<br>Meningitis | IPV1<br>Polio | MCV1<br>Measles | MCV2<br>Measles | PCV3<br>Lower respiratory | Pol3<br>Polio | RCV1<br>Rubella | RotaC<br>Diarrhoeal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Afghanistan | 88 | 69 | 69 | 69 | 71 | 68 | 49 | 67 | 76 | | 63 |
| Iraq | 96 | 93 | 93 | 93 | 96 | 88 | 97 | 0 | 92 | 97 | 38 |
| Libya | 74 | 73 | 73 | 73 | 74 | 73 | 72 | 73 | 73 | 73 | 73 |
| Pakistan | 95 | 85 | 85 | 85 | 90 | 82 | 79 | 85 | 85 | | 88 |
| Somalia | 37 | 42 | 42 | 42 | 42 | 46 | 8 | | 47 | | |
| Sudan | 80 | 84 | 84 | 84 | 94 | 81 | 63 | 85 | 85 | | 84 |
| Syrian Arab Republic | 76 | 46 | 46 | 46 | 65 | 41 | 38 | | 48 | 41 | |
| Yemen | 73 | 74 | 74 | 74 | 72 | 73 | 56 | 74 | 68 | 73 | 76 |
| | | | | | | | | | | | |
| Region 2022 | 90 | 84 | 84 | 84 | 88 | 83 | 78 | 55 | 85 | 42 | 58 |
| Region 2019 | 89 | 85 | 85 | 85 | 86 | 83 | 76 | 57 | 85 | 43 | 55 |

BCG: Bacillus Calmette-Guérin; DTPCV3: diphtheria-tetanus-pertussis, third dose; HepB3: hepatitis B, third dose; Hib3: *Haemophilus influenzae* type b, third dose; IPV1: inactivated polio-containing vaccine, first dose; MCV1: measles-containing vaccine, first dose; MCV2: measles-containing vaccine, second dose; PCV3: pneumococcal conjugate vaccine, third dose; Pol3: polio-containing vaccine, third dose; RCV1: rubella-containing vaccine, first dose; RotaC: rotavirus vaccines, completed dose.

*Source*: WHO (2023c).

## 1.4 Socioeconomic conditions in the study countries

The eight study countries in the Region are among the least politically stable countries in the world according to the World Bank political stability and absence of violence rankings (World Bank, 2023a). Six countries – Syrian Arab Republic, Yemen, Afghanistan, Somalia, Iraq and Libya – are ranked as the least stable in the world, while Sudan and Pakistan are ranked 12th and 15th, respectively (see Fig. 1). Sudan's position would be subject to review following the recent crisis.

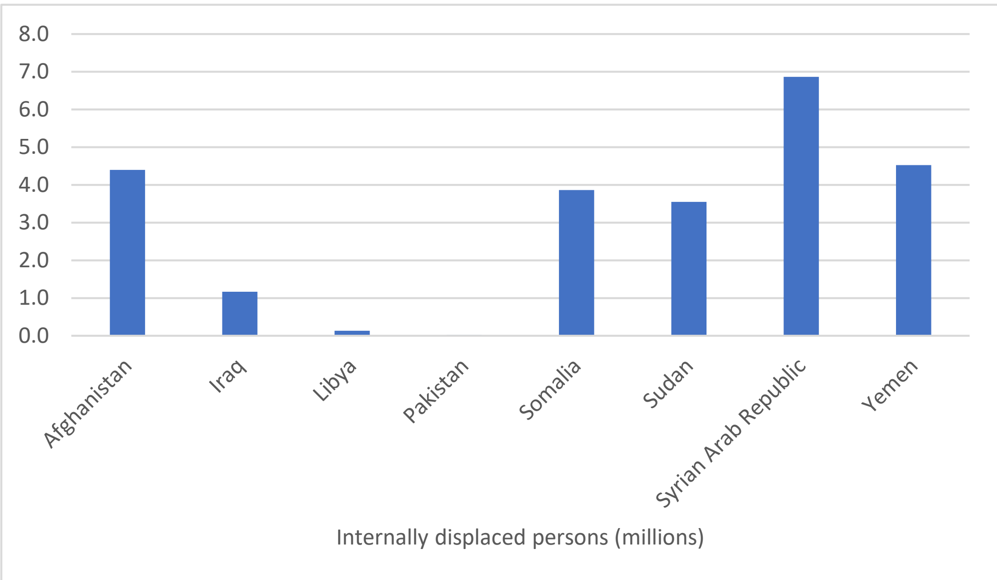



*Note*: *Somalia 2020 rank.
*Source*: World Bank (2023a).

**Fig. 1. Top 20 countries for political instability and violence/terrorism, World Bank rankings, 2021***

This instability and violence magnifies the already serious challenges facing the delivery of health services in these countries. In many cases, the health infrastructure has been damaged, there is a shortage of medical personnel, equipment and supplies, and few facilities are functional. Several of the countries are subject to sanctions, which prevent them from readily accessing equipment and supplies.

In addition, this has led to large-scale displacement of populations, both internally within the countries and externally. In the eight countries, there are over 24.5 million internally displaced people. Almost 7 million of these are in the Syrian Arab Republic, and around 4 million displaced people are living in each of Afghanistan, Somalia, Sudan and Yemen (see Fig. 2).




*Source*: World Bank (2023d).

**Fig. 2. Number of internally displaced persons (in millions), displaced by conflict and violence, in selected countries, 2022**

These displaced persons represent a challenging context for WHO's surveillance, emergency response and vaccination coverage. The large movement of people facilitates the spread of diseases that might otherwise not have been prevalent. The displaced persons are generally living in overcrowded unsanitary camps, with large congregations of unvaccinated people, providing ripe conditions for disease transmission (such as measles and cholera). People are also difficult to track, presenting challenging conditions for any kind of immunization programme.

## 1.5 Human development levels in the study countries

The increase in the spread of infectious diseases and the reduced access to health services are closely related. Both stem from emergencies experienced by the countries and the resulting chronic weakening of the health system, increased poverty, poor sanitation and community breakdown, which lead to breakdown of hygiene infrastructure and increased rates of infectious diseases. At the same time, interventions, most notably immunizations, aimed at controlling certain infectious diseases, would relieve some of the pressure on the health systems.

Apart from Libya and Iraq, the remaining countries are ranked in the bottom third of the 191 countries included in the Human Development Index (HDI) estimation. On this basis Yemen, Afghanistan and Sudan are in the lower 10% of the index, while Pakistan is in the lower 15%.

The HDI combines three dimensions of human development: long and healthy life, knowledge, and standard of living. Indicators of these components are included in Table 5.

These low HDI rankings increase the challenges of maintaining effective health systems that protect their populations against infectious and other diseases.

## 1.6 Summary

The introductory section suggests that this group of eight countries in the Eastern Mediterranean Region will require significant investment to achieve the desired results in immunization, surveillance and emergency response. All countries in the group suffer from a decline in health status of their populations, weak health systems and a high level of political instability. This means that national surveillance systems are underfunded and poorly resourced. Data and other information are often intermittent or very limited.

For many countries, the existing surveillance and emergency response systems are not well equipped to meet their needs; and often, in particular at subnational level, polio teams and their infrastructure are the main support capacity available.

**Table 5. Human Development Index (HDI) and component indicators, in selected countries**

| | Population | HDI 2022 ranking | Life expectancy at birth, total (years) | GNI per capita, Atlas method (current US$) 2021 | Mean years of schooling |
|---|---|---|---|---|---|
| **Afghanistan** | 40.1 | 180 | 62.0 | 390 | 3.0 |
| **Iraq** | 43.5 | 121 | 70.4 | 4670 | 7.9 |
| **Libya** | 6.7 | 104 | 71.9 | 7880 | 7.6 |
| **Pakistan** | 231.4 | 161 | 66.1 | 1470 | 4.5 |
| **Somalia** | 17.1 | No score | 55.3 | 430 | |
| **Sudan** | 45.7 | 172 | 65.3 | 650 | 3.8 |
| **Syrian Arab Republic** | 21.3 | 150 | 72.0 | 760 | 5.1 |
| **Yemen** | 33.0 | 183 | 63.8 | 840 | 3.2 |

GNI: gross national income.
*Source*: UNDP Human Development Data (2023).

The following sections of this report provide estimates of the BCRs for increasing the coverage of the routine vaccinations programmes and improving surveillance and emergency response by repurposing the polio assets in each of the selected countries towards VPDs.

The investment in improving the surveillance and response systems and the national vaccination programmes is closely related. The higher the vaccination coverage of the target populations, the lower the stress on the surveillance and response system. As discussed below, we have assumed that the national vaccination programmes are consistent with the Immunization Agenda 2030 (WHO, 2020) objectives, which seeks to achieve 90% coverage rates for most childhood and adolescent diseases. This will reduce the size and likelihood of disease outbreaks monitored and addressed by the surveillance and response system. In modelling the impact of polio transition on the surveillance and response system, we take into account the increasing coverage rates projected for national immunization, as assumed in the modelling of the national programmes and discussed in the next section.

# 2. Methodology

At the core of the methodology employed in this study, is the proposition that there is a strong relationship between health outcomes and economic development. While this did not originate with the *World development report 1993: investing in health* (World Bank, 1993 p. 17),[1] it represented an influential milestone. To quote:

> Improved health contributes to economic growth in four ways: it reduces production losses caused by worker illness; it permits the use of natural resources that had been totally or nearly inaccessible because of disease; it increases the enrollment of children in school and makes them better able to learn; and it frees for alternative uses resources that would otherwise have to be spent on treating illness. The economic gains are relatively greater for poor people, who are typically most handicapped by ill health.

It was followed by other reports presenting similar arguments, such as that commissioned by WHO, *Macroeconomics and health: investing in health for economic development* (WHO Commission on Macroeconomics and Health, 2001).[2] These reports were important in advancing the argument that expenditure on health services was not simply a matter of cost, but also an investment in future economic benefits. This report employs the methodologies which have been developed to quantify the benefits of the investment in health, and to estimate a return on that investment following the approach used in previous studies (Stenberg et al., 2014; Sheehan et al., 2017; Sweeny et al., 2019).

To estimate the return on investment for health intervention programmes, it is necessary to express the improved health outcomes in economic terms and compare these with the costs of the programmes. The methodology adopted in this analysis is to estimate the value of deaths avoided from the immunization, surveillance and emergency response programmes. The analysis estimates two types of benefits: economic and social.

## 2.1 Economic benefits

The economic benefits of interventions preventing deaths occur when people who would otherwise not be alive enter the workforce and produce economic output.

[1] Commissioned by Dr Larry Summers, then Chief Economist, later United States Secretary of the Treasury, and undertaken by Professor Dean Jamison.

[2] Chaired by Professor Jeffery Sachs, then Director of the Center for International Development, Harvard Kennedy School.

For each of the eight countries, the economic modelling of mortality follows the cohort of avoided deaths as compared with no vaccines for each of the years from 2021 to 2030. Each cohort is classified by age and sex. As the cohort ages, it is subject to the mortality rates applicable to that age group, sex and year, based on estimates from the United Nations World Population Prospects data (United Nations, 2022b) for that country. The effect of avoided mortality on the labour force is calculated by taking the numbers of deaths avoided by age and gender, and applying a corresponding labour force participation rate for this age, gender and year sourced from the International Labour Organization projections of labour force participation rates (ILO, 2023) for that country.

The contribution that each of these labour force cohorts makes to economic output is calculated by multiplying the number in each age and sex category by a productivity level that varies with age and year. To do this, the average productivity is first calculated by dividing the World Bank estimate of GDP in current United States dollars by the labour force for the most recent year for which data are available (2021) (World Bank, 2023e).

## 2.2 Social benefits

It is common when estimating the benefits of improved health to put a value on being alive. This is usually done by estimating the value of a statistical life year. Building on the results of Viscusi & Aldy (2003), Jamison et al. (2013) estimated the value of a life year as between 1.4 and 4.2 times GDP per capita, averaging 1.6 globally.

Stenberg et al. (2014) modified this approach by assuming the value of a life year of 1.5 times GDP per capita and assuming the economic benefit represented 1 times GDP per capita, leaving a residual value of 0.5 times GDP per capita as the social benefit. Following this approach, a value of 0.5 times the GDP per capita is assigned to each healthy life year gained from the interventions to estimate the social benefit of improved health. This is consistent with the more recent work of Robinson et al. (2019). The GDP per capita for each of the eight countries was calculated and the average used as a common measure of GDP per capita for each country in calculating the social benefit, meaning that the estimated social value of a life was the same for each country.

## 2.3 Return on investment

The rate of return on investment can be expressed in a number of different, but related, ways. In this study we report BCRs, as they are intuitively easier to understand. The BCR is the result of dividing the estimate of benefits by the estimate of costs, thus a BCR greater than 1 means that the benefits of an intervention programme are greater than the costs of the programme.

It is standard practice when calculating BCRs to express these benefits and costs in net present value terms. Because benefits and costs for years in the future are usually regarded as having a lower value than those in the present, a discount rate is applied to these future benefits and costs.

Most analyses of long-term projects adopt the standard World Bank discount rate of 3% to calculate net present values (Weitzman, 2001; US Office of Management and Budget, 2003; Arrow et al., 2013; Campos et al., 2015).

The rates of return are estimated from a societal perspective. This means that they are based on the long-term benefits received by the whole society, not restricted to particular programme participants or stakeholders.

### *2.3.1 Rate of return assumptions for the national immunization programmes*

While employing the methodology outlined above, estimating the rate of return for the national immunization programmes depends on four factors, listed below.

- Assumed rate of increase in vaccination coverage. In this study, we have assumed that increase would be in accordance with Immunization Agenda 2030[1] targets (WHO, 2020).
- Number of deaths averted by increased vaccination rates.
- Costs of increased vaccination programme.
- The value of lives saved from the Immunization Agenda 2030[1] vaccination programme.

The analysis draws upon recent multi-country studies that have estimated the deaths averted and cost of achieving the Immunization Agenda 2030 targets. These estimates of costs and deaths averted are based on data sourced from staff and colleagues working at WHO headquarters.[2]

In a comprehensive study, Carter et al. (2021) estimated the number of deaths averted if the Immunization Agenda 2030 targets are met by 2030. They calculated the deaths averted due to vaccination against 10 pathogens (hepatitis B virus, *haemophilus influenzae* type B, human papillomavirus, Japanese encephalitis, measles, *Neisseria meningitidis* serogroup A, *streptococcus pneumoniae*, rotavirus, rubella and yellow fever) from 2021 to 2030 in 194 countries. The results are based on the estimates of deaths averted under the target scale-up coverage scenario compared to no vaccination to capture the full impact of vaccination.

### *2.3.2 Modelling the benefits and costs of surveillance and emergency response*

In estimating the rate of return for the surveillance and emergency response programme, we have focused on the programme interventions for which the outcomes are deaths avoided. We readily acknowledge that surveillance and emergency response is complex and far reaching, and has multiple outcomes, some of which are uncertain and difficult to quantify.

#### *2.3.2.1 Purpose of surveillance and emergency response*

Effective surveillance can improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It also provides the necessary information to implement rapid response mass vaccination campaigns and the baseline data to monitor effectiveness of various interventions.

Public health surveillance includes systematic collection, analysis and dissemination of health data to all relevant stakeholders (Langmuir, 1971; Krishna, 2021). It is vital for the prevention and control of both communicable diseases and NCDs. It is an essential tool in the early detection of outbreaks, in determining the burden of the disease and the extent of its spread (Thacker & Stroup, 1998), and in assessing risk factors and populations at risk.

The strengthening of key responsibilities of surveillance systems, such as overall emergency management, communications and social mobilization, water, sanitation and hygiene (WASH) in case of waterborne diseases such as cholera, coordination of vaccination response monitoring and evaluation of vaccine

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[1] The Immunization Agenda 2030 is a strategy to improve immunization rates all over the world, led by countries and implemented through broad partnerships. The targets for the Immunization Agenda 2030 include achieving 90% coverage for essential vaccines given in childhood and adolescence.

[2] We thank Dr Austin Carter (University of Washington), Dr So Yoon Sim (WHO), Dr Andrew Shattock (Swiss Tropical and Public Health Institute) and Dr Salin Sriudomporn (Johns Hopkins Bloomberg School of Public Health) for making available country-level data to enable this analysis to occur.

implementation, and enhancement of surveillance for adverse events after immunization, are broad and complex with multiple outcomes. In modelling the benefits of surveillance and emergency response, we are restricted to those indicators that can be quantified and have direct implications for social and economic outcomes. For instance, estimates of the impact and effectiveness of WASH programmes in emergency or humanitarian situations are limited (Bauza et al., 2023; Ramesh et al., 2015). Our focus is on modelling lives saved and, to the extent possible, on reductions in serious morbidity.

The surveillance and emergency response capacity of the study countries varies, but in view of the many emergencies they faced, surveillance overall became weakened. As part of the polio transition strategy, focus is on strengthening surveillance, and creating integrated surveillance and response capacity in countries.

The focus of this report is on VPDs. Therefore, the analysis is on the role of surveillance and emergency response systems in addressing VPDs for which rapid response vaccination campaigns form a major component of public health emergency responses, and as such are a major focus of the modelling approach to be discussed in the next section.

Our modelling has focused on vaccination programmes to control the scale of outbreaks of VPDs for which estimates of lives saved can be calculated.

#### *2.3.2.2 The model*

The modelling has three broad objectives, which are to:

- estimate the number of lives saved by surveillance and emergency response, largely as result of vaccination; the estimates do not include morbidity, except for polio where there are long-term implications for employment;
- estimate the economic benefits of saving lives, through projecting likely earnings generated by those who are gainfully employed during their lifetime, and estimating social benefits as a measure of the intrinsic value of life; and
- estimate the additional funding for surveillance and emergency response made available by progressively transitioning funds previously allocated to polio to include other VPDs.

Following a disease outbreak, vaccination campaigns undertaken by WHO involve vaccinating targeted age groups of every household in a particular area. They generally deliver vaccination to all targeted individuals regardless of their vaccination status (prior history). The aim is to rapidly raise population-level immunity and reduce the number of susceptible people in order to achieve disease control or elimination goals (WHO, n.d.).

The characteristics of each VPD are different and important in determining the size and nature of a disease outbreak. Disease characteristics outlined below (and explained in greater detail in the Appendix).

- Reproduction number and herd immunity – the expected number of cases directly generated by one case in a population where all individuals are equally susceptible to infection. The larger the value of the reproduction number, the more difficult it is to control the epidemic.
- Vaccination rates – which affect the frequency and size of outbreaks, although the relationship between vaccination rates and reduction in infection is not linear.
- Vaccine effectiveness – a measure of how well vaccination protects people against health outcomes such as infection, symptomatic illness, hospitalization and death. Vaccine effectiveness is generally measured by comparing the frequency of health outcomes in vaccinated and unvaccinated people (CDC, 2023b).
- Disease incidence – which affects the probability of a disease outbreak, as the higher the number of cases, the greater the likelihood of an outbreak.

These factors are included in the model.

The approach taken in this study builds on modelling approaches by Pinner et al. (1992), Nokes & Anderson (1988) and Kucharski et al. (2016) to estimate the effect of improved surveillance and emergency response through mass vaccinations. This methodology incorporates the factors affecting the spread of outbreaks to estimate deaths averted for each VPD (or in the case of polio, paralysis averted). The characteristics of each VPD are different and important in determining the size and other characteristics of the disease outbreaks, as discussed above.

The number of deaths averted is the product of the forecast baseline deaths in each year for a country and disease, and a country and disease-specific factor (CDSF). The CDSF is the product of the specific disease reproduction number, the country-relative incidence of that disease, the proportion of unvaccinated population, the implementation rate and the outbreak weighting, divided by the vaccine effectiveness.

Equation 1. Surveillance and emergency response model structure

$$DA_{sevid} = \sum_{2020}^{2030} \mu \times \frac{RN_d RI_{din}(1 - VaccPop)_{din} \times Impl_{din} \times OW_{di}}{VaccEff_{di}}$$

where:

DA = deaths averted
sev = surveillance emergency vaccination
$\mu$ = average deaths per annum (WHO data 2010–2017)
i = country
n = year
d = disease
RN = reproduction number
RI = relative incidence of disease, d, in country i
OW = outbreak weighting, the relative probability of an outbreak
VaccPop = percentage of the population that has received a particular vaccine type
VaccEff = effectiveness of particular vaccine
VaccTrend = gradient of linear model of population vaccination rate
VaccConst = constant for linear model of population vaccination rate
Impl = level of implementation of funding from polio transition

One of the important factors affecting the capacity of surveillance and emergency response systems to detect disease outbreaks is the adequacy of funding. The model assumes that the initial capacity reflects the existing level of funding received, which will increase as funding is transitioned from polio to other VPDs.

In parallel with the increased surveillance and emergency response vaccination capacity, it is assumed that there is an increase in routine vaccination as discussed in Section 2.3.1. The increase in surveillance and emergency response vaccination capacity results in a rise in the number of deaths averted, which is then assumed to diminish closer to 2030 as the impact of the increased routine vaccination programme takes over. As the proportion of unvaccinated population decreases, the probability of outbreaks decreases, and hence, deaths averted through the surveillance and emergency response systems will also decrease.

#### *2.3.2.3 Vaccines included in the model*

The vaccines included in the surveillance and emergency response model incorporate some, but not all, of those reported by Carter et al. (2021) that address the following pathogens:

- tuberculosis
- diphtheria
- tetanus
- pertussis
- hepatitis B
- *haemophilus influenzae* type B
- measles
- *streptococcus pneumoniae*
- rotavirus
- polio
- rubella.

The vaccines to reduce the above pathogens modelled in surveillance and emergency response include the following:

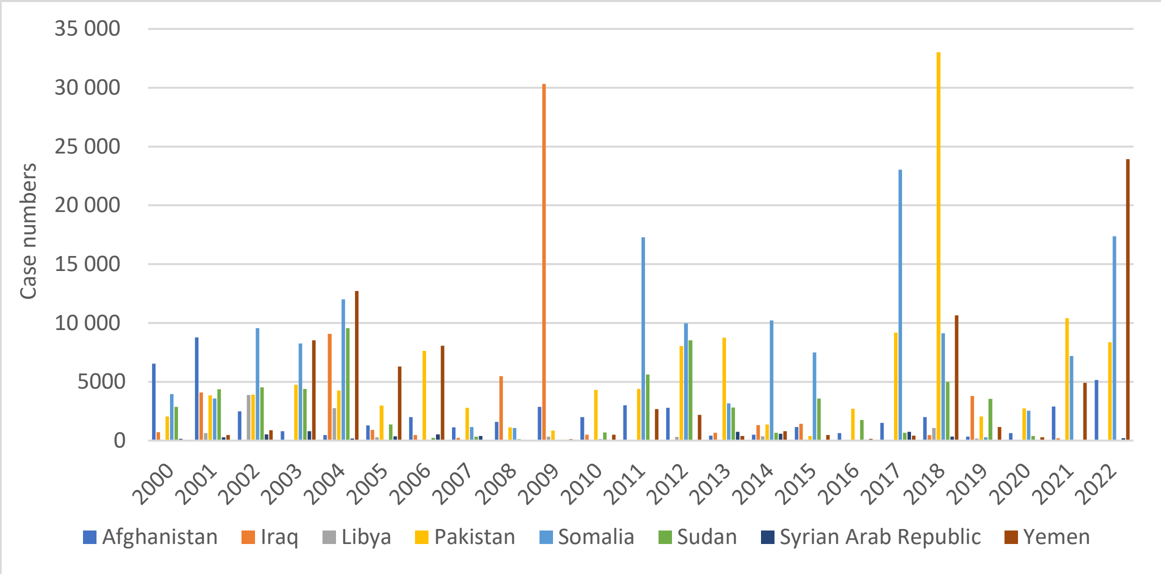
- Bacillus Calmette-Guérin (BCG)
- diphtheria-tetanus-pertussis-containing vaccine, third dose (DTP3)
- hepatitis B, third dose (HepB)
- *Haemophilus influenzae* type b, third dose (Hib3)
- measles-containing vaccine (MCV)
- inactivated polio-containing vaccine (IPV) and polio-containing vaccine, third dose (Pol3)
- rubella-containing vaccine, first dose (RCV1)
- pneumococcal conjugate vaccine (PCV)
- rotavirus vaccines, completed dose (RotaC).

Some of these vaccines, such as RotaC and BCG, are not generally part of the emergency response. However, we have included them because of the role surveillance has in vaccine introduction decisions (Agócs et al., 2014) and in monitoring vaccine performance (Nair et al., 2019). While the impact of these factors is more difficult to quantify, they are consistent with the proposition that, due to these factors, a small proportion of total vaccinations arise from surveillance activities. This approach was also followed by the Deloitte study in the WHO African Region (WHO, 2019).

#### *2.3.2.4 Data issues*

Data for each of these variables are available from WHO's Global Health Observatory (WHO, 2023d) and the literature (e.g. Amanna & Slifka, 2020).

There are data on the frequency and size of outbreaks from WHO's Global Health Observatory, although the data are not always complete due to reporting omissions. The data for measles illustrate the randomness and uncertainty of disease outbreaks (see Fig. 3).




*Source*: WHO (2023e).

**Fig. 3. Reported case numbers for measles in selected countries, 2000–2022**

We project the likely deaths from future outbreaks by modifying the long-term average based on the historical outbreaks. The past deaths and incidence rates attributable to each VPD are obtained from WHO's Global Health Observatory. While outbreaks are not expected every year, the deaths attributable to each disease are based on an average of outbreaks over time, with the incidence rates related to the likelihood of an outbreak. The average is modified by an "outbreak weighting factor" determined by an econometric model that estimates future outbreaks based on the variance of the size and frequency of past outbreaks.

Vaccination rates are based on WHO/UNICEF Estimates of National Immunization Coverage; however, outbreaks may still occur due to below-average vaccination rates in a particular region of a country.

#### *2.3.2.5 Limitations of the model*

Factors not included in the modelling are the timing of emergency responses, nor the number and duration of vaccines administered. These are important factors that can significantly affect the outcomes of rapid mass vaccination campaigns.

# 3. Results

## 3.1 Return on investment: national immunization programmes

### *3.1.1 Immunization deaths averted: results*

This section of the report is concerned with estimating the return on investment from national immunization programmes against a range of VPDs in eight countries of the Eastern Mediterranean Region – Afghanistan, Iraq, Libya, Pakistan, Somalia, Sudan, Syrian Arab Republic and Yemen.

Table 6 shows that the projected number of deaths averted by immunization for the period 2021 to 2030 for the eight countries was estimated to be 2.7 million. More than two thirds (69.4%) of deaths averted were from the measles vaccines (MCV1, MCV2), of which 65.9% were expected to be from Pakistan. Overall, more than 60% of deaths averted were from Pakistan.

**Table 6. Deaths averted by immunization in selected countries, by vaccine, 2021–2030**

| Vaccine | Afghanistan | Iraq | Libya | Pakistan | Somalia | Sudan | Syrian Arab Republic | Yemen | Total |
|---|---|---|---|---|---|---|---|---|---|
| **BCG** | 2 196 | 760 | 66 | 11 589 | 304 | 1 558 | 91 | 482 | 17 045 |
| **DTP3** | 12 500 | 6 732 | 655 | 62 534 | 2 188 | 12 518 | 1 055 | 5 157 | 103 339 |
| **HepB** | 3 770 | 5 788 | 1 542 | 19 455 | 2 596 | 8 211 | 4 370 | 2 586 | 48 318 |
| **HepB_BD** | 1 520 | 5 973 | 0 | 1 479 | 264 | 1 458 | 43 | 131 | 10 868 |
| **Hib3** | 37 417 | 9 104 | 443 | 129 453 | 32 990 | 50 568 | 749 | 17 946 | 278 669 |
| **HPV** | 2 557 | 667 | 0 | 30 098 | 0 | 4 973 | 609 | 0 | 38 903 |
| **MCV1** | 120 459 | 80 812 | 6 409 | 1 194 521 | 143 085 | 189 590 | 25 228 | 53 472 | 1 813 576 |
| **MCV2** | 3 458 | 3 018 | 568 | 32 280 | 1 227 | 3 664 | 2 259 | 2 143 | 48 618 |
| **MenA** | 0 | 0 | 0 | 0 | 0 | 1 716 | 0 | 0 | 1 716 |
| **PCV3** | 36 103 | 6 705 | 457 | 125 706 | 9 564 | 50 301 | 164 | 17 192 | 246 194 |
| **RotaC** | 12 141 | 2 877 | 119 | 23 746 | 2 741 | 12 629 | 76 | 9 713 | 64 042 |
| **Rubella** | 100 | 2 643 | 1 318 | 541 | 46 | 386 | 1 096 | 4 | 6 135 |
| **Yellow fever** | 0 | 0 | 0 | 0 | 0 | 3 979 | 0 | 0 | 3 979 |
| **Total** | 232 222 | 125 077 | 11 577 | 1 631 402 | 195 005 | 341 552 | 35 741 | 108 825 | 2 681 401 |

BCG: Bacillus Calmette-Guérin; DTP3: diphtheria-tetanus-pertussis, third dose; HepB: hepatitis B; HepB_BD: hepatitis B, birth dose; Hib3: *Haemophilus influenzae* type b, third dose; HPV: human papillomavirus; MCV1: measles-containing vaccine, first dose; MCV2: measles-containing vaccine, second dose; MenA: meningococcus A; PCV3: pneumococcal conjugate vaccine, third dose; RotaC: rotavirus vaccines, completed dose.

*Source*: Authors' estimates, based on data from Carter et al. (2021).

Table 7 shows the total number of deaths averted by immunization per year for the period 2021 to 2030 for the eight study countries.

**Table 7. Total deaths averted by immunization in selected countries, by year, 2021–2030**

| | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Afghanistan** | 19 726 | 20 353 | 21 075 | 21 823 | 22 691 | 23 572 | 24 454 | 25 327 | 26 183 | 27 018 |
| **Iraq** | 10 073 | 10 474 | 11 034 | 11 663 | 12 331 | 12 938 | 13 475 | 13 943 | 14 367 | 14 779 |
| **Libya** | 1 087 | 1 088 | 1 101 | 1 122 | 1 145 | 1 167 | 1 188 | 1 208 | 1 226 | 1 245 |
| **Pakistan** | 146 585 | 149 956 | 153 280 | 156 544 | 159 971 | 163 797 | 168 130 | 172 862 | 177 744 | 182 534 |
| **Somalia** | 12 417 | 13 384 | 14 596 | 15 919 | 17 301 | 18 709 | 21 416 | 24 388 | 27 174 | 29 702 |
| **Sudan** | 29 488 | 30 185 | 30 939 | 32 013 | 33 210 | 34 485 | 35 806 | 37 146 | 38 482 | 39 797 |
| **Syrian Arab Republic** | 2 868 | 2 970 | 3 094 | 3 231 | 3 398 | 3 582 | 3 805 | 4 040 | 4 268 | 4 486 |
| **Yemen** | 9 152 | 9 443 | 9 845 | 10 279 | 10 715 | 11 132 | 11 528 | 11 899 | 12 248 | 12 584 |
| | | | | | | | | | | |
| **All 8 countries** | 231 395 | 237 853 | 244 964 | 252 593 | 260 761 | 269 382 | 279 803 | 290 812 | 301 694 | 312 145 |

*Source*: Authors' estimates, based on data from Carter et al. (2021).

### *3.1.2 Costs*

Table 8 shows the cost of the immunization programmes for the same period. These unpublished country-level costs were provided by WHO headquarters in July 2023. Costs include vaccine costs (costs of vaccines, injection supplies, wastage, buffer stock, freight), immunization delivery costs (labour, storage, transportation, other capital costs, recurrent costs), and stockpile costs.

**Table 8. Total cost of immunization in selected countries, 2021–2030, US$ million**

| | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Afghanistan** | 38.8 | 41.1 | 51.9 | 45.5 | 58.0 | 80.1 | 61.2 | 93.8 | 69.5 | 73.2 | 613.1 |
| **Iraq** | 114.4 | 129.0 | 142.2 | 153.2 | 193.7 | 192.7 | 203.3 | 213.2 | 222.5 | 231.4 | 1795.6 |
| **Libya** | 51.0 | 51.5 | 52.9 | 53.3 | 53.7 | 54.1 | 56.1 | 57.6 | 58.8 | 59.7 | 548.7 |
| **Pakistan** | 244.0 | 372.6 | 454.0 | 299.1 | 308.7 | 362.7 | 386.0 | 385.0 | 391.7 | 425.9 | 3629.7 |
| **Somalia** | 3.2 | 3.8 | 7.0 | 4.9 | 5.5 | 9.0 | 14.8 | 19.0 | 33.1 | 28.9 | 129.2 |
| **Sudan** | 55.4 | 87.5 | 58.5 | 73.6 | 73.2 | 87.7 | 81.6 | 85.8 | 89.5 | 103.0 | 795.8 |
| **Syrian Arab Republic** | 4.2 | 4.5 | 4.8 | 5.1 | 8.3 | 7.0 | 10.8 | 12.5 | 14.2 | 15.5 | 86.9 |
| **Yemen** | 34.2 | 42.4 | 38.5 | 40.4 | 42.2 | 50.0 | 46.2 | 48.4 | 50.4 | 58.0 | 450.7 |
| | | | | | | | | | | | |
| **All 8 countries** | 545.2 | 732.4 | 809.8 | 675.2 | 743.3 | 843.4 | 859.9 | 915.2 | 929.6 | 995.6 | 8049.7 |

*Source*: Authors' estimates, based on data from Dr Andrew Shattock of the Swiss Tropical and Public Health Institute.

### 3.1.3 Economic benefits

Employing the costs set out in Table 8, and the benefits derived from the deaths averted (Table 7), yielded a BCR of 23.3 in economic benefits and 38.7 including social benefits, for all eight countries combined. For each of the eight countries, Table 9 reports the economic benefits, social benefits, costs and BCRs expressed in net present value terms. The economic BCR is the economic benefit divided by the cost, while the economic and social BCR also includes social benefits.

**Table 9. Benefits and costs, net present value and BCRs, in selected countries**

| | Economic benefit US$ million | Social benefit US$ million | Cost US$ million | BCR economic | BCR economic and social |
|---|---|---|---|---|---|
| **Afghanistan** | 4 390.4 | 9 112.8 | 512.9 | 8.6 | 26.3 |
| **Iraq** | 22 969.9 | 5 022.6 | 1 503.8 | 15.3 | 18.6 |
| **Libya** | 2 262.5 | 465.4 | 466.0 | 4.9 | 5.9 |
| **Pakistan** | 105 164.8 | 64 667.4 | 3 074.2 | 34.2 | 55.2 |
| **Somalia** | 4 995.4 | 7 125.8 | 103.7 | 48.2 | 116.9 |
| **Sudan** | 14 194.6 | 13 201.6 | 671.1 | 21.2 | 40.8 |
| **Syrian Arab Republic** | 927.2 | 1 418.8 | 71.4 | 13.0 | 33.8 |
| **Yemen** | 3 442.5 | 3 642.7 | 380.1 | 9.1 | 17.7 |
| | | | | | |
| **All 8 countries** | 158 347.2 | 104 657.0 | 6 783.1 | 23.3 | 38.7 |

*Source*: Authors' estimates.

Table 10 shows that the results vary significantly when different discount rates are used. This is because a large proportion of the benefits occur some distance into the future, while the costs are incurred over a shorter period of time.

**Table 10. Economic and social BCRs, diminishing cost assumption, different discount rates, in selected countries**

| | 0% | 2% | 3% | 5% |
|---|---|---|---|---|
| **Afghanistan** | 74.1 | 35.9 | 26.3 | 15.7 |
| **Iraq** | 55.3 | 26.1 | 18.6 | 10.2 |
| **Libya** | 16.1 | 8.0 | 5.9 | 3.3 |
| **Pakistan** | 164.5 | 77.1 | 55.2 | 30.9 |
| **Somalia** | 322.6 | 158.5 | 116.9 | 69.8 |
| **Sudan** | 123.7 | 57.2 | 40.8 | 22.8 |
| **Syrian Arab Republic** | 91.6 | 45.6 | 33.8 | 20.5 |
| **Yemen** | 44.1 | 23.2 | 17.7 | 11.3 |
| | | | | |
| **All 8 countries** | 111.5 | 53.9 | 38.7 | 23.1 |

*Source*: Authors' estimates.

The BCRs demonstrate that achieving the Immunization Agenda 2030 targets by 2030 would generate a large return on investment. While substantial, these BCRs are in line with those found by other health intervention studies and the aggregate BCRs reported in Sim et al. (2020).

## 3.2 Return on investment: surveillance and emergency response

This section presents the results of the analysis for the surveillance and emergency response systems. It includes estimates of the number of deaths averted, the benefits arising from that and the assumed cost of future funding for polio transition.

### 3.2.1 Surveillance and emergency response deaths averted: results

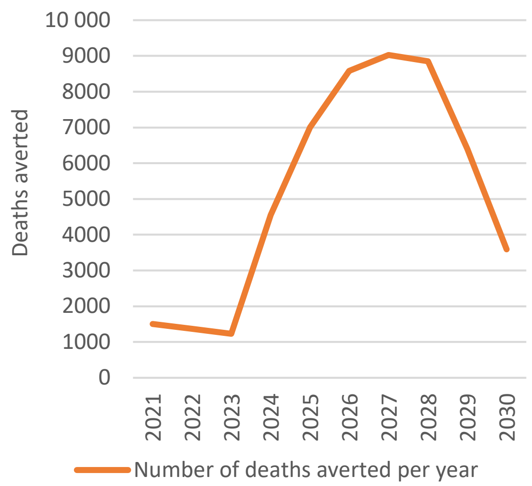
The projected number of deaths averted over the modelled period (2021–2030) due to increased surveillance and emergency response are summarized in Table 11.

**Table 11. Total deaths averted due to increased surveillance and emergency response, in selected countries, 2021–2030**

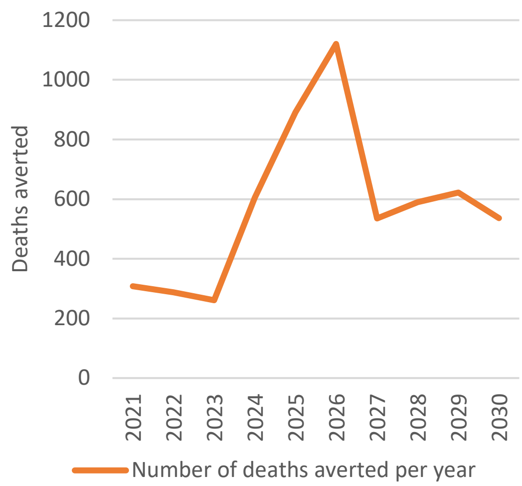
| Country | Deaths averted |
|---|---|
| **Afghanistan** | 52 118 |
| **Iraq** | 5 756 |
| **Libya** | 269 |
| **Pakistan** | 100 026 |
| **Somalia** | 113 973 |
| **Sudan** | 25 994 |
| **Syrian Arab Republic** | 6 269 |
| **Yemen** | 33 645 |
| **All** | 338 049 |

*Source*: Authors' estimates.

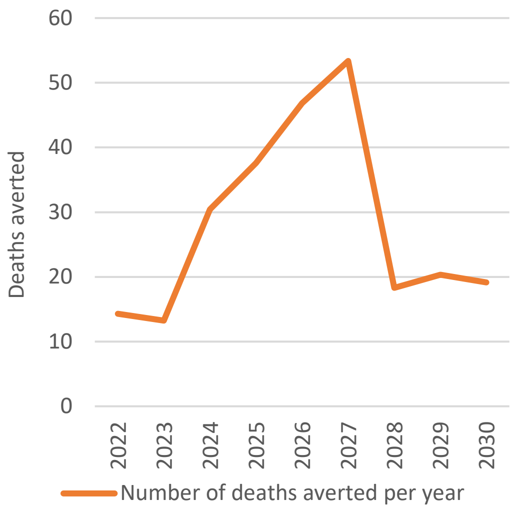
The increase in deaths averted for each country through strengthened surveillance response is illustrated in Fig. 4 and the aggregated deaths averted for all eight countries are shown Fig. 5. The deaths averted in Somalia are disproportionately high, mainly due to lower initial routine vaccination rates as well as the very high incidence levels of the VPDs relative to the other countries.



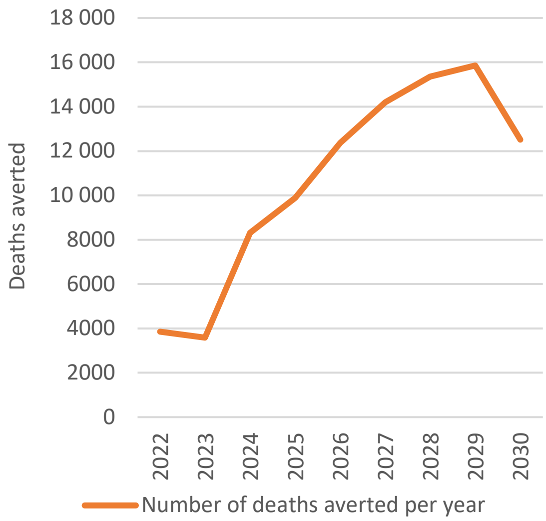

**Afghanistan**



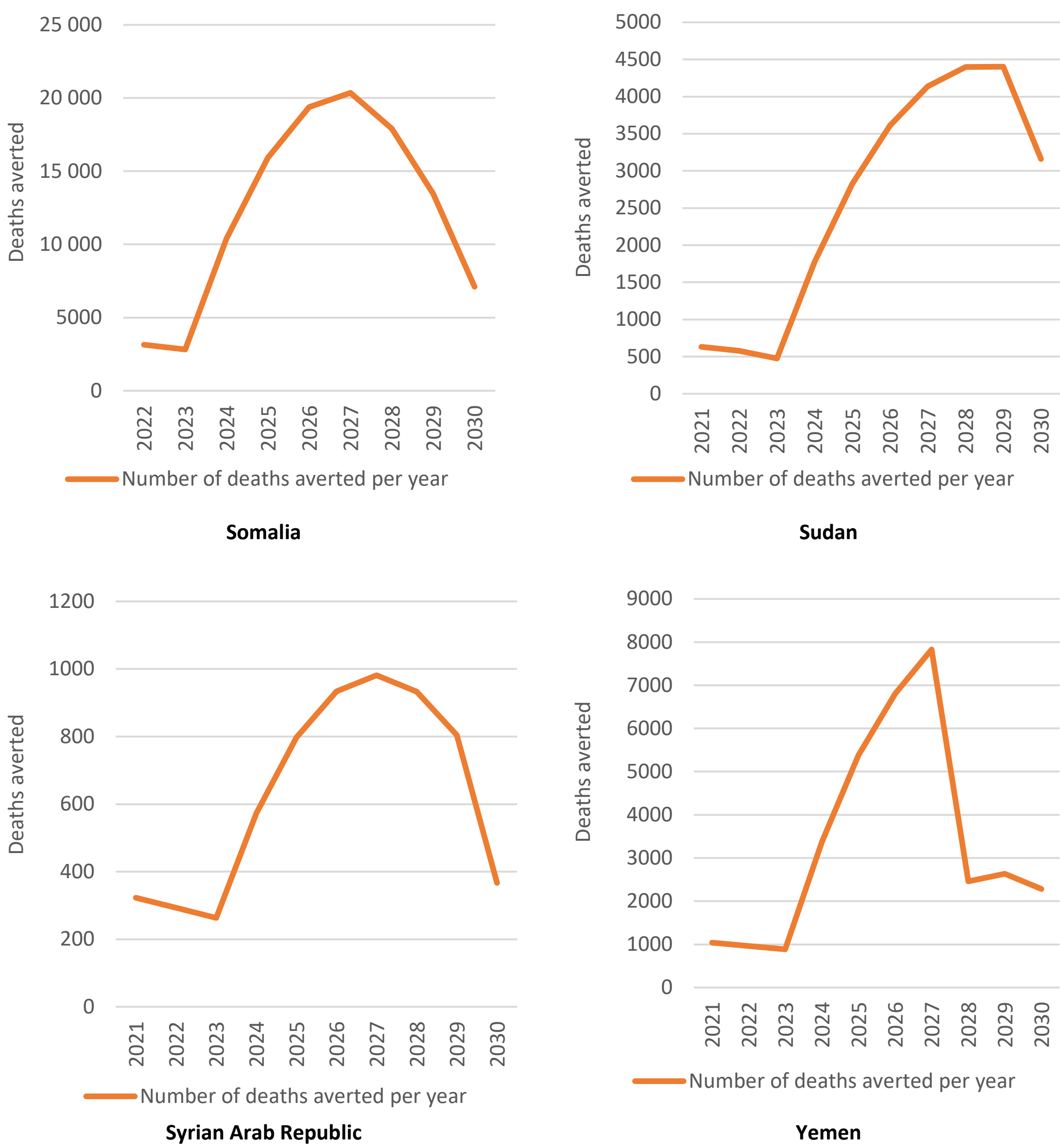

**Iraq**




**Libya**

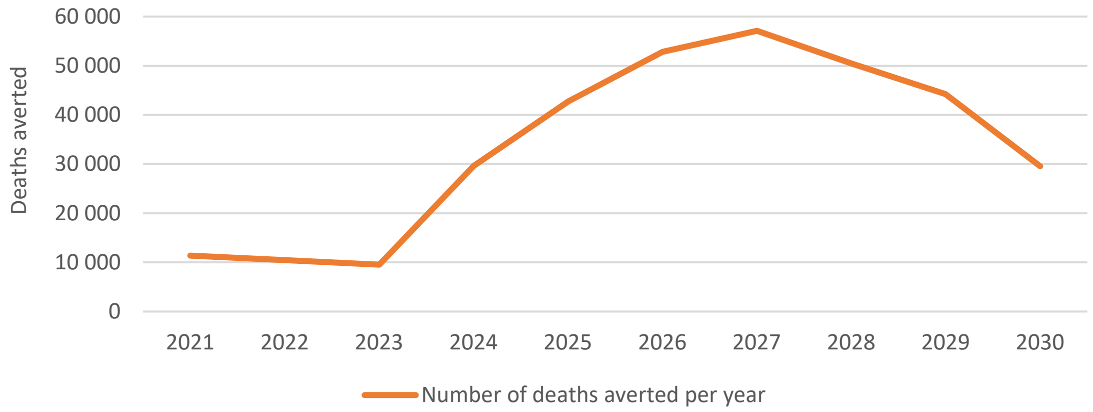



**Pakistan**




*Source*: Authors' estimates.

**Fig. 4. Deaths averted by additional surveillance response, all vaccines, in individual selected countries, 2021–2030**




*Source*: Authors' estimates.

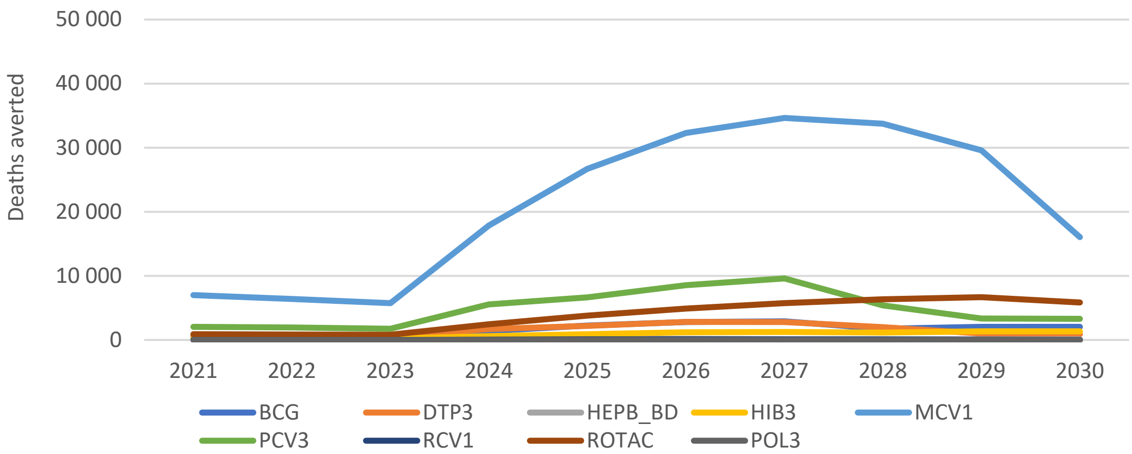
**Fig. 5. Deaths averted in selected countries, 2021–2030**

Measles and tuberculosis have high levels of deaths averted, with measles having a well-established pattern of outbreaks. Tuberculosis also has a high level of estimated deaths averted, with approximately half of these occurring in Somalia where the disease has a high prevalence (Fig. 6).

### *3.2.2 Economic benefits*

As discussed in Section 2.1, the health impacts associated with deaths averted are converted into economic benefits based on the expectation that a proportion of those saved will eventually enter the workforce and produce economic output. An exception for this approach applies to polio, which has very low fatality rates, but much higher rates of morbidity due to paralysis.

In one in 200 cases, the polio virus can migrate into the central nervous system and lead to paralysis, known as acute flaccid paralysis (AFP). AFP most commonly affects the legs, and less commonly involves the muscles of the head, neck and diaphragm. For the purposes of the economic modelling, cases of paralysis are considered to substantially diminish the probability of people with AFP from entering the workforce.




*Source*: Authors' estimates.

**Fig. 6. Death averted by individual emergency response vaccines, in selected countries, 2021–2030**

The economic modelling of mortality follows, for each country, the cohort of avoided deaths (and paralysis in the case of polio) for each of the years from 2024 up to 2030. Each cohort is classified by age and sex, and is subject to the mortality rates applicable to the year based on estimates from the United Nations World Population Prospects data (United Nations, 2022b).

The economic benefits from the deaths averted in the strengthened surveillance and emergency response are discounted at 3% and are summarized in Table 12 in Section 3.2.3.

The total economic benefits derived from the strengthened surveillance and emergency response have a net present value of US$ 13.5 billion and the social benefits are US$ 13.0 billion, for a total of US$ 26.5 billion.

### *3.2.3 Funding costs*

Costs for the surveillance and emergency response programmes were obtained from the WHO Regional Office for the Eastern Mediterranean, and included only those associated with surveillance and emergency response vaccinations. These are modelled as baseline costs.

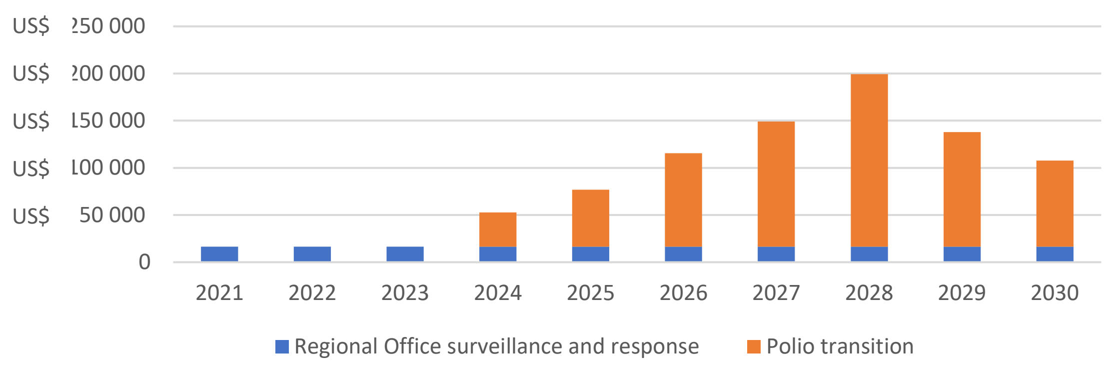
Estimates of future total polio transition funding to VPDs are modelled based on the most recently available data for polio surveillance, an assumed transition rate of this level of funding to all VPDs, and a reduction in surveillance funding requirements as the national vaccination rates approach the Immunization Agenda 2030 rates. The total surveillance funding for 2021 has been extracted from the WHO Regional Office's data collection conducted for this project, together with estimates of UNICEF funding based on expended GPEI allocations to UNICEF sourced from the GPEI website. Total funding for polio for 2021 for the eight countries was estimated to be US$ 288.7 million, of which US$ 164.7 million was for WHO and US$ 124.0 million was for UNICEF.

We assumed that the polio transition funding would not be immediately fully available but would be made progressively, to peak in 2028. After that we assumed that it would taper down, reflecting reduced requirements as the national vaccination levels approached the Immunization Agenda 2030 rate. Based on these assumptions, the projected funding of transitioning from polio programmes for VPDs in the eight countries is shown in Fig. 7. The base costs are the current surveillance and emergency response costs, sourced from the WHO Regional Office's data collection of US$ 16.46 million as in Table 12, which we assumed would continue for the period to 2030. These are shown in Fig. 7 as the blue bars.

**Table 12. Surveillance and vaccination funding, in selected countries, yearly average, 2018–2021, US$ million**

| Country | Estimated annual funding, non-polio VPDs |
|---|---|
| **Afghanistan** | US$ 3 416 862 |
| **Iraq** | US$ 639 361 |
| **Libya** | US$ 408 727 |
| **Pakistan** | US$ 4 929 562 |
| **Somalia** | US$ 1 316 745 |
| **Sudan** | US$ 3 137 461 |
| **Syrian Arab Republic** | US$ 1 540 532 |
| **Yemen*** | US$ 1 078 445 |
| **Total** | US$ 16 467 695 |

*Note*: *Estimate based on per capita average.
*Sources*: WHO Regional Office for the Eastern Mediterranean, CDC and GPEI.




*Source*: Authors' estimates.

**Fig. 7. Existing WHO surveillance and response costs and projected polio transition funding, in selected countries, 2021–2030, US$ thousands**

A net present value of these estimated costs was then calculated, which totalled US$ 726.5 million for the eight countries using a discount rate of 3% over the period 2021–2030.

### *3.2.4 Rate of return: surveillance and emergency response*

The rate of return on investment is expressed as a BCR, where the net present value of the economic and social benefits is divided by the net present value of the costs. This ratio was computed for a discount rate of 3%. These values generate BCRs of 18.5 for economic benefits only and 36.4 for economic and social benefits combined.

The results presented in Table 13 show that the proposal to lift the capabilities of surveillance and response would produce economic and social benefits – substantially in excess of the costs of not doing so. The costs are for the period 2021–2030. The benefits extend to retirement of the cohorts vaccinated over the period 2021–2030.

**Table 13. Strengthened surveillance and emergency response benefits and costs, in selected countries, 2021–2030**

| | |
|---|---|
| **Economic benefit US$ million** | US$ 13 454.0 |
| **Social benefit US$ million** | US$ 12 995.9 |
| **Cost US$ million** | US$ 726.5 |
| **BCR economic** | 18.5 |
| **BCR economic and social** | 36.4 |

*Source*: Authors' estimates.

Individual country benefits and costs are shown in Table 14.

**Table 14. Surveillance and emergency response benefits and costs, in individual selected countries, 2021–2030**

| Country | Economic benefits US$ million | Social benefit US$ million | Cost US$ million | BCR economic | BCR economic and social |
|---|---|---|---|---|---|
| **Afghanistan** | US$ 973.2 | US$ 2 035.8 | US$ 203.2 | 4.8 | 14.8 |
| **Iraq** | US$ 1 006.3 | US$ 233.4 | US$ 11.9 | 84.7 | 104.3 |
| **Libya** | US$ 47.3 | US$ 11.0 | US$ 3.5 | 13.6 | 16.7 |
| **Pakistan** | US$ 6 199.7 | US$ 3 935.6 | US$ 359.0 | 17.3 | 28.2 |
| **Somalia** | US$ 2 950.5 | US$ 4 203.3 | US$ 57.9 | 50.9 | 123.5 |
| **Sudan** | US$ 1 053.3 | US$ 991.3 | US$ 43.6 | 24.2 | 46.9 |
| **Syrian Arab Republic** | US$ 166.3 | US$ 253.9 | US$ 32.1 | 5.2 | 13.1 |
| **Yemen** | US$ 1 057.4 | US$ 1 331.5 | US$ 15.3 | 69.3 | 156.6 |
| **Total** | US$ 13 454.0 | US$ 12 995.9 | US$ 726.5 | 18.5 | 36.4 |

*Source*: Authors' estimates.

## 4. Limitations

As with all models constructed to analyse likely outcomes in the context of an uncertain future, there are assumptions about the future which may prove to be wrong. The modelling undertaken for this report contains abstractions of the present to make the analysis manageable, which means that there are factors which influence the main estimated outcomes which are not included in the modelling.

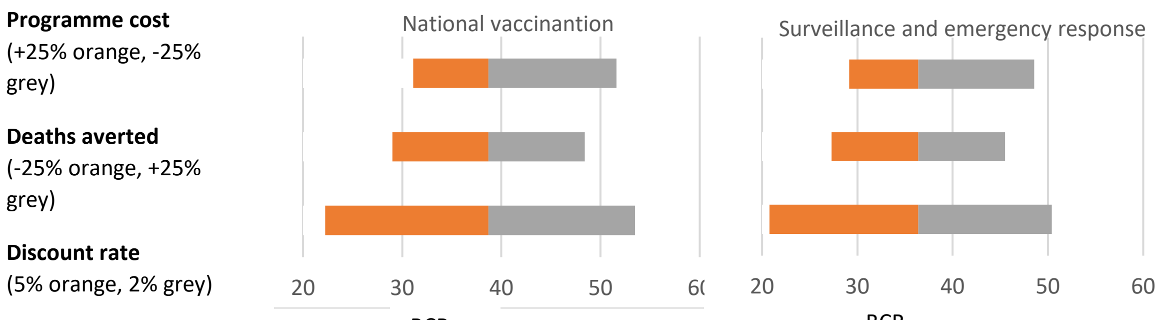
For instance, our modelling of the benefits of surveillance and response has been restricted to interventions through vaccination, when in reality, there are other interventions for certain diseases such as WASH and communication programmes which are more difficult to model. This means that the estimated benefits are less than would be the case if all interventions could be included.

The models make a large number of assumptions to reach their conclusions. This is undertaken based on the best evidence available. However, it is acknowledged that this is incomplete and introduces uncertainties to the calculation of the results. There are details of emergency response, such the timing of responses, and the number and duration of vaccines administered which are not available. The economic benefits depend on various assumptions about the economic futures of those who lives are saved. For instance, we assume that the proportion of lives saved who will work in the future is much the same as current practice. The future workforce participation rate depends on a complex set of variables about future economic opportunities, and social and cultural attitudes to work, which could lead to lower or higher rates in the future.

The availability of funding for VPD surveillance is assumed. In practice, it could follow a different pattern over time and between countries, depending on needs. This could lead to either higher or lower BCRs.

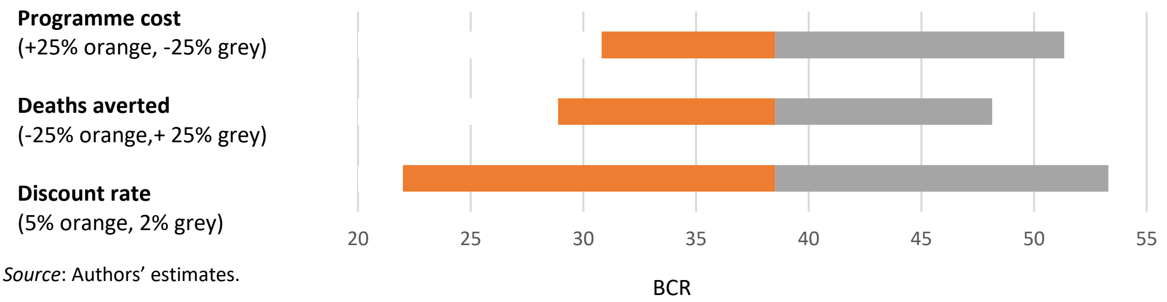
To address some of the uncertainties in the modelling, we undertake sensitivity analysis of some of the main variables to assess the impact of large changes on the results. These are presented in Fig. 8 which shows the sensitivity of the BCR variations in the key variables that determine the BCRs. For instance, if deaths averted by the national vaccination programme was to be 25% lower, the BCR would be reduced by 9.7 to 29 (orange bar), or if they were 25% higher, the BCR would be increased by 9.7 to 48 (grey bar).

This sensitivity analysis for large variations (+/- 25%) in costs and deaths averted indicate that while such changes can have a significant impact on the results, the BCRs remain highly supportive of investment in the two programmes.




*Source*: Authors' estimates.

**Fig. 8. BCR sensitivity to variation in key variable, national vaccination, and surveillance and emergency response, in selected countries**




*Source*: Authors' estimates.

**Fig. 9. BCR sensitivity to variation in key variable, for the overall programme, in selected countries**

The overall result of the sensitivity analysis for the combined results, as shown in Fig. 9, confirms that the results of the modelling remain robust to large variations in key assumptions around costs, deaths averted and the discount rate. These are shown in Fig. 9, for example, where an increase in assumed costs of 25% reduces the BCR to just over 30, while a decrease in costs of 25% increases the BCR to over 50.

## 5. Conclusion

The results of the benefit-cost analysis, shown in Table 15, show that the investment returns to strengthening both routine immunization and surveillance and emergency response programmes in the eight countries are very high. Employing our preferred assumption with respect to the discount rate (3%):

- strengthening routine immunization programmes to achieve Immunization Agenda 2030 targets by 2030 provides an estimated BCR of 38.7 (meaning that for each dollar invested US$ 38.70 are returned);
- strengthening the surveillance and emergency response programme by repurposing the polio programme assets yields a BCR of 36.4 (meaning that for each dollar invested, US$ 36.4 are returned); and
- overall, the combined programme yields total estimated benefits in present value terms of US$ 289.2 billion at a present value cost of US$ 7.5 billion, providing an estimated BCR of 38.5.

**Table 15. Summary of benefit and cost results for immunization, surveillance and emergency response, in selected countries**

| | Economic benefit US$ million | Social benefit US$ million | Economic and social benefits US$ million | Cost US$ million | BCR economic | BCR economic and social |
|---|---|---|---|---|---|---|
| **Routine vaccination** | U$ 158 069.6 | US$ 104 657.0 | US$ 262 726.6 | US$ 6 783.1 | 23.3 | 38.7 |
| **Surveillance and emergency response** | US$ 13 454.0 | US$ 12 995.9 | US$ 26 449.8 | US$ 726.5 | 18.5 | 36.4 |
| **Overall result** | US$ 171 523.6 | US$ 117 652.9 | US$ 289 176.4 | US $7 509.6 | 22.8 | 38.5 |

*Source*: Authors' estimates.

In many respects, we regard these estimates as conservative. As discussed, the modelling on which these results are based requires assumptions about immunization, surveillance and emergency response that has simplified the complex relationships between interventions and outcomes. This has in general acted to reduce the estimated lives saved and therefore the benefits estimated.

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# Appendix 1. Disease characteristics

## A.1. Reproduction number and herd immunity

The basic reproduction number of an infectious disease ($R_0$) is the expected number of cases directly generated by one case in a population where all individuals are equally susceptible to infection. This definition assumes that no other individuals are infected or immunized. The basic reproduction number is not necessarily the same as the effective reproduction number R (usually $R_t$ [t for time]), which is the number of cases generated in the current state of a population, which does not have to be the uninfected state.

$R_0$ is not a biological constant for a pathogen, as it is affected by factors such as environmental conditions and the behaviour of the relevant population. $R_0$ values are usually estimated from mathematical models, and the estimated values are dependent on the model used and values of other parameters. Consequently, values reported in studies are most relevant to the particular setting and time, and the use of obsolete values can lead to misleading estimates. $R_0$ by itself does not estimate how quickly an infection will spread through a population.

Generally, the larger the value of $R_0$, the more difficult it is to control an epidemic. For simple models, the proportion of the population that needs to be effectively immunized (meaning not susceptible to infection) to prevent sustained spread of the infection has to be larger than $1 - 1 / R_0$. This is the so-called herd immunity threshold or herd immunity level. Herd immunity means that the disease cannot spread in the population because each infected person, on average, can only transmit the infection to less than one other contact. The basic reproduction number is affected by several factors, including the duration of infectivity of affected people, the infectiousness of the pathogen causing the disease, and the number of susceptible people in the population that the infected people contact.

## A.2. Vaccination rates

Vaccination rates affect the frequency and size of outbreaks; however, the relationship does not have a linear fashion. For example, vaccination rates of 50% do not result in a 50% reduction in the incidence of infection. In reality, the behaviour of the host/infectious disease agent interaction is invariably non-linear (i.e. complex) at the population level. There is a complex interaction between different portions of the population with respect to their immunity, susceptibility, infectiousness and latent disease status. Consequently, the impact of routine immunization programmes is not intuitively obvious and therefore not easy to predict. The effects are as dependent upon the typical course of infection within the individual patient, the biology of the infectious agent, and the social and demographic makeup of the community, as on the type of mass vaccination policy implemented to control the spread of infection.

The current routine vaccination rates were obtained from Carter et al. (2021), and hence indirectly through the Vaccine Impact Model Consortium (VIMC). The current vaccine rates are modelled by Carter et al. to increase to 2030 to meet the WHO Immunization Agenda 2030 (WHO, 2020), a strategy for vaccines and immunization for the decade 2021–2030. For modelling purposes, the effect of any emergency response mass vaccination campaign is dependent upon the unvaccinated proportion of the population, as these are the ones who are considered most susceptible to diseases compared to the vaccinated proportion of the population.

## A.3. Vaccine efficacy and effectiveness

A vaccine's efficacy is measured in a controlled clinical trial and is based on how many people who have been vaccinated develop the disease, compared with how many people who got a placebo (dummy vaccine) developed the same outcome. The numbers of sick people in each group are compared, in order to calculate the relative risk of getting sick, depending on whether or not the subjects received the vaccine. This is called the efficacy – a measure of how much the vaccine lowered the risk of getting sick. If a vaccine has high efficacy, a lot fewer people in the group who received the vaccine got sick than the people in the group who received the placebo. For example, a vaccine with an efficacy of 90% means that those who received the vaccine have a 90% lower risk of developing disease. This is calculated by comparing the number of cases of disease in the vaccinated group versus the placebo group. An efficacy of 90% does not mean that 10% of the vaccinated group will become ill.

Vaccine effectiveness is a measure of how well vaccines work in the real world. Effectiveness in the real world can differ from the efficacy measured in a trial, as it is not possible to predict exactly how effective vaccination will be for a much bigger and more variable population getting vaccinated in real-life conditions, where some may not receive all the recommended doses or at the correct time (WHO, 2021).

Vaccine efficacy and effectiveness varies considerably between different vaccines, with the influenza vaccine being 40–60% effective, whereas one dose of the measles, mumps and rubella (MMR) vaccine is 93% effective at preventing measles after one dose and 97% effective after two doses.

## A.4. Disease incidence

Disease incidence affects the probability of a disease outbreak, as the more cases, the higher the likelihood of an outbreak. As vaccination coverage increases, disease outbreaks usually follow a trend towards elimination, defined by declines in mean incidence, but high variability in outbreak size (Graham et al., 2019). Inconsistent vaccination rates across a country may allow the population susceptibility to increase so that outbreaks can occur if the disease is reintroduced; for example, through movement across borders (Baker et al., 2022).