Imagining the future of pandemics and epidemics

A 2022 perspective

World Health Organization

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Imagining the future of pandemics and epidemics: a 2022 perspective
ISBN 978-92-4-005209-3 (electronic version)
ISBN 978-92-4-005210-9 (print version)

Suggested citation. Imagining the future of pandemics and epidemics: a 2022 perspective. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.
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Foreword

Dr Tedros Adhanom Ghebreyesus
Director-General
WHO

This is a historical moment
The COVID-19 pandemic is one of the biggest challenges we have faced in the 21st century. It has been a painful reminder that no one is safe until everyone is safe. COVID-19 has demonstrated in stark terms that a pandemic is a complex phenomenon fuelled by a multitude of diverse, interconnected factors and revealed deeply rooted structural weaknesses and insufficiencies in our health, socioeconomic, environmental and political systems.

Hindsight - critical reviews of past infectious threats - helped us react better, but the current pandemic taught us that this is not enough. To better manage the ongoing pandemic and to be better prepared for other infectious threats in the future, a forward-looking, coordinated and collaborative approach across all levels of planning and response is vital.

This is an opportunity
Being better prepared for the next infectious threat requires a mindset shift and the adoption of approaches different to what we are used to. Foresight can support the transition from emergency response to proactive infectious threat planning and management.

Leveraging futures thinking and foresight methodologies, practical applications and tools in the context of epidemic and pandemic threats, can help us identify trends, key factors, and emerging issues, negotiate uncertainties, and articulate scenarios and strategic visions.

Foresight can also help us design robust policies and strategies today which will help the global community be better prepared for tomorrow.

By engaging with a wide range of traditional and non-traditional actors and stakeholders, foresight can provide us with the opportunity to shake our habitual beliefs and shape new, inclusive narratives that allow us to imagine the future in different ways.

This is a snapshot of the future
This report is an attempt to collectively explore what the future of infectious threats might look like. We set a short time horizon (three to five years) to encourage immediate action. Inspired by the COVID-19 pandemic, the scenarios illustrated in the following pages are not a prediction of the future. Instead, they are an invitation to imagine the different directions that the current and future pandemics might take and to expand the range of plausible futures.

They are also an opportunity to identify possible risks and solutions, discuss implications and propose actions aimed at preventing the occurrence or mitigating the impact of current and future infectious threats.

This is a way forward
Through a series of conversations with stakeholders, a way forward has been highlighted. One of the strengths of foresight is its approach, bringing traditional collaborators and new actors around the table to collectively build the future of pandemic preparedness and to take actions together. Three key principles repeatedly emerged during our discussions and should be seen as the basis of any future pandemic preparedness: trust, solidarity and equity, and sustainable development.

Improved pandemic preparedness will also require more effective communication between governments, scientists, public health authorities, health care communities, the private sector, media and citizens. It will require a solid basis for a much-needed restoration of trust between individuals and collectives, and it will mean that, in the future, nations share more information, data, knowledge, expertise and resources.

Success in being better prepared for the next pandemic and epidemic threats will mean being ready to ensure access to the benefits of health technology and scientific innovation for those most in need. It will mean that medical supplies including vaccines, diagnostics, antivirals, oxygen and other essentials are distributed fairly, and that environmental goals and strategies are aligned with planetary and human health.

Overall, advancing pandemic preparedness will require a universal acceptance of pandemics as global human experiences that affect people, communities and nations in different ways. Paired with bespoke and flexible approaches, adaptable tools, platforms, and infrastructure, and underpinned by a spirit of collaboration, trust and solidarity, preparedness means we will be able to protect people, communities, economies and the environment against future infectious threats.

This report does not aim to be an exhaustive list of practical actions. It reflects the conversations we had with representatives from diverse fields, geographical locations and demographic contexts.

Foresight is a new attitude and the way forward, in-between, but also during emergencies. Taking the time to reflect on the current situation, what has led to it and how it might evolve in the future, should not be seen as a nice-to-have. On the contrary, I truly believe that these exercises will enable us to save lives, time and valuable resources in the future, and to be better prepared to tackle future infectious threats.

I am very happy that we took the time collectively, during this pandemic, to step back and to reflect, and I would like to warmly thank everyone who has contributed to the discussions.

Acknowledgements

This report was produced under the leadership of Michael J. Ryan, Executive Director of WHO Health Emergencies Programme and under the oversight of Sylvie Briand, Director of WHO Epidemic and Pandemic Preparedness and Prevention Department. The report and the wider programme were co-delivered by Arup. Foresight project team: from WHO - Nahoko Shindo, Margaux Mathis, Victoria Haldane, Matthew L. Lim, Zorica Loncar, Sandra Le Port, Hanan Twal, Jianfang Liu. From Arup - Josef Hargrave, Alexander Alexiou, Mona Ivinskis, Eleanor Tomlinson, Felicitas zu Dohna, Sonia Sousa, Selin Ergiden, Annabel Rabbets, Eleanor Davis, Conor Morris.

Advice, feedback, and support were gratefully received from the Strategic and Technical Advisory Group on Infectious Hazards (STAG-IH), the WHO Taskforce, other WHO technical units and a wide variety of subject matter experts from different fields and industries.

Trend and key factor research were undertaken by Mona Ivinskis of Arup. Engagement sessions (workshops and public roundtable discussions) were planned by Alexander Alexiou and Felicitas zu Dohna of Arup. Webinars were planned by Margaux Mathis of WHO and Sarah Hess of WHO Information Network for Epidemics (EPI-WIN).

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Executive Summary

The aim
In 2021, WHO embarked on its first foresight initiative to explore the future of pandemics and epidemics. Foresight is different from a prediction or forecasting of the future. It presents a new approach for better preparedness. It is forward looking, action-oriented and fosters collective ownership of the future.

This initiative aims to achieve a two-fold goal. Firstly, to ensure that we are collectively better prepared to tackle future epidemics and pandemics by bringing key players together. Secondly, to support informed decision-making for leaders on the transition from emergency response to future preparedness.

The method
Central to the foresight initiative is the development of scenarios. Scenarios are hypothetical, yet plausible, illustrations of the future. They are an invitation to conversations; a way of "thinking the unthinkable".[1] They are a tool for framing imagination, aiding decision-making, identifying recommendations, testing, and refining strategy and policy options.

For scenario building, the morphological approach was chosen by the foresight professionals.[2]

"We have our future in our hands. Choices we make over the coming months and years will determine the future."

Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

The approach is a well-established, systematic and thorough method, frequently used in the business world and increasingly by governments. The approach offers a structured, transparent, process-driven and software-enabled way to build scenarios.

The first step involved identifying the key components of the system of change through consultations with the Strategic Advisory Group on Infectious Hazards (STAG-IH)[3] and the WHO Foresight Task Team. From these consultations, critical determinants of pandemic and other infectious threats were identified and split into three categories:

1. Pathogen and host characteristics
2. Public health and social measures
3. Contextual factors

The second step was to agree on a time horizon within which to explore the future. For this exercise, it was set in the next three to five years to inspire immediately actionable recommendations. The time horizon determines what trends and key factors should be considered for exploration. Further, the use of the social, technological economic, environmental, political (STEEP) framework ensured a comprehensive approach and led us to identify 25 high-impact trends that will shape the future.

Analysis of the key components of the system and a review of the trends resulted in an initial set of key factors across the three categories. The key factors were validated and refined in two workshops involving subject matter experts and stakeholders from organizations and institutions representing a variety of fields and sectors.

[1] As described by futurist, military strategist and systems theorist Herman Kahn.

[2] WHO engaged Arup for this exercise. www.arup.com

[3] STAG-IH provides independent advice and analysis to WHO Health Emergencies Programme on the infectious hazards that may pose a potential threat to global health security. See https://www.who.int/groups/strategic-and-technical-advisory-group-for-infectious-hazards

The final selection of key factors provided the baseline structure for the development of the morphological box.

The morphological box comprises key factors and associated projections and helps produce consistent combinations of projections. Through this process, four alternative, consistent, and plausible pathways into the future (that is, scenarios) were selected for further development.

The scenarios and their associated implications were discussed in two public roundtable discussions. The roundtables had several aims including highlighting the role of different stakeholders in each of the four future worlds, identifying recommendations and actions for the future, as well as discussing the crucial role of leadership. The members of the panel included influential personalities from the public and private sectors, including youth and faith leaders, policy consultants, trade union representatives, anthropologists, academics, public health experts, biotech experts, health care services providers and representatives of the United Nations.

The outcome
Three pillars were established as fundamental, overarching, guiding principles for the overall effort of strengthening future pandemic preparedness:

1. Trust
2. Solidarity and equity
3. Sustainable development

They are accompanied by five themes, or areas of focus, which are key in formulating an all-encompassing approach when managing and responding to the complexity of infectious threats. In summary, the key messages under the five themes are:

1. Science, policy and environment
A sound scientific evidence base must be developed and communicated, informing transparent knowledge translation across policy and practice with a goal to master decent management of uncertainty. WHO should lead the development of a research agenda, with increased attention to science for equity. The independence of research and academic institutions must be protected and international research collaboration should be further encouraged, emphasizing diversity and in-country research capacity development. Research funders have an important role to play in realizing these goals.

Scientific evidence must inform decision-making. A multidisciplinary scientific advisory group of experts should be set up to inform decision-makers, and policies need to be translated into context specific actions. Meta-analyses of scientific information related to evolving emerging infectious threats should be widely available and easily accessible to everyone. Human-centred scientific disciplines must be funded and leveraged.

A global environment that facilitates preparedness and response to infectious threats must be created. Policy and international frameworks for future pandemic and epidemic preparedness must be solidified. There is a need to create common regulatory pathways to ensure equitable resource distribution. WHO and partners must plan for the impact of different and combined causes of migration including climate, conflicts, natural disasters, infectious threats and associated restrictions to ensure future pandemic and epidemic preparedness. Finally, a One Health approach needs to be strengthened given that the health of people is closely linked to the health of animals and our shared environment.

"It is healthy for the World Health Organization to be listening to diverse views and opinions."

Dr Jaouad Mahjour, Assistant Director-General, WHO Health Emergency Preparedness

2. People, communication and education
Infectious threats are global human experiences that start and end in communities. Engagement for preparedness includes fostering trust and actively engaging communities to protect the health and well-being of their members. Foresight underscores the need to recognize, respect and learn from knowledge held across cultural, religious, generational and other groups. Engaging with the health care workforce to provide accurate health communication and involving the youth is of particular importance. In addition, the private sector has an importation role to play, a role that must be recognized and mobilized.

The impact of public health and social measures on mental health needs to be assessed and monitored. There is a need to raise public awareness of mental health, as well as to develop community-based mental health initiatives and societal mechanisms. Highlighting the importance of education as a tool to inform safe behaviours and actions is key. Health authorities need to invest in modern communication channels and tools for health information dissemination, as well as to master infodemic management. The global development community should work towards solutions that address digital inequity and improve digital literacy.

3. Economy, infrastructure and systems
Strengthened and resilient systems are necessary to respond to shocks, both known and unknown, to save lives and livelihoods, while ensuring ongoing essential services across sectors. We need to design organizations, institutions and systems for a desirable future and fund them accordingly.

"This foresight initiative is about shifting from a reactive to a proactive approach in addressing infectious threats."

Dr Sylvie Briand, Director
Epidemic and Pandemic Preparedness and Prevention, WHO

Investment must be made in primary health care and in achieving Universal Health Coverage, including a sustainable health workforce. Infection prevention and control should be systematically implemented across all health care settings. Global health partners should set up a global health protection fund to support countries with limited capacities. For supply chain and logistical aspects of pandemic preparedness and response, a systems thinking and all-hazard approach must be applied to manage associated risks and benefits. Technology, including artificial intelligence (AI) and machine learning (ML), must be harnessed and applied to supply chain networks. Local production capacities should be strengthened, including empowering local communities to contribute, for example, through production of high-quality personal protective equipment (PPE).

4. Technology and innovation
Technology and innovation play a key role in realizing ambitions regarding future preparedness. Advancements in genomic science and nanobiotechnology must be leveraged to achieve pan-viral prevention. The application of emerging technologies to data gathering, conversion, integration, analysis and projection will increase access to medical countermeasures, essential life supplies and health information. Widespread sharing of benefits stemming from health care innovation is key. Biosafety must be strengthened and the benefits of biobanks and biodepositories in investigating novel pathogens must be leveraged. Further investment in training and future skills development must be made to accelerate and harness innovation. Lessons learned from seasonal influenza and other disease epidemics must be used to inform capacity building and future public health and social measures. Simulation exercises should be multisectoral and multidisciplinary. They should also include roles for multilateral partners and they should take place at multiple spatial scales (cities, regions and countries).

5. Leadership and collaboration
There is a pressing need to champion equity, foster trust, and to uphold transparency and accountability in the highest levels of decision-making. Data, knowledge and solution sharing are crucial to ensuring global solidarity. At the same time, they require an environment of global multilateral collaboration that promotes collective action and adaptive approaches. Multinational organizations must be empowered and encouraged to collaborate with agencies from a variety of sectors. Successful interventions should be identified, analysed and documented to update pandemic preparedness guidance. In addition, public-private partnerships with new stakeholders outside of the health sector should be explored.

The next steps
The WHO foresight initiative is the beginning of a new way to build stronger preparedness for future infectious threats. The outcomes described in this report offer a base for future foresight exercises. Yet, they need to be strengthened with coordinated dialogue and actions. Continuing the conversation through exercises at local, regional and national levels, as well as through frequent testing of the key assumptions of each scenario in specific regions, are effective ways to better prepare for future pandemics and epidemics.

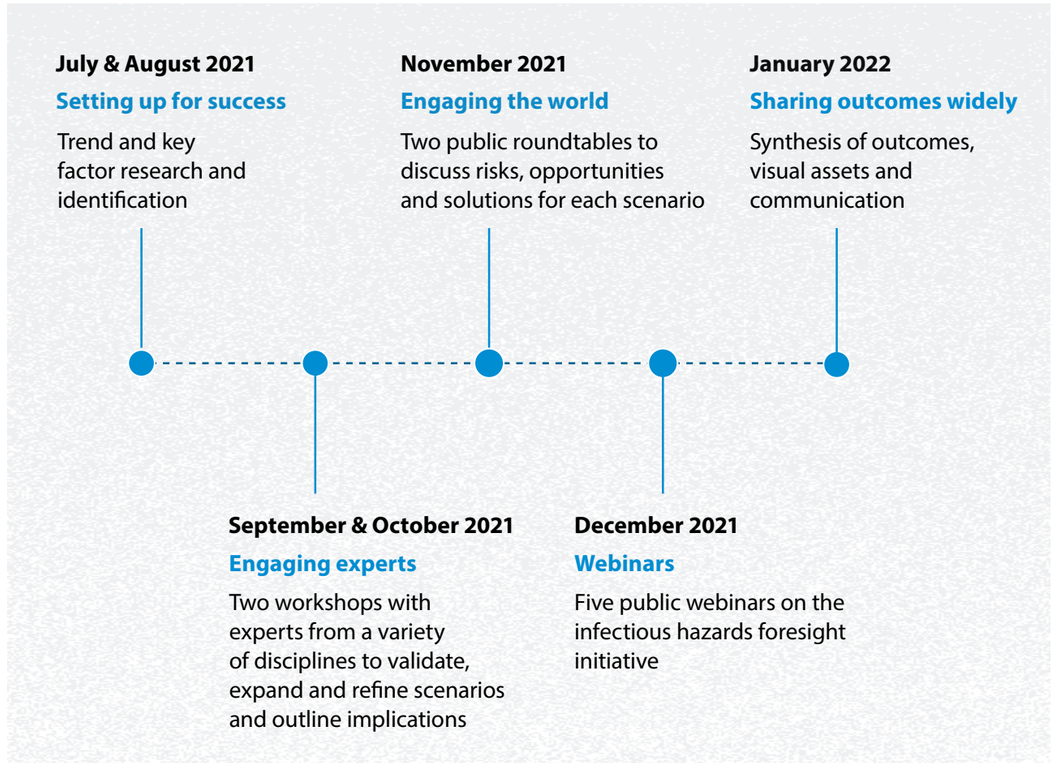

Fig.1 Project timeline

1. Foresight process and methodology

1. Foresight process and methodology

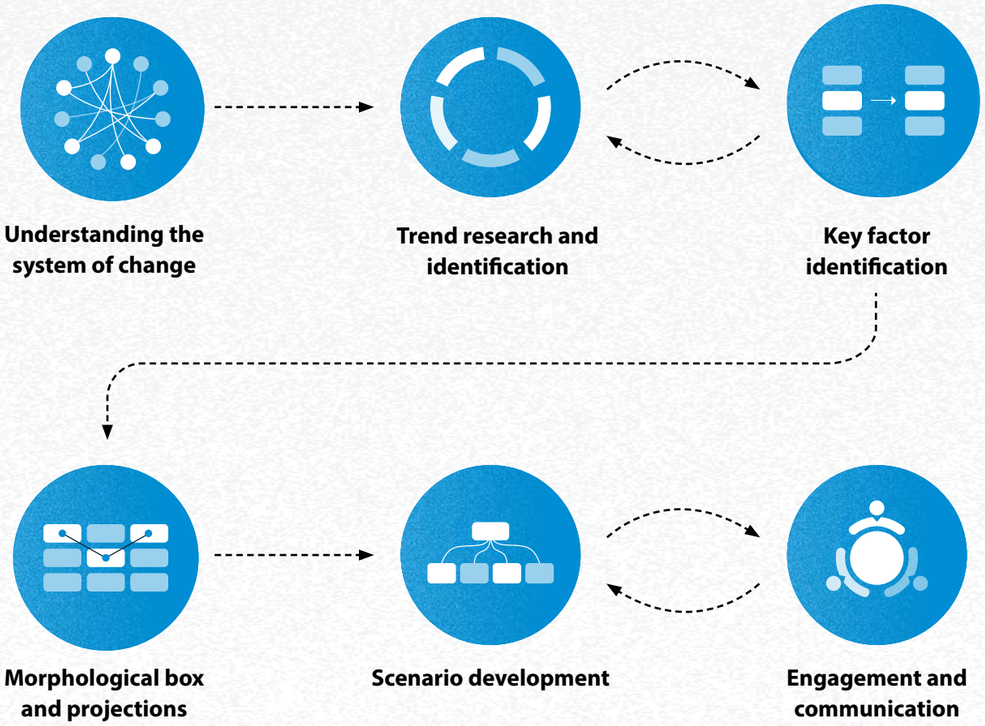

Fig. 2 Foresight process and methodology

1.1 Overview

In June 2021, the World Health Organization (WHO) commissioned Arup to develop a set of scenarios on the future of the COVID-19 pandemic and other infectious threats. The project engaged experts from WHO Strategic and Technical Advisory Group on Infectious Hazards (STAG-IH), experts from WHO partner organizations, stakeholders from across the world, and the wider public on how the pandemic and other infectious threats might evolve in the future. Arup supported WHO in identifying the key trends and factors shaping the future of the pandemic, developing a set of plausible scenarios for the coming three to five years and working with expert groups to identify associated risks, implications and recommendations.

A set of expert workshops delivered in September and October 2021 were followed by a series of public roundtable discussions in November 2021. Both the workshops and roundtables aimed at engaging a broad and diverse audience in the scenario planning process and to further assess and discuss implications. The aim of the initiative is to identify leadership recommendations and to build consensus on the collective actions the global community can take to mitigate the ongoing and anticipated risks of COVID-19 and be better prepared for future infectious threats.

Scenarios are hypothetical yet plausible illustrations of the future. They tend to include both qualitative and quantitative elements and are intentionally applied in multiples to show indeterminacy and possible alternatives. Scenarios are neither predictions nor forecasts, but plausible chains of cause and effect. They are an invitation to strategic dialogue. Hermann Kahn (systems theorist at the RAND Corporation) called scenarios a way of "thinking the unthinkable". Scenarios help leaders and decision-makers frame their strategic thinking, identify recommendations, and test and refine strategy and policy options.

"Foresight is a really powerful tool to bring people together, to look at different options, and for societies to pick the way forward that they would like to see happen."

Dr William Karesh, Executive Vice President for Health and Policy, EcoHealth Alliance

The project team selected the morphological approach to scenario building as the core methodology for this project. The key steps of this methodology are outlined below along with key dates and stakeholder engagements that supported the process.

The morphological approach to scenario building is one of many methodologies that can be used to create plausible future worlds. It is named the morphological approach because the baseline scenarios are captured and constructed in a so-called morphological box of key factors, associated projections and consistent combinations of projections that form scenarios.

In this case, this method was chosen as it offers a transparent, process-driven and software-enabled approach to scenario building that is highly robust and structured. This can be useful in situations where the system of investigation is of particularly high complexity, where many different factors shape the future of a system and where a wide range of stakeholders needs to be engaged in the development of scenarios, associated narratives and implications. Even within the morphological approach there are variations across practitioners and over time. The method described below is based on previous projects delivered by Arup. It has been customized to this project and its specific requirements but it is consistent with the core method described in key foresight literature such as *Using Trends and Scenarios as Tools for Strategy Development*, a book by Ulf Pillkahn.

The morphological approach to scenario building can be sub-divided into the following core stages:

1. **Understanding the system of change**
2. **Trend research and identification**
3. **Key factor identification**
4. **Morphological box and projections**
5. **Scenario development**
6. **Engagement and communication**

1.1.1 Understanding the system of change

Step 1: Identify the key components of the system of change
This first phase of the methodology was to identify the key components of the system being investigated. The team identified critical determinants of the COVID-19 pandemic and other infectious threats. Through consultation with experts from STAG-IH, the team determined that factors could be split into three key categories:

1. Pathogen and host characteristics: the evolution and characteristics of the virus itself, the susceptibility of host populations, new pandemic threats, etc.

2. Public health and social measures: how health systems respond, the effectiveness of vaccines, treatment options, etc.

3. Contextual factors: a wide range of other factors driving the future of the pandemic, across social, technological, environmental, economic and political domains.

These categories play a key role in determining the overall behaviour and direction of the system. They are critical determinants of the future path of change and in turn offer opportunities for intervention and possible focal areas for monitoring change.

A holistic and systems-based approach to understanding the future shape of the pandemic is essential because to date the development of the pandemic has clearly highlighted that the public health response and other contextual factors are key determinants of what could happen next. The virus shapes the system, but the system also shapes the path and evolution of the virus. The two are intrinsically linked and thereby highlight the complexity of change, the uncertainty around future pathways and the need for a systems-based approach when exploring the future of the pandemic through a scenario-based approach.

Another key driver of complexity is the role of various stakeholders, decision-makers and the response of wider society. This includes:

- Individuals in their role as citizens, voters, consumers, decision-makers and influencers.
- Communities at a variety of spatial levels, across a wide range of interests, and in both formal and informal settings, including digital networks.
- Enterprises both commercial and non-commercial, health-sector specific and more general, local/Indigenous, and transnational/global; ranging from micro-enterprises to large-scale corporations.
- Non-governmental institutions including universities, trade unions, media companies, charitable trusts, faith institutions and so forth.
- Intergovernmental agencies including the World Health Organization, United Nations, World Trade Organization, development banks and so forth.
- Governmental institutions including local, regional, national and international government bodies, as well as agencies of the state such as regulatory bodies, quangos, etc.

This multiplicity of actors, and the relationships between them, comprises a major part of the complex adaptive system under consideration. How citizens respond to vaccine offers, how information spreads between actors, how economic decisions are weighed against public health decisions, how trust evolves across different interest groups, how national interest relates to the global common good, these are all critical factors in determining the future shape of the pandemic and plausible scenarios for the future.

1.1.2 Trend research and identification

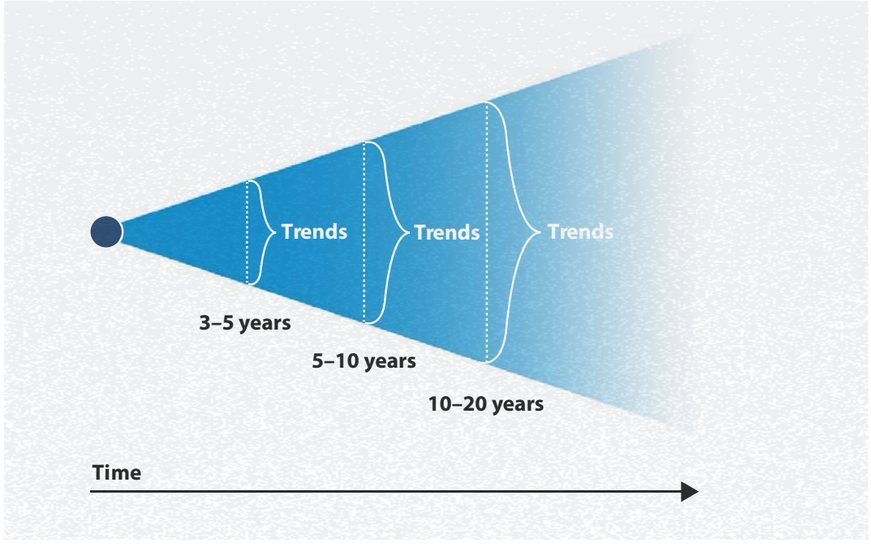

Fig. 3 The time horizon determines what trends and key factors should be considered for exploration

Step 2: Agree on the time horizon for the exploration of future trends and factors
The second step in the process was to agree on a time horizon for the scenarios. Following consultation with STAG-IH, and considering the categories identified in Step 1, the team settled on a range-based time horizon of three to five years as the target space for the scenarios. A range based time horizon recognizes underlying uncertainty in the speed of change, reflects the fast pace and rapidly changing nature of the pandemic, while still providing a medium-term look into the future that allowed the development of various mutually exclusive future pathways. The shorter timeframe ensured that scenarios could be frequently updated, if required, to reflect changing real world conditions. For the development of scenarios, the time horizon also determines what trends and additional key factors should be considered. Shorter time horizons provide a smaller option space compared to, for example, 10 to 20 years where a larger number of megatrends would come into play.

Step 3: Identify trends shaping the future of the pandemic and other infectious threats
The team conducted a horizon scan of the trends and identified weak signals shaping the future of the COVID-19 pandemic and other infectious threats. This key step of the process involved literature reviews and brainstorming sessions. In addition, it built upon existing, relevant work that the Arup Foresight team has undertaken, such as thought leadership reports on the future of health care and scenario-based, insight-driven projects exploring the implications of the ongoing public policy response to the COVID-19 pandemic. The use of the social, technological, economic, environmental, political (STEEP) framework ensured that the trends reflect a wide coverage of issues and that the work took a comprehensive and holistic approach to future thinking. By utilizing the time horizon of three to five years, several trends were identified that the team considered relevant in actively shaping the future of the pandemic. This step resulted in 25 high-impact trends, analysed in the form of the STEEP trend matrix.

1.1.3 Key factor identification

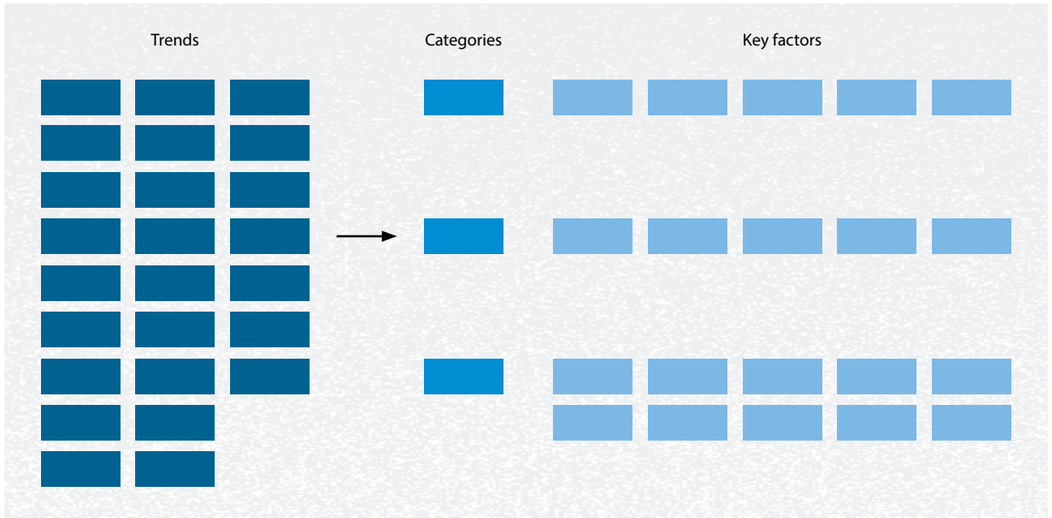

Fig. 4 Key factors

Step 4: Establish the key factors shaping our future system

Once the components of the system were mapped, the time horizon was set and the trends were identified, the team undertook a comprehensive desk study - coupled with brainstorming and expert review sessions - to agree on the key factors shaping the future of COVID-19 and other infectious threats. Key factors are defined as those factors that are actively driving the future shape of the system we are investigating. Active means factors that are driving change and influencing the response in other parts of the system. For example, the reproductive rate of the virus will actively drive the public health response. Communication patterns will actively shape human behaviour. Public health measures will actively influence the spread of the virus. Being active does not mean that a factor cannot be shaped by another, it just means it plays a critical part in how the overall system responds when there is a change in direction.

Analysis of the key components of the system and a review of the trends resulted in an initial set of key factors across our three core categories: *Pathogen and host characteristics, Public health and social measures and Contextual factors*. A good spread of key factors across the three categories was essential to ensure that there was a balanced focus on both the importance of the characteristics of the pathogen itself, but also the effectiveness of the public health response and the highly significant impact of contextual factors such as human behaviour. This is one of the benefits of the morphological approach to scenario building, as it can consider the complexity of all components shaping the future of a system.

The key factors were validated and refined in two workshop sessions with experts from STAG-IH, WHO and external organizations and institutions representing a variety of industries, fields and sectors. These sessions not only refined the draft list but developed a deeper understanding of the potential impacts of these factors on the COVID-19 pandemic and other infectious threats. After debating the draft list, a final set of 20 key factors was agreed upon. The team brought together information on each key factor and produced concise descriptions that offer insight into their relevance and, where possible, evidence of their impacts on the complex ecosystem of change being investigated.

1.1.4 Morphological box and projections

Step 5: Identify plausible, mutually exclusive projections for each key factor

The final selection of key factors provided the baseline structure for the development of the morphological box (see Fig. 5). Key factors form the top row of the morphological box and they are captured as neutral descriptions of drivers that are actively shaping the system of change. For example, the key factor of *Vaccine efficacy and access* does not indicate a direction or state, it is neutral. For the purpose of the exercise, there is no indication yet on whether efficacy is high or low, or whether access is high or low. Plausible directions are instead described through a set of individual projections for each of the key factors. These can also be understood as mini-scenarios. As such, projections are future states or alternative plausible developments of a key factor. Each projection needs to be mutually exclusive to all others within a key factor, that is two projections within a key factor column cannot happen at the same time. For each key factor, the team developed between three and five projections. Comprehensive desk research, as well as trend analysis, were used to create the draft projections. These were then reviewed and further validated by experts from STAG-IH. For each key factor, the trends were also considered and reviewed again to ensure that there were no gaps in our future assumptions. A standardized template was used to describe each key factor and its projections.

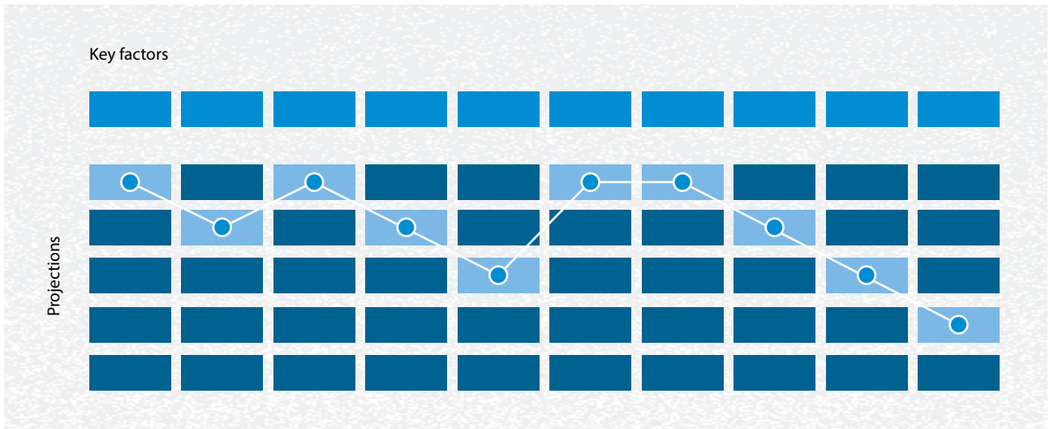

Fig. 5 Morphological box

Step 6: Complete consistency analysis to determine combinations across the morphological box

Once the morphological box had been completed, the team delivered a consistency analysis across all projections. In this process, each projection from a key factor is rated against all other projections across the morphological box to record its fit across each combination. For example, how consistent is *Increased human transmissibility* with *High vaccine efficacy and access*. This combination would be given a low consistency as one would expect that high vaccine efficacy would reduce human transmissibility. These logic-based decisions are made across all combinations of projections and recorded using a software tool, in this case Arup's in-house Arup Scenario*. Where the relationship between two projections is unclear, a neutral consistency is recorded.

The consistency analysis results in a high number of plausible consistent combinations of projections across the morphological box. In each case, baseline scenarios are built by combining one projection from each key factor with consistent projections from all others. The team used the outcomes of the analysis to determine and select four distinct baseline scenarios for further review and refinement. There is an almost infinite number of scenarios that could result from a software-based consistency analysis, so the project team needed to make an informed judgement on which combinations best reflect the research, expert conversations and outcomes to date. The final combinations selected provided a set of alternative, consistent, and crucially, plausible pathways into the future that could be used as a tool for strategic dialogue.

"This is more realistic than previous approaches."

Dr Rick Bright, CEO
Pandemic Prevention Institute & Senior Vice President, Pandemic Prevention & Response
The Rockefeller Foundation

"The four scenarios are all plausible. They are not predictions. Rather, they are invitations for achieving cross-sector, strategic dialogue."

Professor Nahoko Shindo, Unit Head
Epidemic and Pandemic Preparedness and Prevention
WHO

*In Arup Scenario the relationship between projections is assigned a score from -3 to +3. Relationships that are scored as a negative indicate that the projections are potentially conflicting and less likely to occur in the same future. Relationships with a positive score indicate that the projections reinforce each other and may be more likely to occur together. Neutral scores or scores of zero indicate that there may not be a direct relationship between the projections. These relationship scores are fed into an algorithm that can be used to generate scenarios with a higher overall plausibility score. This function can also be used with manually created scenarios to test their plausibility. Conducting scenario planning with plausible futures is an essential part of the process for ensuring stakeholder buy-in, as well as for the effective use of scenarios to guide the creation of strategy and allow for their use in adaptive planning approaches.

1.1.5 Scenario development

Step 7: Four scenarios are selected and outline narratives are developed

Scenarios are evidence-based, plausible stories of the future. They are not predictions, but narratives on how the future could turn out considering the interplay of key factors or critical uncertainties. The development of the morphological box resulted in four plausible scenarios. Each of the four scenarios should be considered as highly plausible. No probabilities are attached to the scenarios as each should be considered equally in terms of likelihood. This ensures that any strategic dialogue around the scenarios balances equally across all of them and that they are considered as a set of plausible pathways and not as individual visions.

Once the key components and logic for each scenario were captured in the morphological box, the team developed an early set of titles and a short narrative for each of the scenarios. Since the scenario development process is designed as a participatory process, this phase consisted of discussions with key experts from STAG-IH, WHO and external organizations and institutions representing a variety of industries, fields and sectors, and led to the elaboration of the final scenarios. Two workshops were held to engage with participants. The workshops resulted in several recommendations on how the scenarios could be further improved and validated, ensuring that any plausible futures outlined also reflected the views and options as seen by experts in the fields of infectious disease, pandemic management and public health.

Step 8: Identification and description of associated scenario indicators (conducted independently by Arup)

To substantiate the scenarios and their narratives, a set of five key indicators was identified and described in detail. The key indicators chosen are:

1. Gross domestic product (GDP)
2. Proportion of world population fully vaccinated
3. COVAX doses distributed
4. Number of COVID-19 cases
5. Number of deaths reported due to COVID-19

Projections of annual figures for each of these indicators were prepared, taking into account the time horizon of the scenarios. For practical reasons, COVID-19 was used as the ongoing, live example of a pandemic. The projections are based on upside and downside factors impacting each indicator and they reflect the key assumptions made in each scenario about where the world might be in the next five years (which can be in a better position than where we are today, similar, worse or much worse). Table 1 depicts the correspondence between projection scenarios and narrative scenarios.

Projections	Narrative scenarios
Upside scenario	Scenario 1: Happy Days
Central scenario	Scenario 2: I Love You, I Hate You
Downside scenario	Scenario 3: Heartbreak Hotel
Downside+ scenario	Scenario 4: Here Comes Trouble

Table 1 Correspondence between projection scenarios and narrative scenarios

The projections refer to the world population, albeit for some indicators the worldwide projections were created following a bottom-up approach, building on country-level projections (for further information, please see methodology for each indicator).

The projections were created primarily based on secondary research, as opposed to developing projection models. Projections and quantitative research prepared by organizations such as Gavi, The Vaccine Alliance, Institute for Health Metrics and Evaluation (IHME) at the University of Washington, International Monetary Fund (IMF), Organisation for Economic Co-operation and Development (OECD), WHO SeroTracker, World Bank and UNICEF were used in the process.

In the case of gaps in secondary research and discrepancies in the assumptions made in our scenario assumptions, these gaps are closed or calibrated in the projections using expert judgement based on a combination of trend analysis of historic data and qualitative research.

The analysis includes quantitative data from a wide number of research reports and statistical databases that meet minimum quality standards, such as COVAX, Gavi, The Vaccine Alliance, IMF, OECD, Oxford University's Our World in Data, WHO's SeroTracker, World Bank and UNICEF. Quantitative data analysis is combined with qualitative insights gathered through content analysis of scientific and grey literature on factors impacting the COVID-19 pandemic.

For COVID-19 cases and deaths, the projections are based on the numbers observed during the selected timeframe. They do not take into account other critical considerations and assumptions such as emergence and proportion of virus variants, their virulence, individual and population immunity acquired either through natural infection or vaccination and duration of protective immunity.

Inevitably, the information being collected on the COVID-19 pandemic keeps improving as more methods, more data and greater consistency of definitions and methodologies emerge and gain ground. The projections in this report are, therefore, based on best judgement given the data, information, and time limitations.

"We need a paradigm shift; from managing disasters, to managing risks."

Mr Ricardo Mena, Director
United Nations Office for Disaster Risk Reduction (UNDRR)

"It is important to involve young people in the scenario thinking."

Dr Marion Koopmans, Head of the Erasmus MC Department of Viroscience

1.1.6 Engagement and communication

Step 9: Public roundtables to discuss and explore implications and recommendations for scenarios

The scenarios and associated implications were discussed in two public roundtable discussions with a wide variety of participants. The selection of panellists aimed at ensuring strong diversity in views, and representation across regions, age groups and gender. This was essential in facilitating a stimulating debate among the participants. Roundtables were open to the public, who were encouraged to ask questions, participate in live polls and leave comments. The sessions took place on 4 and 9 November 2021 and covered all global time zones. Participants ranged from experts in epidemiology, public health strategy, academia and science to public policy, youth, religion, economics and trade, as well as sustainability and disaster risk management. Recordings of the roundtables can be found here*, and a full list of panellists can be found in the Acknowledgements section at the end of this report. The roundtables were particularly useful in understanding the role of different stakeholders in each of the four future worlds, from younger generations to faith groups, as well as in identifying recommendations and suitable actions resulting from the work. Following the public roundtable sessions, actions for key stakeholders were identified and described, scenarios were refined further and key recommendations were captured.

"Rather than returning to a pre-COVID era, we need to focus on building mature sustainable cities and strong societies."

Ms Yuriko Koike
Governor of Tokyo

Step 10: Completion and communication of final scenarios and associated recommendations

Following the roundtables, the team worked to further refine the scenarios and complete any associated assets for the scenario narratives and communications. These included a short film, a series of day-in-the-life stories and illustrations for each of the scenarios. These assets were combined with the detailed final narratives for each scenario, the description of trends, the description of key factors, the methodology and other components of the project to form the final report and a set of communication assets. The aim of this final stage is to communicate the overall project outcome widely and to ensure that more WHO decision-making processes are supported by a futures thinking approach. The project will shape the ongoing development of the WHO COVID-19 emergency response and support the transition from emergency response to better preparedness and management of this pandemic and future threats.

"The foresight journey will stimulate our creativity and cross-pollinate our ideas into reality. "

Ms Margaux Mathis, Technical Officer
Epidemic and Pandemic Preparedness and Prevention
WHO

*https://www.youtube.com/channel/UC-t0AL4GoNJYJOOtt2UhvMg/featured

1.2 Trends

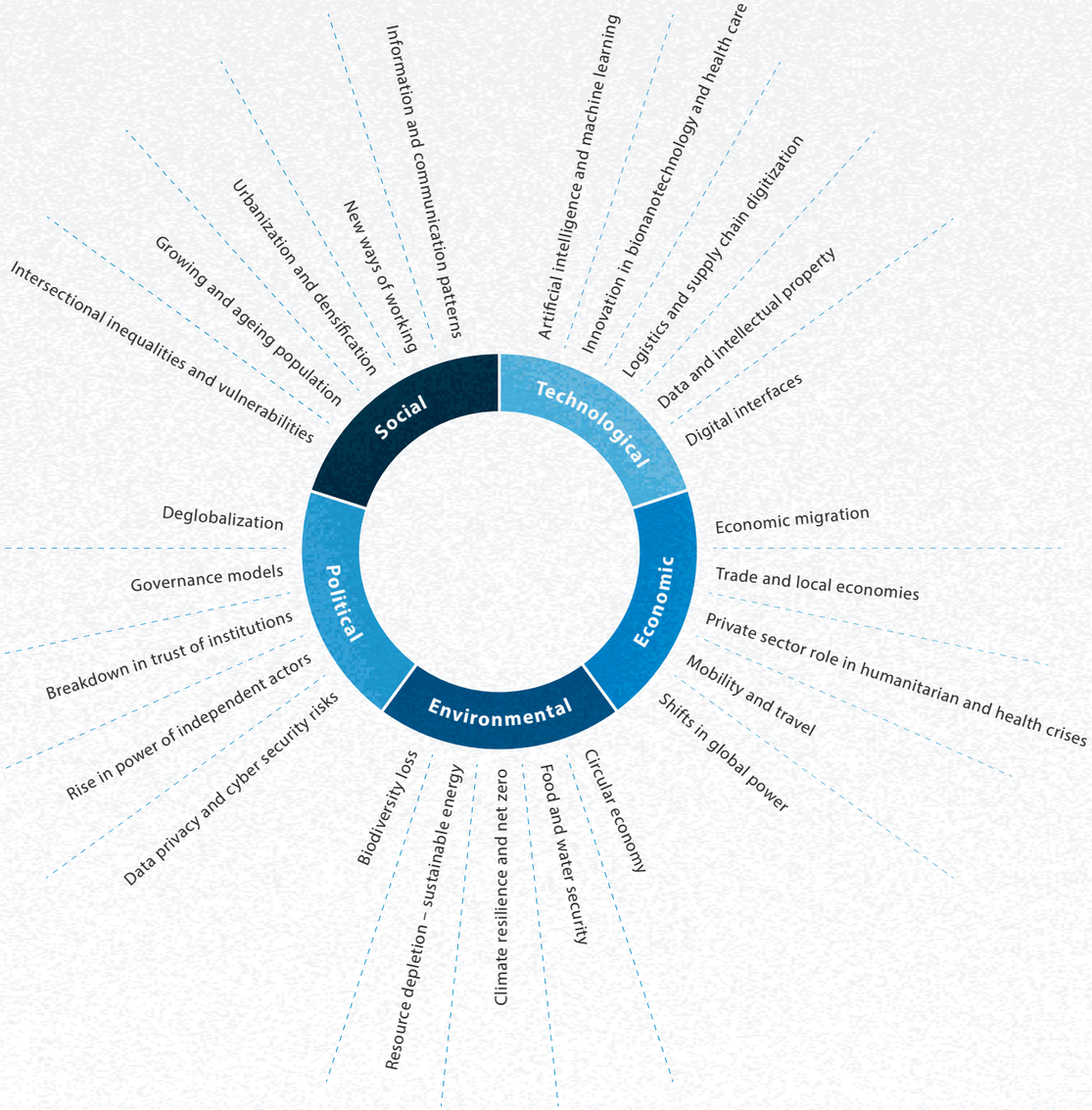

Fig. 6 Trend diagram

1.2.1 Social

Intersectional inequalities and vulnerabilities on the rise

Global inequalities are growing. It is estimated that inequality impacts more than 70% of the global population, who in turn experience disparities in health care and education amidst accelerating poverty.[1] Inequalities within societies have been exacerbated by the COVID-19 pandemic. The pandemic has disproportionally affected marginalized groups as a result of structural vulnerabilities including, but not limited to, a lack of access to health care, type of employment or crowded living environments.

Inequality is experienced in different intersectional ways by different people or populations. The lived experience and consequences of inequality depends on interconnected social categorizations including race, class and gender (amongst others). Within an individual or group, these social categorizations create overlapping and interdependent systems of discrimination or disadvantage.[2] Intersectionality offers an important lens towards understanding how aspects of a person's social and political identities combine to create different modes of discrimination or privilege. For example, the pandemic saw many people become essential workers providing front-line services even during the height of waves of infection. For many, essential high-risk jobs offer low pay, limited benefits and minimal employment security. Pre-existing intersectional inequities were amplified during the pandemic and essential jobs often disproportionately fell to groups long made vulnerable including racial/ethnic minorities, women and undocumented workers.[3]

Growing and ageing population

The global population is both growing and ageing. It is projected that in the next 30 years the world's population will grow by 26% to reach 9.7 billion people. This growth is matched by increasing longevity, with projections that by 2050 one in six people will be over the age of 65.[4] An ageing population has important implications for health and human capital across the lifecourse, with increasing rates of non-communicable diseases and growing care needs for older adults globally.

However, an ageing population, particularly one with high rates of co-morbidities, is also vulnerable to infectious hazards. Indeed, studies have highlighted age as a key factor in disease severity and poor outcomes for people with COVID-19.[5] Heightened risk and vulnerabilities have not only led to poorer health outcomes for older adults, but also significant COVID-19 outbreaks at long term care facilities worldwide. In these ways, the pandemic has prompted larger questions of how to provide person-centred care for the ageing population and how to better protect their health and well-being before, during and after pandemics.

Urbanization and densification continues

Urbanization and densification are also accelerating with over half the world's population currently living in urban areas. Rapid urban growth will only continue with increasing numbers of people living in rapidly expanding, and increasingly high-density, cities across Asia and Africa.[6]

Cities pose a paradox for health and well-being. While urban centres offer opportunities and a greater density of services including health care, vast urban inequities pose barriers to access for many. Indeed, urban centres can amplify poverty, conflict and deepen inequities.[7] As COVID-19 has shown, during epidemics and pandemics, cities,

"In the future, we are going to see more complex epidemics. COVID-19 is a symptom of the drivers we will live with throughout the 21st century."

Sir Jeremy Farrar, Director
Wellcome Trust

in particular dense urban centres, become major sites of disease transmission. Those living in dense urban conditions are also more limited in their ability to fully adhere to public health and social measures, thus further challenging the efforts to limit spread.[8] In this way, the future of pandemics is deeply linked with the future of urban planning and our collective commitment to urban health.

New ways of working

Globally there has been a move away from manual employment towards automation of the workforce.[9] Innovation in internet speed and software has facilitated flexible employment, including working from home and freelancing. Models like the gig and sharing economy are set to reach US$ 335 billion by 2025, while the numbers of workers employed in the informal sector also continue to grow.[10]

The pandemic has accelerated these trends as public health and social measures required physical distancing to curb community transmission. During April 2020, across 90 countries, over half of the global population were under some form of physical distancing or restricted mobility policy.[11] Extended public health measures highlight the potential to rethink many office portfolios and ways of working. However, new ways of working have also emphasized global workforce and labour inequities, particularly for those employed in the informal economy, manual labour or across site-based sectors such as agriculture. Ensuring equitable protection for the entire global workforce requires innovation across sectors towards ways of working that support health and well-being.

Information and communication patterns shift

Technology is crucial to how and where people communicate. With widespread global access to mobile phones, connectivity is more accessible and necessary than ever. It is estimated that there were over 3.8 billion smartphone users in 2021 and over 4.2 billion active social media users.[12, 13] In areas such as sub-Saharan Africa and Asia the use of mobile phones has increased dramatically over recent years. The impact of increased connectivity between mobile phone users has transformed access to markets and services and created broader economic development benefits.[14]

Public health and social measures such as physical distancing policies, limits on gatherings and the wearing of facemasks in public spaces have reduced physical interaction and accelerated digital technologies for socializing and working.[15]

© Norma Mortenson, Pexels

The gig and sharing economy is set to reach US$ 335 billion by 2025, while the numbers of workers employed in the informal sector also continues to grow.[10]

1.2.2 Technological

Artificial intelligence and machine learning

Advanced digital technologies including data capture and analysis, autonomous systems, artificial intelligence (AI), machine learning (ML) and Internet of Things (IoT) are increasingly ubiquitous. Such technologies are implemented across sectors, from the management of transport networks through to creating digital representations of systems or processes, known as digital twins, to simulate future scenarios.

During the pandemic, technologies have been applied in many ways to guide the COVID-19 response. Applications of technologies include use in disease monitoring and forecasting, as well as for pharmaceutical research and development.[16] Technologies including AI and ML can be applied to learn from the pandemic, better understand which interventions were most impactful and advance global efforts towards pandemic preparedness. However, technological advancement must be coupled with technological equity and a commitment to build up local capacity to harness, share and apply data to decision-making.

Innovations in bionanotechnology and health care

Bionanotechnology sits at the intersection of nanotechnology and biology and is transforming sectors including pharmaceuticals, agriculture, and water purification. Bionanotechnology has also been applied to medicine including novel work on repairing white blood cells, as well as developing cancer and diabetes treatments.[17] COVID-19 has seen bionanotechnology emerge as a key public health tool with the rapid development and widespread deployment of safe and effective nanomedicine-based vaccines, such as those produced by Moderna and BioNTech/Pfizer. Bionanotechnology has many promising future applications including drug and diagnostic test development, as well as improving PPE effectiveness.[18]

However, with rising geopolitical tensions and potential risks, it will also be important to monitor the development of these nano-medicine innovations and move to regulate and prioritize safety by ensuring and implementing international standards.

Logistics and supply chain digitization

Technological innovations have led to increasingly digitized, efficient and interconnected supply chains.[19] Nevertheless, COVID-19 put unparalleled strains upon even the most modern global supply networks. Ongoing delays in accessing essential supplies, including PPE and medical products, highlighted the need for supply chains to become more agile in the face of immediate and unpredictable changes. The pandemic has forced years of digital transformation to take place in a few short months leading to rapid acceleration of digitization plans across the sector.[20, 21]

Companies are also moving to ensure digital capabilities are a part of comprehensive risk mitigation and management strategies for ongoing and future crises.[20] One key example is a move away from static sequential supply chains to fully integrated digital supply networks (DSN's) which allow for greater end-to-end visibility across the supply chain.[22] Digital supply networks allow companies to quickly adapt to the impacts of crises by using technologies such as AI and blockchain to measure and report on performance.


© Lewis Reed, Unsplash

Technology has been a key tool to address the spread of the virus with nanomedicine-based vaccines, such as Moderna and BioNTech/Pfizer both being developed and used globally.

Data and intellectual property

In a global economy driven by digitization and international collaboration, ownership of data and intellectual property rights are increasingly important. Sharing and ensuring access to information is essential to advance global equity. However, nations are increasingly adopting an isolationist approach. An example is the rapid production of COVID-19 vaccines. Despite availability, many many low- and middle-income countries (LMICs) have limited access to them with the majority of doses going to those living in high- and upper middle-income countries.[23]

Strong intellectual property rights for vaccines ensures investment and regulation and restricts where vaccines can be manufactured, meaning prices and distribution are tightly controlled. Despite initiatives, such as COVAX, which aims to ensure global access to vaccines and other health technologies, global distribution of vaccines remains deeply inequitable. A temporary waiver for the World Trade Organization's intellectual property rules for COVID-19 vaccines in some countries is a potential route to rapidly increase production and a way to support LMICs to access vaccines.

Digital interfaces

Advancements in smart sensors and AI devices are seen as the next step in human-computer interaction. Collectively known as Zero UI, this advancement is the effective removal of a visual screen based user interface enabling people to communicate through voice, gestures, and biometric authentication. Zero UI marks a departure from our traditional reliance on smartphones and personal computers to interact with software.

During the COVID-19 pandemic, public health and social measures to ensure physical distancing normalized increased space between people and decreased contact. Our adaptations and behavioural changes to these interventions have been suggested to have a lasting effect on our communication behaviours and interactions.[24] Such a change may accelerate the shift towards the touchless sensory interfaces that characterize Zero UI.[25] Technologies, such as voice assistants, promise to be more intuitive and immediate, pointing to a future where the interface is embedded in our environment, enabling frictionless, anticipatory, responsive and predictive interactions.

1.2.3 Economic

Zero UI will change how we access information, make decisions, experience and navigate the physical and digital worlds and potentially increase data collection and monitoring.

Economic migration

The 21st century has been characterized by increasing labour migration with an estimated 169 million people globally migrating for work.[26] Migrant workers are an integral and substantial part of the global workforce constituting an estimated 5% of the global labour supply and comprising over 15% of the workforce in both North America and western Europe. Public health and social measures limiting travel or restricting border crossing had a significant impact on migrant workers. For example, migrant flows to OECD countries alone fell by 46% in the first half of 2020. Reduced migrant labour flows had significant impacts on host countries' economies in the short term and pushed many migrant workers and their families into poverty and instability.[27]

Trade and local economies

Globalized trade and supply chains have spread in step with improved transport networks and corporate incentives to lower production costs, leverage a specialized workforce and access diverse markets. During the pandemic, both trade and supply chains faced significant challenges globally. Border controls and other public health measures led to production and transport disruptions against a backdrop of increasing economic protectionism.

The pandemic magnified vulnerabilities in globalized production strategies as many organizations relied on single specialized suppliers or factories in other countries. The pandemic has also raised doubts about the resilience and benefits of a global supply network. There has also been increased pressure on companies to diversify and build new supplier networks in multiple areas or scale up domestic production.

Role of the private sector in humanitarian aid and health crises

With accelerating crises has come increasing private sector involvement in global humanitarian aid and health crises response.[28] Indeed, during the 2014 Ebola outbreak in western Africa, global businesses contributed US$ 300 million to the outbreak response. The strain placed on public institutions and global systems by the COVID-19 pandemic has similarly spurred increasing private services to meet public health response needs. Private industry globally has created partnerships, made donations and repurposed resources, expertise and factories to fill key gaps.[29, 30]

While the contribution of the private sector has supported the global public health response to COVID-19, increasingly frequent and complex humanitarian and health crises will demand innovative and equitable involvement in the private sector, for example through strengthened public-private partnerships.[31, 32]

Mobility and travel

As the global population urbanizes, development of mass transit networks has surged to connect dense urban centres. With the growth of the global middle class, air passenger demand and car ownership has similarly grown. Yet, public health and social measures implemented in response to the COVID-19 pandemic led to rapid changes in travel behaviours globally. Increasingly digital interactions resulting from the pandemic have accelerated sustainable trends, at least in the short term.[33]

For example, it is estimated that global air travel fell by approximately 76% in 2020 with video meeting platforms filling the gap of in-person gatherings. In turn, many people and businesses have adopted lower carbon modes of transport given benefits in pricing, ease of mobility in urban centres and reduced CO2 emissions.[34] Alongside this, a reduced need to commute, advances in autonomous vehicles and the

development of mobility as a service may provide greater flexibility[35] for urban populations to move away from individual vehicle ownership and increase micro-mobility and active travel networks.

Shifts in global power

By 2050 it is estimated that the largest global economies will predominantly be emerging economies, signalling a restructuring of global power towards non-OECD economies.[36]

However, COVID-19 has caused major economic downturns around the globe that threaten the economic progress of emerging economies. While an economic rebound began in 2021, this was seen unevenly across countries, with lower income countries experiencing longer downturns than more developed economies.[37] Such unequal growth is due to a variety of factors including wealth distribution, health system financing, as well as access to and distribution of vaccines leading to prolonged outbreaks.[38] As a result, per capita income growth is projected to stall in low-income countries, temporarily slowing the predicted shift of power.[36] Until global vaccine equity is achieved, long standing global economic power differentials will be perpetuated and the shift towards emerging economies further delayed.

"We are living in a VUCA world… Volatile, Uncertain, Complex and Ambiguous…"

Mr Josef Hargrave, Global Foresight Leader, Arup

"Vaccine nationalism cannot happen again. We need to turn this into a political commitment."

Dr Bruce Gellin, Chief of Global Public Health Strategy, The Rockefeller Foundation

1.2.4 Environmental

Biodiversity loss

Biodiversity is declining at an unprecedented rate, with over 100 000 species threatened by extinction.[39, 40] Human activity, including shifting land use patterns, pollution and the resulting ecological and climate change are driving biodiversity loss globally. Over the last 50 years these changes have led to drastic and accelerating wildlife population loss.[41, 40]

During the COVID-19 pandemic, a series of measures to prevent viral transmission led to a marked reduction in human mobility, with an 80% decrease in international flights by May 2020.[42] Reduced human activity may have had positive effects in some areas, such as a reduced human impact on wildlife, and reductions in atmospheric pollution. Indeed, declines were reported in the concentration of nitrogen dioxide and fine particle matter across 34 countries in 2020.[43] However, the long-term positive effects on biodiversity resulting from these temporary measures remain to be seen. These benefits may also be offset by a loss of funding and staffing to conservation projects and reduced presence of personnel to protect assets like forest areas or wildlife. Further, instability resulting from the pandemic has increased conflict and poverty which has negative environmental consequences as communities more heavily rely on limited natural resources and fragile ecosystems.[44] Addressing the root causes of biodiversity loss requires longer term societal transformation grounded in a commitment to planetary health and equity at the highest levels.

Resource depletion – sustainable energy

Although the demand for and production of sustainable energy has been steadily growing, as of 2019 fossil fuels still accounted for the vast majority of the world's primary energy consumption.[45] The renewable energy supply sector has been challenged during the pandemic by supply chain disruptions and movement restrictions leading to projections of slower growth.[46]

Nevertheless, global economic downturns resulting from the pandemic, also provide an opportunity to lead the economic recovery through investment and development of green sectors, renewable energies as well as capitalizing on recent behavioural changes such as reduced air travel. There is an opportunity to use the pandemic as a means to supercharge a movement towards renewable resources.

Climate change resilience and net zero

Climate and ecological change has accelerated since the late 19th century as human activity fundamentally changes the Earth's biosphere.[47] The effects of climate and ecological change have resulted in increasingly frequent and severe extreme weather events, rising sea levels and habitat destruction across geographies. These changes have profound impacts on human life including increasingly fragile food supplies, heightened vulnerability for coastal populations, and increased risk of emergence and spread of zoonotic and waterborne pathogens.[48]

While restrictions on movement to limit the spread of COVID-19 resulted in some reduction in emissions, these gains may be largely offset by the emissions caused by providing intensive health care during the pandemic.[49] The health care industry is among the most carbon-intensive service sectors in the industrialized world.[50] Indeed, environmental gains achieved during the pandemic are ultimately short term and unsustainable without the political will to achieve net zero and ambitiously decarbonize towards greener societies.

Food and water security

Global food insecurity has consistently increased since 2014 with an additional 10 million people becoming undernourished between 2018 and 2019 alone.[51] Food insecurity is made more complex by easily accessible and affordable ultra-processed foods worldwide. As such, food insecurity is matched by rising global obesity as nutritious and culturally appropriate food is replaced by accessible food with less nutritional value. [52] Importantly, gaps and inefficiencies in the global food chain couple with food use preferences and behaviours to result in high amounts of global food loss or wastage.[53]

Food insecurity has increased globally during the COVID-19 pandemic and an estimated 768 million people are now undernourished globally. [54] Increasing food insecurity has been driven by short term factors including movement restrictions, disrupted supply chains and increasing poverty. Additionally, sites of food production, such as abattoirs, became hotspots for COVID-19 outbreaks. The largely migrant agricultural workforce was also disproportionately impacted by border closures. However, these pandemic-related drivers point to longer-term determinants of food insecurity including rising household debt, conflicts, altered weather conditions impacting crops, problematic labour practices and a reliance on food and goods from outside a country's borders.[51]

Ethical food production and the impacts of global warming on crop growth are being addressed by the development of sustainable, site-flexible production methods and versatile growth systems such as aeroponic farming.
Emerging alternative food habits, such as veganism or food production methods based on lab-grown meat and sustainable protein-rich algae, suggest ways of combating food shortages, malnutrition and the environmental impact of production. However, there is much work to be done to ensure that innovations in food security are equitable, culturally appropriate and restorative to the natural environment.

COVID-19 has underlined the need for resilient global systems with nations, populations and organizations being able to mobilize and change behaviours quickly.

Circular economy

A circular economy aims to move away from a linear model of value and decouple economic growth from resource consumption. Within a circular economy, products, assets and systems are designed to be more durable, repaired, refurbished, reused and disassembled over time. Importance is placed on minimizing waste and maximizing material utilization. Amidst governments imposing restrictions on waste, the growing climate crisis and resource prices becoming more volatile, circular economy practices are gaining traction. Indeed, organizations across all sectors are now aiming to capture more value from resources and processes. [55] By focusing on the reduce-redesign-reuse paradigm, economies may in turn become more resilient.

However, a sustainable circular economy requires buy-in from the highest levels of decision-making. As seen during the pandemic, many systems were sent into shock and immediate responses were required, few of which were circular.[56] Poverty and emergencies can often push people and nations into making decisions that are less sustainable as they have to focus on the least expensive options in the short term. A circular approach, together with the evolution of the sharing economy, could be at the heart of global pandemic recovery but must be coupled with strategies to ensure circular economy principles can be upheld even during times of crisis or uncertainty.

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1.2.5 Political

Deglobalization
Globalization has been accelerating since the end of the Second World War. The world has become increasingly interconnected with the mass integration of national economies into a global economic system, the rise of internet connectivity and the birth of global organizations such as the UN. However, while this greater connection has many benefits, there are also risks. For example, cross-regional and intra-regional potentials for conflict are also increasing. The risk of conflict is exacerbated by the rise of protectionist policies, which has led to nations reducing their interdependencies in recent years.

The COVID-19 crisis and the necessary public health response has caused the largest and fastest decline in international flows in modern history, while highlighting fundamental flaws and inequities in international supply chains and manufacturing models.

"Right now, public health is in trouble because it tries to depoliticize itself as a discipline but every decision about the use of public resource is political. Public health is one of the most political disciplines around."
Dr David Nabarro, Special Envoy of WHO Director-General on COVID-19

COVID-19 has highlighted the pitfalls of nations not being transparent or collaborative. Amidst accelerating global humanitarian crises, a strengthened and coordinated global response both before and after emergencies will be needed to protect lives and livelihoods.

Governance models
Global governance models are changing and evolving. Recent shifts include increased integration and inclusion of the whole population emphasized through whole-of-society approaches. In many regions there has been marked decentralization of governance and increased autonomy at the sub-national level.

The COVID-19 pandemic highlights many challenges in governance and decision-making globally. Across models of governance, decision-makers at all levels were asked to make difficult choices amidst great uncertainty and emerging scientific evidence. Launching a response required coordinated efforts across states and jurisdictions emphasizing the importance of coordination. There is no one-size-fits-all emergency response a nation can follow, however lessons from this pandemic may provide a blueprint for responding to future complex emergencies across governance models in ways that meet local needs in communities.


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The COVID-19 pandemic has seen a rise in distrust globally fuelled by misinformation on vaccines, the virus and the public health response.

Breakdown of trust in institutions
Technological innovations, including the internet and mobile phone technology, have broadened our exposure to a variety of information sources. Technology has advanced access to education, provided a place for empowerment and a platform for multiple independent voices. Unfortunately, it has also facilitated the spread of misinformation, radicalization and biases. This, paired with rising inequalities and the perception of governing organizations as opaque or under-representative of the broader population, has led to a growing mistrust of decision-makers and public institutions.

During COVID-19, far-reaching public health and social measures, including vaccination, have been rapidly implemented and in some cases made compulsory. Misinformation about the vaccines, coupled with an evolving scientific evidence base and emerging public health information, have converged with pre-existing erosion of trust to create an infodemic. These factors have further undermined public confidence in institutions. In particular, young people's trust in government has been damaged by COVID-19. Studies suggest that Generation Z are less likely to have faith in elections and their own governments as a result of their experiences during the pandemic.[57] Public distrust must be comprehensively addressed before, during and after emergencies to prevent infodemics and ensure more people-centred crisis response.

Rise in the power of independent actors
Private organizations are growing in both economic power and political influence globally. Recent decades have seen a marked shift from small business to large multinational corporations. In particular, tech giants are expanding far beyond their original remit. These companies, and through their partnerships with other organizations across sectors, have fundamentally changed commerce and communications.

"The pandemic is politically exploited."
Professor Ilona Kickbusch, Director Global Health Centre, Graduate Institute of International and Development Studies

Restrictions to reduce community transmission of the virus took a disproportionate economic toll on small and medium enterprises globally, while larger organizations with online platforms prospered.[58] Indeed, the pandemic underscored the rising economic power and reach of corporations.

The pandemic has raised many questions on the power of these actors, ranging from how corporate entities are regulated and taxed, to data security and use, to what is their role in public health emergency preparedness and response.

Data privacy and cyber security risks
Data collection has always been central to understanding populations. Innovations such as the internet have led to exponential increases in the type and amount of data collected and analysed globally. The COVID-19 pandemic has seen widespread advancement in the collection of data for public health purposes. Indeed, countries increasingly rely on monitoring nonclinical data, such as mobility patterns taken from mobile phone data, to better understand the COVID-19 pandemic and the effects of public health and social measures.[59]

Such measures have raised concerns regarding populations' privacy and the increased threat of data breaches through cyber attacks. Information has been collected quickly, in unprecedented quantities, with the security in place often not fit for purpose.[60] Interpol has highlighted significant growth in cybercriminals targeting major organizations, governments and critical infrastructures.[61, 62] At the same time, increased working from home has led to reduced control of corporate information technology security and a mass rise in spam phishing messages as criminals leverage government announcements to craft cyber-crime campaigns.[63] These risks may lead populations to be more reluctant to share much-needed information during future pandemics.

1.3 Key factors

Categories	Key factors		
Pathogen and host characteristics	Transmissibility	Variant diversity and susceptibility	Human immunity and vulnerability levels
	Symptom range and mortality rate	New pandemic risk	
Public health and social measures	Vaccine efficacy and access	Public health measures	Diagnostics, surveillance and tracking
	Treatment and prevention	Health care systems' response and capacity	Communications patterns
Contextual factors	Human behaviours, values and opinions	Equality and intersectionality	Digital access and participation
	Health care innovation	Global economic development	Climate change impacts
	Non-state actors	Global governance and politics	Conflict and civil unrest

Table 2 Key factors per category

1.3.1 Pathogen and host characteristics

Transmissibility

Transmissibility is the level of ease with which a virus can be transmitted between hosts. It is determined through a range of factors relating to the infected individual and the broader environment. These include the infectivity of the pathogen, such as its ability to bind to cells; its incubation and production time; the immunity, viral load exposure and contagiousness of the infected individual, as well as the wider society's herd immunity. In the case of COVID-19, transmissibility also depends upon which variant is being spread, for example, the Delta variant is estimated to be more than twice as transmissible as the original strain of SARS-CoV-2.[64]

COVID-19 is primarily transmitted from person to person via respiratory droplets, such as aerosols produced when coughing or speaking, that are either inhaled or deposited upon mucosal surfaces. Transmission through contact with contaminated surfaces is considered possible, although it has not yet been documented for SARS-CoV-2.[65]

Experimental studies indicate that some animal species, such as cats, are susceptible to SARS-CoV-2 infection and that cat-to-cat transmission can take place via contact and air. Even though human-to-animal spill-over has been reported on several occasions such as with white tailed deer, SARS-CoV-2 transmission from animals to humans has only been reported from mink to humans in mink farms during an outbreak of a mink variant amongst humans in Denmark in 2020.[66, 67, 68]

Variant diversity and susceptibility

A virus must produce copies of itself to spread. This replication process may not always be exact and can result in mutations in the genetic sequence. Viruses with new mutations are known as variants. A variant that becomes established in the population with novel functional properties is known as a strain.[69] Growth of COVID-19 infections increases opportunities for mutations to form and there is potential for these to have a selective advantage. This could be a change in transmissibility, increased disease severity, evasion of detection, reduced susceptibility to treatments or the ability to evade natural or vaccine-induced immunity.

Since December 2019, WHO in collaboration with a network of partners, authorities, and institutions, has been monitoring the evolution of SARS-CoV-2. In late 2020, variants emerged that posed an increased risk to global public health. These variants are categorized as Variants of Interest (VOIs) and Variants of Concern (VOCs). As of early 2022, five VOCs (Alpha, Beta, Gamma, Delta and Omicron) and four VOIs (Eta, Iota, Kappa, Lambda) have been identified.[70] These variants can pose greater risks, for instance in many countries the Delta variant has been linked with a resurgence of COVID-19. It is approximately 60% more transmissible, more resistant to vaccines and, once infected, people are roughly twice as likely to be hospitalised, compared to those infected with the Alpha variant.[71] To reduce global risk, it is important to minimize opportunities for mutations. One way to achieve this is through increased global access to vaccines.

Human immunity and vulnerability levels

Immunity is an organism's capability to resist harmful microorganisms, either occurring naturally or through vaccination. COVID-19 infects the body by latching onto ACE2 receptors of healthy cells and multiplying throughout the body. In response, T cells and antibodies are created to combat the virus. Afterward, these antibodies remember how to eliminate the infection and therefore provide future immunity. However, these memory cells can fade over time.

In the majority of healthy individuals, symptoms are mild to moderate, but COVID-19 can cause life-threatening disease when the immune system overreacts or in some cases persistent debilitating symptoms can remain, as is the case for those with post COVID-19 condition also known as long COVID.[72] Herd immunity occurs when a large proportion of the community becomes immune to COVID-19,

reducing the likelihood of person-to-person spread. The two paths to reach herd immunity are natural infection and vaccination. As the length of protection from natural infection is unclear and associated deaths can be high from COVID-19 infections, vaccination is the preferred route to maintain protection against SARS-CoV-2.[73]

The most important determinant of disease severity is age, with individuals over 65 years old having the greatest risk of requiring intensive care, alongside those with underlying health conditions.[74] Patients with more severe symptoms also generally suffer from a decreased level of lymphocytes, particularly helper T-cells and cytotoxic killer T-cells that play a vital role in the body's inflammation-mediated immune response.[75]

Symptom range and mortality rate

Symptoms of COVID-19 can appear anywhere between 2–14 days after exposure. For eight out of ten people symptoms are mild, a result of the immune system responding to the infection. These generally include a fever, a dry cough or tiredness[76] but there are a range of other reported symptoms such as muscle aches, chest pain and diarrhoea.[77] Indeed, those living with post COVID-19 condition have reported more than 200 symptoms across 10 organ systems.[78]

Approximately 14% of unvaccinated people infected with COVID-19 will experience severe symptoms due to the immune system overreacting, this causes lung inflammation, which leads to difficulty in breathing.[76] About 6% of unvaccinated people infected with COVID-19 become critically ill, including experiencing sepsis, low blood pressure, lack of oxygen and organ failure. Patients who are older or have underlying health conditions have an increased risk of becoming severely or critically ill from COVID-19 infection.

Mortality rate is one of the most important ways to measure the impact of the COVID-19 pandemic. Case fatality ratios (the number of deaths divided by the number of confirmed cases) is a common way of assessing the impact of a virus.

New pandemic risk

A pandemic is a disease that is prevalent across borders, whether regionally or globally. Pandemics are increasingly common, driven by human activity.[79] Factors such as increased population density and urbanization, global trade and connectivity, intensification of agriculture, human expansion into animal habitats and the effects of climate change all increase the risk of new diseases emerging, and new or known diseases turning into pandemics. COVID-19 is at least the sixth global pandemic since the Spanish Flu influenza pandemic of 1918. In the future, it is predicted that pandemics will emerge more often, spread more rapidly, cause more damage to the global economy and lead to greater global morbidity and mortality.[80]

Most emerging diseases stem from the transmission of pathogens from animals to humans in spillover events.[81] The risk of spillover will only increase as human activity encroaches further into animal habitats.[82] There are currently 1.7 million unknown viruses that exist in mammals and birds, up to 850 000 of which could potentially infect humans.[80] Animal-to-human transmission can remain undetected for years. For example, using sero-surveys, Ebola antibodies were found in more than 5% of people tested in Liberia in 1982, decades before the West African epidemic in 2014.[80] Mitigating future pandemics will involve behaviour and industry change, global collaboration using a One Health approach and preventative, real-time surveillance in settings where animal-to-human disease spillover is common.

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1.3.2 Public health and social measures

Vaccine efficacy and access

Vaccines prevent diseases by teaching the immune system to safely recognize and block an infection, allowing it to effectively eliminate the same infection in the future. Vaccines are an essential element of a public health response to the outbreak of a novel virus. At least 13 different COVID-19 vaccines have been administered across four different platforms.[83] These include, messenger RNA (mRNA), inactivated or weakened virus, protein subunit and viral vector vaccines. All are designed to elicit immune responses, ideally creating neutralizing antibodies (NAbs) against the SARS-CoV-2 spike protein. Vaccines go through a thorough review of their safety, quality and efficacy in large clinical trials, being regulated in the country where the vaccine is manufactured, as well as independently. Efficacy is generally measured as relative risk reduction (RRR), the ratio of attack rates with and without the vaccine.[84] Trials have shown several COVID-19 vaccines to have high levels of efficacy ranging from 60% to 95%.[85]

Apart from how rapidly vaccines are approved, manufactured, and delivered, global equitable access to them is critical in order to respond to the COVID-19 pandemic effectively. Intellectual property rights alongside mass pre-ordering by wealthier nations has left limited supplies for LMICs. COVAX, which is a surplus dose sharing initiative, shipped over half a billion donated COVID-19 vaccines to 105 countries by January 2022. Collective action is needed to address the global inequities in vaccine distribution.

COVAX, a surplus dose sharing initiative, shipped over half a billion doses of COVID-19 vaccines by January 2022.

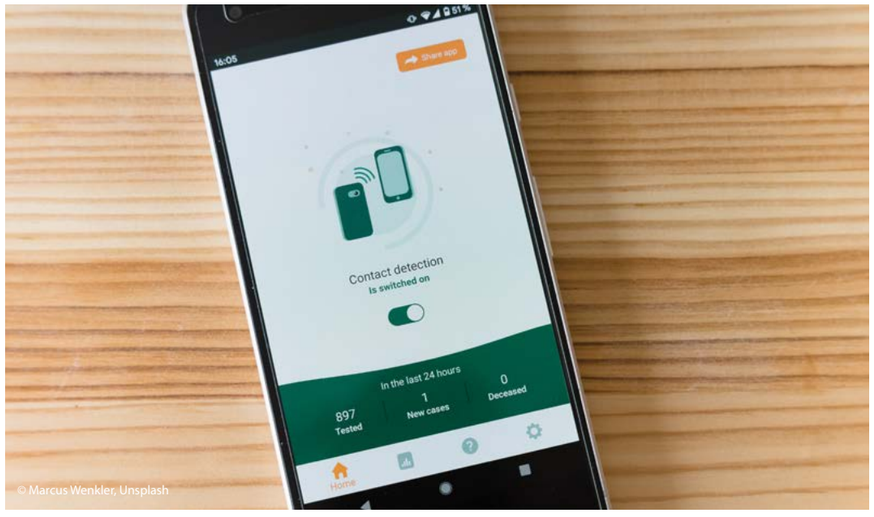
Public health measures

Public health measures are organized efforts to prevent or mitigate the spread of diseases. During the COVID-19 pandemic, measures such as physical distancing, limits on public gathering, school and workplace closures, border controls and mask wearing policies were implemented to reduce transmission of the virus in communities. As the pandemic spread across the globe, governments have applied different combinations of these measures at different times to flatten the curve of increasing case numbers.

When taken together, public health and social measures inform different strategies taken by decision-makers as part of pandemic responses.[86] Some jurisdictions have pursued elimination strategies, implementing strict national interventions. Such strategies have relied on strict public health and social measures, and comprehensive test, trace and isolate approaches to limit community transmission. Others have pursued less restrictive mitigation strategies, relying instead on track and trace apps, investing in vaccination and booster shots. While some jurisdictions have opted for a herd immunity approach allowing community transmission with limited testing, contact tracing or restrictions implemented. Public health strategies have seen some public opposition and resulted in complex interactions between law enforcement and health sector actors, including enforcing so-called lockdowns, border controls, health services in incarcerated populations and policing cybercrime.

Diagnostics, surveillance and tracking

Digital technologies are being harnessed worldwide to support the COVID-19 public-health response including contact tracing, case identification and population surveillance. This allows for rapid mass interconnectivity by leveraging billions of mobile phones, large online data sets and advances in technology such as machine learning and natural language processing.[87] Effectiveness of interventions can be seen through evaluation of trends in mobility data. Tech giants also publish mobility data trends, but this has raised questions around the role of the private sector alongside legal, ethical and privacy concerns.



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Digital technologies are being harnessed worldwide to support the COVID-19 public-health response.

Genomic surveillance is the analysis of mutations in the genetic code of virus samples, allowing the monitoring and detection of new variants alongside providing insights into where and when they are evolving. WHO and its partners have been monitoring and assessing specific VOIs and VOCs in order to prioritize global monitoring and research and will also inform the on-going response to the COVID-19 pandemic such as with vaccination development.[70] Globally, systems have been established and are being strengthened to detect signals of potential VOIs or VOCs and assess these based on the risk posed to global public health.

Treatment and prevention

Treatment for COVID-19 depends on the severity of the infection. For milder cases, resting at home and taking fever reducing medication is often sufficient, but severe cases can require hospitalization, assisted ventilation and antivirals to speed up recovery time. Since their development, vaccines have repeatedly shown to be the most effective protection against the virus. However, the length of immunity is unclear and the global distribution of vaccines is marred by challenges of equity, public distrust and logistical complexity.[88]

Various treatments for COVID-19 have also proven to be useful. Monoclonal antibody treatments (laboratory-engineered proteins that act like antibodies in the human immune system) have been granted emergency use authorisation (EUA) by the United States Food and Drug Administration. In May 2021, regulators in the United Kingdom of Great Britain and Northern Ireland approved Ronapreve, the first treatment in Britain using man-made antibodies to treat COVID-19.[89, 90] However, consensus on treatment is not always universal. In May 2020, the United States Food and Drug Administration approved Remdesivir for treatment in hospitalized patients, while WHO recommended against it at the time.[91, 92] Meanwhile, pharmaceutical companies and laboratories worldwide are undertaking ongoing clinical trials to develop and test other medicines to treat COVID-19.

Health care systems' response and capacity
The pandemic has emphasized the long-standing gaps and limitations of chronically underfunded and fragmented health systems globally. As many countries face ongoing waves of COVID-19 transmission, hospitalizations rise and health care systems are overwhelmed. With rising case numbers, an already over-extended and underpaid health workforce must struggle to provide essential health services alongside COVID-19 care. From community health workers to primary care providers, to tertiary care specialists, health service delivery globally is challenged by limited resources and unprecedented need.

The pressure of caring for large numbers of seriously ill patients has led to significantly longer delays in receiving care, a reduction in referrals and some people have chosen not to seek medical advice altogether. These missing patients remain the biggest unknown in planning to address the backlog of unmet needs created by the pandemic.[93] Ensuring that health systems are strengthened and resilient, beginning with primary care in communities, is essential to finding these patients and linking them to appropriate and person-centred care.[94]

"Distrust comes when people don't know what you are doing."

Professor Akin Abayomi, Honorable Commissioner for Health of Lagos State

"The interaction between virus behaviour and human behaviour drives the pandemic and its impacts. The virus is reacting to evolutionary opportunities."

Dr Michael J. Ryan, Executive Director WHO Health Emergencies Programme

Communication patterns
Communication increasingly occurs online. As of January 2021, there were 4.66 billion active internet users[95] and over 3 billion individuals using social media regularly.[96] As populations are increasingly receiving their information via these platforms, they can be effective tools for the dissemination of medical and scientific knowledge. Unfortunately, these same platforms are also effective at disseminating fake news, which can lead to an infodemic of misinformation, where people become overwhelmed by the amount of information and begin to mistrust evidence and those communicating public health information.[97] As social media giants publish the majority of the most-read content, they have an important role in limiting the spread of misinformation and have been required to institute a series of quality controls.

Transparent communication between and within governments is also crucial to pandemic preparedness and response. Communication between these stakeholders ensures accurate knowledge sharing for effective emergency responses. Communication includes information on pathogen identification, incidence and transmission patterns, and public health strategies. The International Health Regulation (IHR) 2005 provides a legal framework that defines countries' rights and obligations[98], relying on them to communicate timely and accurate information about health risks during an outbreak.[98] Despite a collective approach being accepted as the most effective, the international response has exposed fundamental gaps in global collaboration that render the world vulnerable to infectious threats.[99]

1.3.3 Contextual factors

Human behaviour, values and opinions
A wide range of socio-economic factors including inequalities, demographics and societal norms shape a population's behaviour and values. Combatting COVID-19 relies on citizens relating their actions to broader society, such as through compliance with public health measures. Thus, variations in cultural and individual values have a profound effect on our ability to react to the pandemic. Trust in fellow citizens and public institutions is vital for governments to respond rapidly and secure citizen support of pandemic responses.[100] Trust levels can fluctuate between and within societies. Nations where the population feels connected to the government, and where individuals perceive their position and treatment as equal to that of the broader society, are more likely to be able to mount a unified, effective response to health emergencies.

Equality and intersectionality
Public health emergencies exacerbate existing societal inequalities across regions, race, gender, age and income. The pandemic specifically affects communities living in overcrowded housing, deeply entrenched poverty, with inadequate access to health care and limited employment flexibility.[101] Death rates and spread of COVID-19 positively correlate with community vulnerability, with minorities, oppressed groups and migrant communities facing higher risks of contagion.[102, 103]

These asymmetries result from systemic inequalities that increase the likelihood of exposure to the virus and of having pre-existing health conditions that render people more vulnerable to poorer health outcomes. They can also result from public health and social measures themselves, which can disproportionately impact marginalized groups. For instance, following school closures, by April 2020, 1.6 billion learners had been sent home.[104] School closures had a gendered impact, as it is estimated that 20 million girls will never return to school due to sexual exploitation, pregnancy, forced marriage, child labour and a greater burden of care work at home.[105]

Global inequalities between nations have also increased, in part due to the actions of wealthy countries. The high bidding and pre-ordering of medical supplies and vaccines has meant that LMICs have minimal access to these life-saving products, increasing the impact of the virus in many regions and prolonging the pandemic.[106]

Digital access and participation
The pandemic has accelerated societies' digital transformation. Many children and workers began attending classes and jobs remotely. Numerous firms adopted digital business models and internet traffic in some countries increased by up to 60% in 2020.[107] Meanwhile, mobile applications were developed to conduct contact tracing and researchers employed AI to accelerate vaccine development.

This increased reliance on technology has added urgency to concerns around privacy, security and access. People can be excluded due to lack of skills, access to devices and internet or limited motivation to use technology.[108] Age also influences the digital divide; in 2019 across OECD countries only 58% of those aged 50–74 years old used the internet daily compared with almost 95% of 16–24 year olds.[109] These barriers can lead to reduced access to jobs, education and healthcare services and limited internet literacy is linked with an increased risk of falling victim to online misinformation, fraud and computer viruses.[108]

Public health emergencies expose societal disparities across race, gender and income with the vulnerability of different social groups influenced by economic inequalities.

As COVID-19 vaccination rates in high-income countries increase, some governments are proposing digital health passes or vaccine passports. These will be used to facilitate international travel but will exclude countries that lack the ability to fully vaccinate their populations for several years.[110]

Health care innovation

The COVID-19 outbreak has accelerated health care innovation across the globe. Advances include improvements in the production of ventilators, vaccines and diagnostic techniques. This is due to increased funding, multi-sectoral collaboration and reduced administrative barriers in response to COVID-19.[111] To facilitate physical distancing, mass use of digital health tools, such as the development of telehealth platforms, has accelerated. Express diagnostic techniques have also evolved, enabling rapid mass testing and remote diagnosis.

The success of the mRNA technology which is used in COVID-19 vaccines has accelerated research on other mRNA therapy opportunities, such as the use of mRNA vaccines for cancer immunotherapy[112] and other infectious disease-modifying drugs such as antivirals.[113] The current successes and investment in response to COVID-19 have facilitated the development of numerous mRNA startups. Indeed, the mRNA market is projected to grow to almost US$ 5 billion by 2025.[114]

Global economic development

The global economy has been severely affected by the pandemic, contracting by 3.5% in 2020[115], which was primarily driven by a fall in demand.[116] OECD GDP was down by 1.8% in Q1 2020 with the Eurozone expected to shrink the most in 2020/21, by around 9%.[117] Global recovery is underway with global GDP growing by 5.7% in 2021. For 2022, the global economy is expected to grow 3.2%, according to the World Bank.[118] Recovery will be asymmetrical due to the strength of different countries' COVID-19 policies, vaccination rates and previous stability. Impact on sectors will be varied, with transport expected to experience long lasting effects, specifically aviation, as ways of doing business evolve.

The COVID-19 pandemic accelerated a digital transformation that has been underway for decades.

The hardest-hit industries in 2020 were those requiring in-person transactions such as transport and in-store retail (90% loss of industry-level GDP), followed by manufacturing and construction (up to 50% loss). There is no way to accurately tell what the global economic impact of the COVID-19 pandemic will be, but current evidence suggests that it could be deep and far-reaching.[119] Outcomes will depend on policy responses around re-opening, the size of post-pandemic stimulus and recovery of the supply chain.[120]

Climate change impacts

The survival and transmission of diseases is reliant on specific environmental conditions. Human activity causes climate and ecological changes, which can create environments where infectious diseases flourish.[121] For instance, increased temperatures expand the area where mosquito-borne diseases such as malaria thrive.[122] Anthropogenic activity further drives these risks, as reduction of wildlife habitat and deforestation increase opportunities for animal-human overlaps. Greater interaction between humans and animals accelerates the likelihood of zoonotic disease transmission.[123]

Research has also found direct correlations between exposure to air pollution in general and an increased risk of mortality from COVID-19.[124]Broader factors related to climate change, including the production of harmful air pollutants, are are also known to cause health problems like heart attacks, strokes and diabetes. All of these are key pre-existing medical conditions that are known to raise the risk of death from COVID-19.[125, 126]

WHO has stated there is no direct connection between climate change and the emergence or transmission of COVID-19 but indirectly climate change affects our global ability to respond effectively.[127] Climate change facilitates factors that make populations more vulnerable such as increasing the likelihood of displacement and poverty, food security crises, undermining environmental determinants of health and putting additional stress on economies and health systems.[127]

Non-state actors

The response to COVID-19 has been predominately led by the state, but the private sector and civil society have also played essential roles. Some countries provided authorities with the power to requisition private sector facilities, equipment and staff as needed to respond to the pandemic.[128] Others drew on private sector partnerships to increase testing and response capacity. Reliance on private sector resources and capacity was specifically critical in LMICs, where the private health sector provides a significant proportion of essential health services.

Private companies have adapted quickly to assist the pandemic response. For instance, technology organizations built apps and wearables allowing businesses to track and stop the spread of COVID-19 among employees.[129] Fashion brands mobilized their production facilities to address the global PPE shortage. The private sector can act quickly, but barriers include the need to be financially viable as well as the need to develop ways of working with governments and across sectors.[130] Public-private partnerships can provide a hybrid option to mitigate the social and economic challenges of COVID-19.

"We need to convince politicians that their interest lies in people and the planet first – tackling problems with global inequality – class, race, gender, or we won't survive as a species."

Mr Owen Tudor, Deputy General Secretary
International Trade Union Confederation

Global governance and politics

During the pandemic, international cooperation has led to innovative collaborations such the WHO Solidarity PLUS trial, which provided rapid evaluation of therapies and drugs to treat COVID-19.[131] However, in general, national politics has been prioritized over global cooperation with a rise in protectionist policies and geopolitical tensions.[132] To contain the pandemic, many states introduced border closures or quarantines but often in a selective approach. Sanctions between countries have also not been waived in the name of pandemic solidarity and have undermined sanctioned countries' capacity to respond to the pandemic as they have obstructed humanitarian responses.[133]

"I have been most impressed by the solidarity expressed by the African countries in the integration of public health efforts."

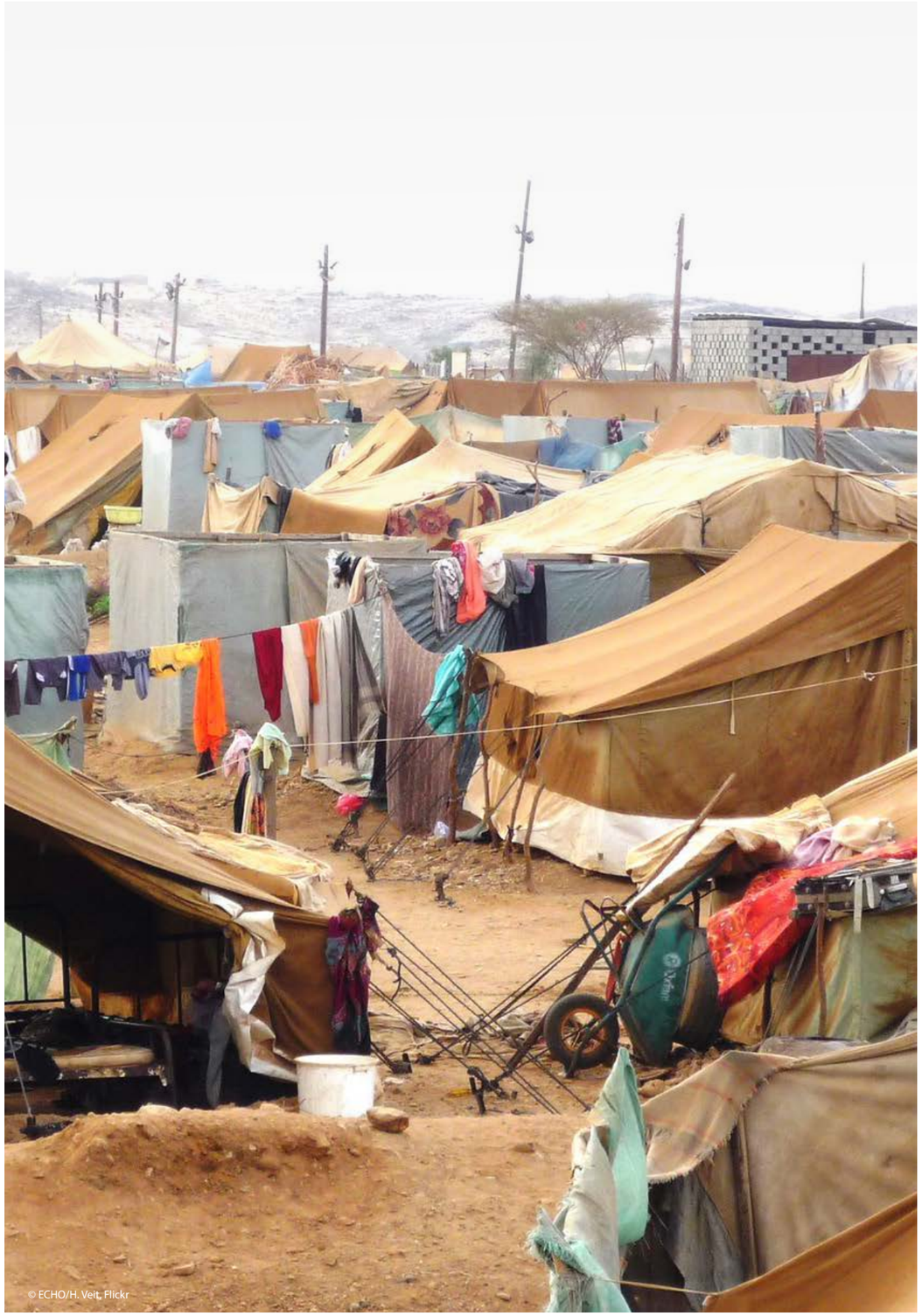
Professor Richard Hatchett, CEO
Coalition for Epidemic Preparedness Innovations (CEPI)

Vaccines have become a method of combatting the pandemic but also a political tool. Vaccine diplomacy is a way for nations to entrench influence across the globe. High-income countries have also contributed to supply scarcity of vaccines by signing advance purchase agreements leading to deepening global vaccine inequity.

High-income countries could help ameliorate inequities through funding and donating vaccine doses to COVAX while building manufacturing capacities in LMICs, including technology transfer.[134]

Conflict and civil unrest

The 2021 Global Peace Index highlights a rise in civil unrest and political insecurity, economic downturns, intensified inequalities and political instabilities related to the pandemic.[135] [136] The IMF estimated the global economy contracted by 3.5% in 2020 and countries already facing economic hardship sank further into debt as aid was also reduced.[115] It could take more than a decade for the poorest nations to recover from the economic fallout, further exacerbating volatility and instability.[136] Evidence suggests that crisis-affected countries have been especially hard-hit by the secondary impacts of the pandemic. Secondary impacts include rising poverty, food insecurity, a rise in domestic and other forms of violence and an erosion of trust between citizens and state. These conditions are exacerbated by low vaccination rates, fragile governments and poorly equipped health systems.



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In some areas, the response to the crisis has been hampered by limited testing, a lack of health care centres, shortages of medical supplies and obstruction of foreign aid.

1.4 Morphological box

Key:
- Scenario 1: Happy Days
- Scenario 2: I Love You, I Hate You
- Scenario 3: Heartbreak Hotel
- Scenario 4: Here Comes Trouble

Categories	Pathogen and host characteristics				
Key factors	**Transmissibility**	**Variant diversity and susceptibility**	**Human immunity and vulnerability levels**	**Symptom range and mortality rate**	**New pandemic risk**
Projections	Increased human transmissibility	High variant diversity, high susceptibility to vaccines	High immunity, low vulnerability	High mortality rate, intense symptoms, long duration	New global pandemic emerges, coupled with more dangerous COVID-19
	Increased human transmissibility + sustainable animal viral reservoirs	High variant diversity, low susceptibility to vaccines	Variable immunity, variable vulnerability by region	High mortality, intense symptoms, short duration	New pandemic emerges, coupled with an endemic COVID-19
	Variable human transmissibility across variants	Low variant diversity, high susceptibility to vaccines	Variable immunity, variable vulnerability by age group and health status	Mixed mortality rate and variable risk of long symptoms across all age groups	New pandemic emerges after COVID-19 herd immunity is reached
	Stable human transmissibility	Low variant diversity, low susceptibility to vaccines	Low immunity, high vulnerability	Low overall mortality rate, but risk of long symptoms across all age groups	Future pandemics appear but do not become a global health crisis
	Reduced human transmissibility		Low immunity, low vulnerability (virus less deadly)	Low mortality rate, low risk of long symptoms	

Public health and social measures					
Vaccine efficacy and access	**Public health measures**	**Diagnostics, surveillance and tracking**	**Treatment and prevention**	**Health care systems' response and capacity**	**Communications patterns**
High efficacy, widespread access	Increase in stricter elimination and/or mitigation strategies globally	Robust local, national, and global systems for diagnostics and surveillance	Widespread use of vaccines as the only global treatment and prevention option	High vulnerability of healthcare systems globally, low resilience, backlog of treatment	High volumes of health care misinformation and disinformation and high susceptibility of the general public
High efficacy, region- or country specific access	Decrease in stricter elimination strategies, increase in mitigation strategies globally	Robust local and national systems for diagnostics and surveillance, limited global or regional cooperation	Widespread use of vaccines coupled with a variety of treatment and prevention options	Low vulnerability of health care systems globally, high resilience, effective adaptation to surges in COVID-19	Health care misinformation and disinformation restricted to some platforms, groups and regions only
Mixed efficacy, widespread access	Increase in stricter elimination strategies globally, decrease in mitigation strategies	Variable quality and reach of local and national systems for diagnostics and surveillance	Reduced use of vaccines, high use of treatment and prevention options	Low vulnerability of health care systems in certain regions, high vulnerability and low resilience in other regions	Risk, reach and impact of health care misinformation and disinformation significantly reduced
Mixed efficacy, region- or country specific access	Widespread decrease in public health measures	Breakdown of local and national systems for diagnostics and surveillance, highly limited provisions	Reduced use of vaccines, limited use of treatment and prevention options		
Limited or reduced efficacy					

Key:

- Scenario 1: Happy Days
- Scenario 2: I Love You, I Hate You
- Scenario 3: Heartbreak Hotel
- Scenario 4: Here Comes Trouble

Categories	Contextual factors					Contextual factors			
Key factors	**Human behaviours, values and opinions**	**Equality and intersectionality**	**Digital access and participation**	**Health care innovation**	**Global economic development**	**Climate change impacts**	**Non-state actors**	**Global governance and politics**	**Conflict and civil unrest**
Projections	High trust in public institutions and guidance	High health inequality and intersectional inequality globally	Widespread global utilization of digital tools and platforms	Environment of rapid innovation and frequent technology/scientific breakthroughs	Short-term pause, rapid recovery	Accelerated ecosystem degradation with increased frequency and intensity of extreme weather events	Strong public-private partnerships, functioning global supply chains with equitable access	Effective global cooperation, data sharing and dialogue – world working as one	High levels of conflict and unrest with limited global intervention and support
	Varying trust in public institutions and guidance	High health inequality and intersectional inequality in most developing and emerging countries	High availability and utilization of digital tools in emerging and developed regions only	Environment of innovation and breakthroughs, but limited global diffusion of benefits	Mid-term pause, partial recovery	Slowdown in ecosystem degradation with increased frequency and intensity of extreme weather events	Strong public-private partnerships in developed regions, limited equitable access	Varying regional and cross-country cooperation – selective support and cooperation	High levels of conflict and unrest with some global intervention and support
	Low trust in public institutions and guidance	Reduced health inequality and intersectional in most developed countries	Highly fragmented use of digital tools determined, enforced by government or private sector	Environment of stagnation and limited transformative innovation	Long-term pause, recurring recessions	Accelerated ecosystem degradation with varying frequency and intensity of extreme weather events	Varying efficiency of public-private partnerships, global supply chains driven by political influence	Fragile global cooperation and alignment – restricted local partnerships	Varying levels of regional conflict and civil unrest, managed nationally
		Reduced health inequality and intersectional inequality globally	Limited access and global utilization of digital tools and platforms coupled with a lack of trust		Long-term pause, eventual economic collapse	Slowdown in ecosystem degradation with varying frequency and intensity of extreme weather events	Breakdown of public-private partnerships, global supply chains driven by profit and price alone	No global or regional cooperation and alignment - each to their own	Limited regional conflict and civil unrest, managed and contained locally

Table 3 Morphological box

1.5 Scenario development

A summary of the scenarios and their key assumptions can be found below. Detailed scenario narratives and 'a day in the life' stories can be found from page 77 onwards.

Scenario 1: Happy Days

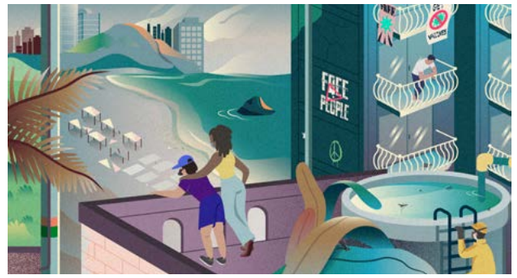
1. Virus less potent, widespread natural or acquired immunity.
2. New COVID-19 treatment and prevention options offered at scale globally.
3. Low mortality rate, low risk of long COVID-19 symptoms.
4. New pandemics appear but they do not become a global health crisis.
5. Economies recover after a short pause.
6. Nations sign Infodemic Treaty to combat mis- and disinformation.
7. Access to health care for all is improved and there are broad societal benefits through improved global coordination and preparedness.
8. Technological and scientific progress and health care innovation are happening at a rapid pace.
9. Widespread climate change mitigation and adaptations slow down rising temperatures.
10. The world is working as one, humanity gets on top.

Scenario 2: I Love You, I Hate You

1. Protracted pandemic with continuous virus evolution.
2. Immunity levels vary depending on age group and health status.
3. Vaccines are playing catch-up, but efficacy levels are high and access is widespread.
4. Stricter elimination and mitigation public health measures are implemented based on season and/or regional strategies.
5. Some health care systems adapt well to the surges of the virus but others struggle, creating a backlog of treatment.
6. Trust in governments and public institutions varies significantly across different parts of the world.
7. Health care innovation is happening at a rapid pace but diffusion of benefits is limited to certain nations and regions.
8. Economies worldwide experience a mid-term pause, with some of them recovering only partially.
9. Climate change mitigation remains sluggish and extreme weather events become more frequent.
10. Humanity (just about) keeps up.

Scenario 3: Heartbreak Hotel

1. The virus evolves to become even more infectious; human transmissibility levels record new highs.
2. New variants emerge, vaccines lose efficacy.
3. COVID-19 causes a wider symptom range and wider age brackets are impacted; long COVID rates increase.
4. Diagnostics, surveillance and tracking vary significantly in quality and reach across nations.
5. Health care systems globally struggle to keep up with the surge in infections.
6. The infodemic surrounding the pandemic is once again thriving and hard to control.
7. Economies are suffering the consequences of long-term pauses; recessions and economic hardship increase.
8. The fight against climate change is not yielding the expected results and the pressure to adapt increases.
9. Regional and cross-country cooperation is inconsistent, with only selective support and cooperation.
10. Collective failure, humanity plays catch up again.



Scenario 4: Here Comes Trouble

1. Another pandemic emerges, in addition to a worsening COVID-19 pandemic, with distinct regional characteristics.
2. Some vaccines seem to be working while others are not. Access to vaccines depends heavily on income and citizenship.
3. Tropical zones are first to suffer the impact of a double pandemic as new Zika strains render the COVID-19 public health response ineffective.
4. Diagnostics, surveillance and tracking systems struggle to cope with two pandemics at the same time.
5. The double pandemic threat has left many health care systems in peril, with low resilience and a growing backlog of treatment.
6. Efforts to tackle health inequality and intersectional inequality are severely hindered.
7. Economies globally experience a protracted pause, leading to eventual collapse for some.
8. Tackling the climate emergency is no longer at the top of many nations' agendas.
9. Breakdown of global collaboration coupled with severe conflict and unrest.
10. Humanity struggles to manage.

2. Key messages for strengthening future pandemic preparedness

2. Key messages for strengthening future pandemic preparedness

WHO experts and collaborators, as well as subject matter experts from a variety of fields, engaged in a series of consultations, workshops and public roundtable discussions to validate, refine and expand the four scenarios, to identify risks and opportunities and to discuss the crucial role of leadership.

A summary of the outcomes and the key messages derived from these engagement sessions is presented below. The key messages are accompanied by practical ways forward and they are together organized across five themes. Three pillars guide the overall effort to strengthen future pandemic preparedness.

Three pillars
Overarching, guiding principles for future pandemic preparedness:

1. **Trust**
2. **Solidarity and equity**
3. **Sustainable development**

Five themes
Areas of focus that are key in formulating an all-encompassing approach when managing and responding to the complexity of infectious threats:

1. **Science, policy and environment**
2. **People, communication and education**
3. **Economy, infrastructure and systems**
4. **Technology and innovation**
5. **Leadership and collaboration**

"Science is only as good as you communicate it. Key is to make sure that the science we do is available for everyone, everywhere."
Dr Andrea Hinwood, Chief Scientist
United Nations Environment Programme (UNEP)

"Research and education are important gaps to fill, especially in low- and middle-income countries."
Ms Mandipa B. Ndlovu, Governance Researcher and Development Policy Analyst
Leiden University

"In order for resources to continue to scale, get ahead of shortages, and keep systems warm, a surveillance base is critical."
Dr Renee Wegrzyn, Head of Innovation
Concentric by Ginkgo

"Trust in scientists is the key driving force for individual attitudes. And it's incredibly important that scientists and scientific institutions are independent. Science is a public servant."
Professor Alice Roberts, Professor of Public Engagement in Science
University of Birmingham

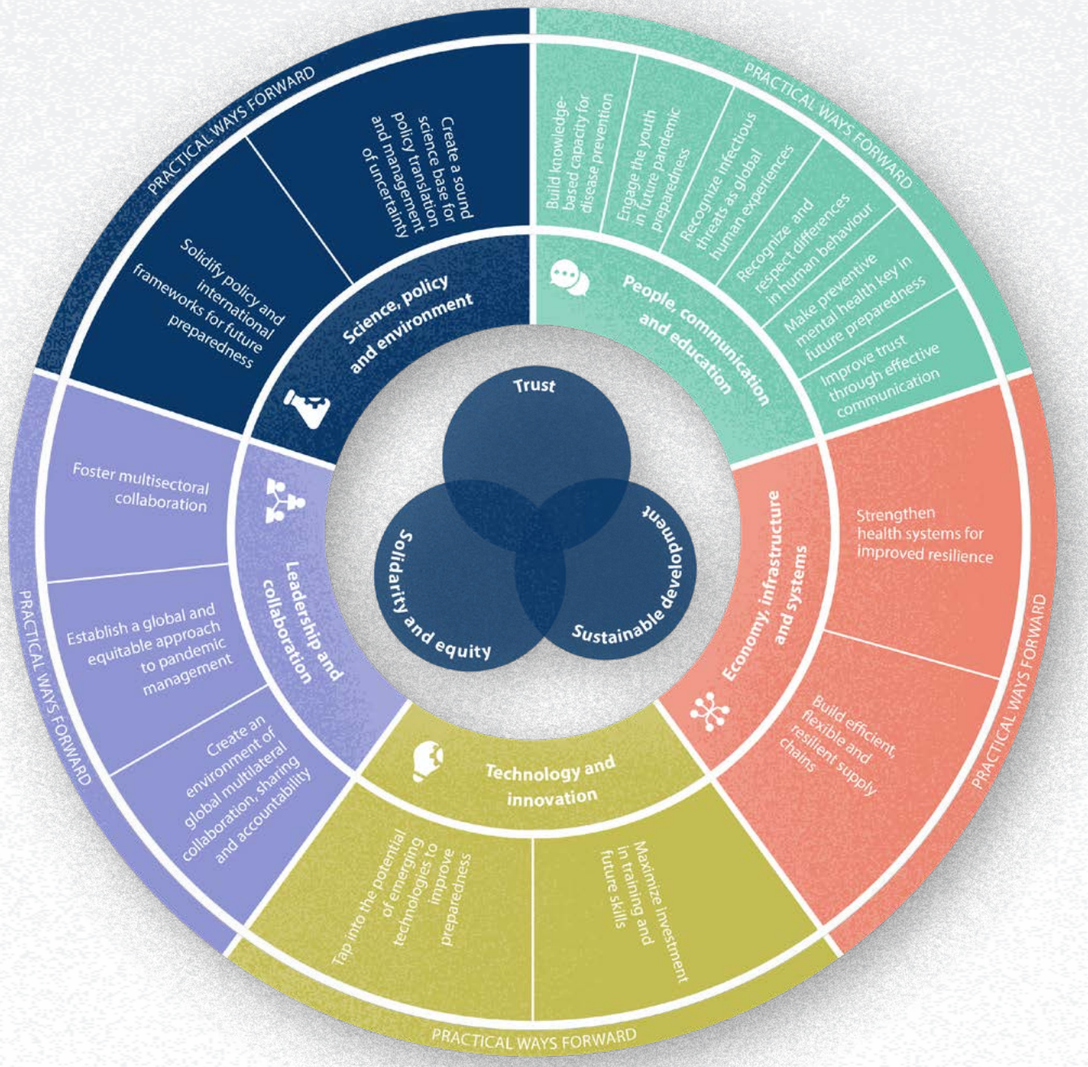


Fig. 7 Key messages for improved future pandemic preparedness, summarized in three pillars and five themes and accompanied by practical ways forward

2.1 Science, policy and environment

Key message:
Work towards a sound science base, set up for transparent policy translation and master decent management of uncertainty.

Practical ways forward:

- *WHO to convene and coordinate global experts and research funding agencies to develop research agenda, promote and monitor progress for knowledge generation.*
- *While funding for product-oriented research is essential, research funding agencies to align, support and fund human-centred scientific disciplines on equal footing. These include sciences dealing with human beliefs, emotion, empathy, cultural elements, and relations, psychology, mental health, social and behavioural science and anthropology.*
- *Research funding agencies to support science for equity that enables making products and supplies accessible for people in need.*
- *Research funding agencies to support principles of international collaboration in science with respect to diversity when calling for research proposals.*
- *Multilateral organizations and funding agencies, with support from academic and research communities, to develop research capacities in all countries.*
- *Governments and national leaders to set up a multi-disciplinary scientific advisory group of experts to inform decision-makers.*
- *Governments and national leaders to have a lead science figure to communicate the science base, clear rationale for policy development and manage scientific dialogue in the country.*
- *Governments and national leaders to invest more in translating policies into context-specific actions.*
- *Governments and national leaders to address the critical importance of managing uncertainty in their pandemic and epidemic preparedness through simulation, scenarios and foresight exercises.*

Key message:
Solidify policy and international frameworks for future pandemic and epidemic preparedness.

Practical ways forward:

- *WHO and global partners to pursue recommendations by the major pandemic response review reports (IPPR, IHR RC, GPMB) and establish monitoring and evaluation (M&E) mechanisms.*
- *Encourage private and public sector actors with a role in global supply chains to operate based on a common system of values and social responsibility.*
- *WHO and regulatory agencies to create common regulatory pathways to ensure equity in vaccine and overall resource distribution.*
- *WHO and partners to strengthen the One Health approach considering the role and impact of population, ecosystem and biodiversity changes.*
- *WHO and partners to plan for the impact of migration due to different and combined causes (climate, conflicts, infectious threats and public health and social measures, etc).*

"No one is safe until everyone is safe."
Dr Tedros Adhanom Ghebreyesus
WHO Director-General

2.2 People, communication and education

Key message:
Build knowledge-based capacity in people to protect themselves, their family and community from infectious threats by providing early opportunities for relevant education and enabling environments.

Practical ways forward:

- *National authorities to integrate the scientific base of infectious disease prevention and control, hygiene and public health into primary and life-long education programmes starting from early age with the aim to grow safe and healthy behaviours.*
- *Health authorities to engage the health workforce in providing accurate health communication in times of crisis.*
- *Health authorities to invest in modern communication channels and tools, for example video, social media, games.*

Key message:
Actively engage the youth to take responsibility and lead cross-generational action for pandemic and epidemic preparedness.

Practical ways forward:

- *Governments and national authorities to include youth representatives in future foresight and other pandemic and preparedness initiatives.*
- *Leverage the digital literacy and technological acumen of youth and utilize their connectivity for community outreach and engagement.*
- *Engage youth as ambassadors for pandemic communication.*

"We must leverage more of the youth and their connectivity."
Dr Renz Argao, Coordinator
Religions for Peace International
Youth Committee

Key message:
Recognize the COVID-19 pandemic and other infectious threats as global human experiences that start and end in communities.

Practical ways forward:

- *Forge strong community partnerships between private and public entities to achieve positive pandemic futures.*
- *Adopt bottom-up approaches for better pandemic preparedness by including community representatives in the decision-making process.*
- *Build agile, nimble, dynamic, fast-track incident response structures at the community level.*
- *National and local authorities to acknowledge the role of communities of practices (for example, faith-based, employers, employees) in addition to traditional communities and develop a mechanism to empower communities so that they can contribute to the response.*

Key message:
Recognize and respect the intercultural, religious and generational differences that shape behaviour, values and ways of accessing and assessing information about infectious threats.

Practical ways forward:

- *Mobilize multi-faith action and inter-faith collaboration to reach, engage and mobilize diverse communities.*
- *Engage faith leaders to foster trust in their communities and ensure that people understand the importance and urgency of public health and social measures.*

Key message:
Make preventive mental health a key element of future pandemic and epidemic preparedness.

Practical ways forward:

- *Strengthen the assessment of the mental/psychological impact of public health and social measures prior to their implementation and establish effective monitoring mechanisms.*
- *Strengthen the societal mechanisms and tools that preserve people's mental health and well-being, foster resilience, and realistic optimism across all levels.*
- *Raise the public's awareness of mental health and its role before, during and after a major epidemic/outbreak.*
- *Develop community-based mental health initiatives and programmes focusing on mental health training and education.*

"When it comes to the relationship between mental health and pandemics, we are not all in this together. Different groups are impacted differently. We need to be more proactive about mental health."

Dr Steven Taylor, Professor and
Clinical Psychologist
University of British Columbia

Key message:
Improve trust through effective communication between governments, citizens, and the scientific community.

Practical ways forward:

- *Health authorities to make meta-analyses of scientific information about COVID-19 and other infectious threats widely available and easily accessible to everyone.*
- *Governments and national authorities to adopt a unified scientific message and to move away from siloed responses to horizontal and integrated responses.*
- *Governments and national authorities to build robust strategies for communication and information dissemination through social media platforms and other modern communication channels.*
- *Health authorities to enhance health and digital literacy in the population, and address digital inequity.*
- *Health authorities to master infodemic management.*
- *National and local authorities to engage with communities early to inform pandemic-related scientific research, outcomes, and communication.*
- *Trust is built before pandemics. Peer-to-peer communication to be strengthened.*
- *WHO to hold roundtable discussions with the scientific community, policy makers, leaders, decision-makers and the public.*

"Epidemics begin and end in communities."

Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

2.3 Economy, infrastructure and systems

Key message:
Strengthen health systems for improved resilience.

Practical ways forward:

- *Strengthen nations' efforts towards Universal Health Coverage with emphasis on strengthening primary health care.*
- *Health Authorities to address systematic implementation of infection prevention and control.*
- *Countries to invest in a sustainable and resilient health workforce.*
- *Foster solidarity through national and international mechanisms (such as emergency medical teams) that can adapt and respond to crises without undermining other operations and services.*
- *Global health community to set up a global health protection fund to support countries with limited capacities for pandemic and epidemic prevention, response and recovery.*
- *Learn the lessons from COVID-19 as an opportunity to rethink health system governance, models and structures on local, regional, national and international level.*
- *Develop local public health capacity by engaging community health workers, NGOs and community leaders to strengthen future pandemic and epidemic response including contact tracing, and by implementing local public health and hygiene measures.*

"Solutions without sharing will bring us to the worst case scenario. "

Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

Key message:
Build efficient but flexible and resilient manufacturing capacity and supply chains that can react and adapt to disruption caused by future infectious threats.

Practical ways forward:

- *Strengthen local capacity by creating onshore, local manufacturing hubs and flexible supply chain networks.*
- *Countries to take a systems approach when identifying and managing risk. Leverage disaster management platforms for supply and logistic aspects of pandemic preparedness and response.*
- *Encourage agile production models and typologies (for example, for stockpile planning) that can be repurposed to respond to sudden surges in demand for PPE and other pandemic-related supplies and equipment.*
- *Empower local communities for local production of quality PPE.*
- *When creating new supply chains, protect human rights, promote ethical and transparent sourcing of materials and consider the overall environmental footprint of the supply chain network.*
- *Leverage the Pandemic Supply Chain Network (PSCN) to access supply chain networks and functionality.*
- *Leverage advancements in artificial intelligence (AI), machine learning (ML) and Computer Vision to boost supply chain innovation, augment human capabilities in manufacturing and to make systems and tools more resilient, adaptive and efficient.*

2.4 Technology and innovation

Key message:
Tap into the potential of emerging technologies to improve future pandemic and epidemic preparedness.

Practical ways forward:

- *Capitalize on current investments in global pathogen genomic surveillance infrastructure and in biotech innovations.*
- *Explore new therapeutics approaches for example, antivirals to prevent severe disease and death.*
- *Leverage advancements in nanobiotechnology and genome editing for future pan-viral prevention.*
- *Improve sharing of benefits stemming from health care innovation and research and development (R&D) across nations and regions.*
- *Strengthen biosafety measures globally and highlight that biosecurity equals bioprosperity.*
- *Leverage the benefits of biobanks and biodepositories to increase preventive capacity and improve the ability to investigate novel pathogens.*

Key message:
Maximize investment in training and future skills to improve pandemic and epidemic preparedness.

Practical ways forward:

- *Exercise public health and social measures for seasonal influenza epidemics and other respiratory pathogen outbreaks to inform capacity building and personnel training.*
- *Consider simulation exercises on a city level to identify gaps in training, skills and operations.*
- *Consider multilateral, multidisciplinary exercises and training programmes to build future skill agendas.*
- *Develop a global funding mechanism for health care and pandemic R&D to support research for global goods and increase research capacity in all countries.*

"Collaborative public-private partnerships are a critical tool to push the world towards the best-case scenario."

Ms Allison Neale, Vice President of Public Policy
Henry Schein, Inc.

Managing Director
Henry Schein Cares Foundation

2.5 Leadership and collaboration

Key message:
Foster multisectoral collaboration such as One Health for pandemic and epidemic prevention.

Practical ways forward:

- *Empower multinational organizations to collaborate with other agencies on pandemic preparedness on behalf of their sector.*
- *Build multidisciplinary taskforces and equip them with systems, platforms, funds and tools able to monitor, respond to and learn from infectious threats.*
- *Put mechanisms in place that allow for systematic implementation of lessons learned from multisectoral collaboration.*

Key message:
Establish a global and equitable approach to pandemic and epidemic management that benefits all.

Practical ways forward:

- *Consider the differential impact of current and future pandemics and other infectious threats on high versus low-income countries and share resources, tools and knowledge where necessary.*
- *Develop analytical models that consider contextual factors such as geopolitics, military tensions, conflict and civil unrest, and political instability and account for their impact on future pandemic preparedness and political instability.*
- *Collect and analyse successful interventions and build on them to define further best practices.*
- *Prioritize international support to marginalized communities and countries to ensure access to critical pandemic and epidemic-related supplies and countermeasures (for example, PPE, diagnostics, vaccines, therapeutics, etc).*
- *WHO to work with governments to understand pain points and to update pandemic preparedness guidance.*

Key message:
Create an environment of global multilateral collaboration, sharing and accountability with improved governing mechanisms for a collective and adaptive approach.

Practical ways forward:

- *Explore public-private partnerships with new stakeholders outside the health sector while encouraging respectful, action-oriented cooperation.*
- *Foster global data sharing and flow, as well as standard and insight generation.*
- *Create a global platform to support decision-making around data interpretation and communication, and consider different indicators to understand the risks of misinformation.*
- *Demand political commitment from governments and international multisectoral leaders to work collaboratively based on trust, honesty and transparency.*
- *WHO and countries to develop an international mechanism for timely sharing of data on pathogens and their genetic sequence with the aim to improve pandemic and epidemic preparedness and response aligned with the spirit of the Nagoya Protocol.*

3. Reflections on the exercise

3. Reflections on the exercise

It has been an incredible journey since the beginning of this foresight project in the spring of 2021. The exercise started in the midst of the ongoing COVID-19 pandemic and it intended to create an opportunity to think about future pandemics and epidemics in the next three to five years.

However, quite naturally at the beginning, our thoughts were hovering around the challenges at hand. In building future scenarios with the help of foresight professionals and a wide range of outstanding contributors around the world, many eye-opening thoughts, lived experiences and ideas were shared, and the project has benefited greatly from the chance to freely extend our imagination.

The four scenarios, each named after a popular song, played a substantial role in this exercise. As expected, they enabled us to think outside the box. The final roundtable discussants unanimously agreed that all four scenarios are plausible.

This report offers a treasure trove of many brilliant and powerful quotes. These gems need little interpretation. They speak volumes and resonate in our minds. It was rather easy to for us to extract the three key guiding principles of trust, equity and solidarity, and sustainable development, as well as the five key themes which define the areas of work that we collectively need to focus on.

What remains to be accomplished is to further develop a solid list of practical ways forward. This exercise has laid important groundwork towards this goal, and we can see some important high level and conceptual next steps. Based on this foresight exercise, future efforts will also require creative thinking to identify specific, concrete and actionable goals and plans.

'… the viewpoint of a cosmic spy satellite, which scans millennia rather than centuries… From such a vantage point it becomes crystal clear that history is moving relentlessly towards unity.'

This quote by Yuval Noah Harari (taken from his book *Sapiens*) rings true as we think about the future of pandemics and epidemics.

A pandemic is a symptom of the world and a reflection of the systems in which we are living.

By applying foresight and futures thinking, we create a chance to design and build the future we want, the way we want it. Not only for ourselves, but for generations to come.

The Project Team

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"We have our future in our hands. Choices we make over the coming months and years will determine the future."
Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

"Trust is everything."
Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

"Are we proud of the way we are handing this world over to the next generation?"
Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

"The double pandemic scenario is of particular concern."
Dr Michael J. Ryan, Executive Director
WHO Health Emergencies Programme

"Universal Health Coverage (UHC) and health security are two sides of the same coin."
Dr Tedros Adhanom Ghebreyesus
WHO Director-General

"Government commitments are extremely important."
Professor David Heymann
Professor of Infectious Disease Epidemiology
London School of Hygiene and Tropical Medicine

"Faith leaders have influence and can raise awareness. They can help people connect with their governments."
The Most Reverend Dr Stephen Kaziimba Mugalu
Archbishop of the Church of Uganda
Chair, Council of President, Inter-religious Council of Uganda

"In the context of worldwide contagion, the biggest contagion may in fact be misinformation as it prevents us from being able to make the right interventions and from working together."
Dr Seth Berkley, CEO
Gavi, the Vaccine Alliance

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Annex

Scenario 1: Happy Days

It is the year 2026. Humanity managed to get on top of the COVID-19 pandemic and the world is now a better place. Individuals, communities and the planet enjoy the widespread benefits of collaboration, focus, determination, community empowerment and hard work.

Key Assumptions

01 **Virus less potent, widespread natural or acquired immunity.**

02 **New COVID-19 treatment and prevention options offered at scale globally.**

03 **Low mortality rate, low risk of long COVID-19 symptoms.**

04 **New pandemics appear but they do not become a global health crisis.**

05 **Economies recover after a short pause.**

06 **Nations sign Infodemic Treaty to combat mis- and disinformation.**

07 **Access to health care for all is improved and there are broad societal benefits through improved global coordination and preparedness.**

08 **Technological and scientific progress and health care innovation are happening at a rapid pace.**

09 **Widespread climate change mitigation and adaptations slow down rising temperatures.**

10 **The world is working as one, humanity gets on top.**

Scenario Narrative

It is the year 2026. Six years have passed since the start of the COVID-19 pandemic and the world is now in a better place. Through collaboration, focus, determination, community empowerment and hard work, humanity managed to get on top of the pandemic and by doing so, yielded benefits for people and the planet.

Annual booster shots, combined with vaccinations for the flu, ensure that the mortality rate from COVID-19 is no higher than the mortality rate of other pathogens. The risk of long COVID-19 symptoms is significantly reduced. Strict public health measures are no longer required although robust mechanisms for diagnostics, surveillance, and case tracking are still in place nationally and globally.

Between 2021 and 2026, WHO managed to prevent several potentially threatening pandemics by utilising the lessons learned from COVID-19. In 2024, WHO's global surveillance system prevented the outbreak of another novel coronavirus in eastern Europe, quickly containing the outbreak and preventing international spread. A key focus has been improved global preparedness and empowerment, ensuring that even low-income countries and regions have domestic capacity to detect outbreaks, manage public health responses and deliver continuous vaccination campaigns.

Today, immunity against COVID-19, natural or acquired, is widespread. Worldwide initiatives aimed at equitable access to COVID-19 vaccines have been successful and vaccine distribution is affordable, efficient and local. Many countries, especially the most vulnerable, have added domestic manufacturing capacity, enabled by more equitable access to patents and better global distribution agreements and mechanisms for key ingredients and components. This has resulted in improved supply chain resilience and self-sufficiency. At the same time, new treatment and prevention options have emerged and are now available at low cost and at scale globally.
This is the result of rapid technological and scientific advancements and accelerated health care innovation.

In 2025, the second generation of vaccines managed to completely prevent virus transmission. Later vaccines, delivered in pill form, further enabled enhanced distribution, reach and affordability.

National health care systems improved their resilience, adaptability and overall capacity. Through increased support, organizations such as UNICEF helped countries which struggled during the period between 2019 and 2021 to better manage the pandemic.

The infodemic that accompanied the pandemic during the first two years of the outbreak is now largely under control thanks to globally coordinated and thoughtful efforts to regulate social media platforms. False information about the pandemic is effectively countered and nations and health care organizations operate based on coordinated common truth campaigns, with consistent scientific messaging and guidance. Community-driven initiatives around health care have reduced the impacts of social media networks in dominating discourse among sceptical interest groups and anti-vax movements. Younger, more tech-savvy generations, as well as community health workers played a key role in designing, implementing and evaluating public policies to combat the infodemic and shift public behaviour and community response. Following a period of criticism around government interventions, which included violations of human rights, trust between public institutions and citizens is largely restored.

Due to the COVID-19 pandemic and its impact on people and communities, preventive health care, tackling health inequality and the aspiration to

In 2025, the second generation of vaccines managed to completely prevent virus transmission. Later vaccines, delivered in pill form, further enabled enhanced distribution, reach and affordability.

provide everyone with equal access to health care are now at the top of most nations' agendas. This is coupled with significant efforts to understand and tackle intersectional inequality, and to eliminate disparities, resulting in more equitable societies. After a short pause during the first year of the pandemic, economies managed to recover, and global supply chains returned to a more stable equilibrium. Some economies even perform better compared to pre-pandemic levels. There was also an increased focus on domestic or regional production capacity to boost future resilience to shocks.

Although economic growth still is varied and region-specific characteristics remain, a widespread restructuring of production systems in high, upper-middle, lower-middle income and low income economies took place in the years following the pandemic. By adopting circular economy principles and by putting the planet first, nations succeeded in accelerating their actions towards the goals set by the Paris Agreement and the UN Framework Convention on Climate Change. The 26th UN Climate Change Conference of the Parties (COP26) that took place at the end of 2021 managed to secure ambitious 2030 emission reduction targets and many nations are on track to achieve net zero. Nations committed to phasing-out coal, investing more in renewable energy, accelerating the switch to electric vehicles and halting deforestation. The green recovery was aided significantly by government-led investment programmes focusing on climate change mitigation and on up- and reskilling initiatives. These aimed at future-proofing areas of the global workforce which are essential for the path to a safer, cleaner future. As a result, the world is now on track to limit global temperature rise to 1.5 °C by 2100.

None of the progress that was made following the COVID-19 outbreak would have been possible without a spirit of science-driven decision-making and strategic collaboration between nations. Strong international partnerships and multilateral coordination, effective links between local and national risk assessment frameworks, constructive dialogue between government, NGOs, businesses and civil society, as well as the sharing of knowledge and resources between countries resulted in robust global governance platforms, reduced nationalism, resilient and efficient supply chains and an environment where conflict and civil unrest is limited. In 2022, following a foresight initiative, WHO Member States signed a pandemic treaty aiming at better preparedness for future infectious diseases including interventions at local, regional and national level.

None of the progress that was made following the COVID-19 outbreak would have been possible without a spirit of science-driven decision-making and strategic collaboration between nations.

A Day in the Life: Let's go to work

Meet Zawadi, an office manager, on her morning commute to work in a world that - following the tough lessons of the pandemic - has learned to work together to build a better future.

Zawadi still wears a mask when she rides the bus. Every day. She doesn't have to, there's no rule saying she must anymore, but most people still do. It just feels courteous, like it's the right thing to do. She's not had a cold or the flu - not even a cough or a sniffle – for at least four years now. Plus it feels weird not wearing one; that jarring feeling like you've forgotten something personal and important, like leaving home without your purse or phone.

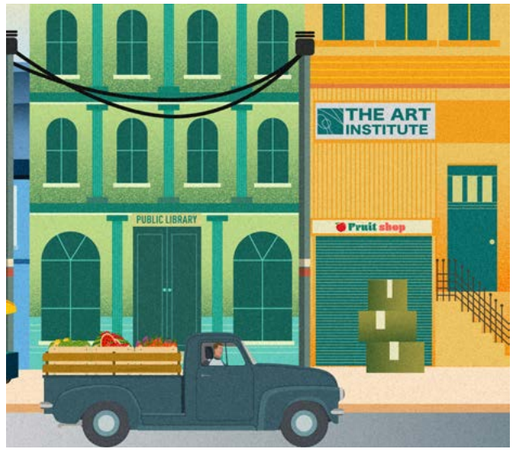
The bus is about two-thirds full of commuters, the streets outside about the same. Zawadi stares out the open window, her hair gently bouncing in the breeze. The city looks hot today, the reflected sun strobing off car windscreens and shop windows as the bus rolls past them on its near-silent electric engine, strong enough to make her squint. She tugs her phone from her jacket pocket, checks the weather forecast on its lock screen. Yeah, it's warm out, but not as hot as she imagined. UV is high, but the air quality is great, much clearer than the seasonal average. Zawadi shudders as she thinks back to the sweltering summers of just two or three years ago, where the sun struggled to push itself through the smog that always hung over the city, and the pavement felt like it was melting into the kind of sticky, black tar that could pull your shoes from your feet.

But things are better now. The heat is stabilizing, the news keeps telling her – this was the first summer in a decade that hadn't broken any temperature records, and the cloud of smog that permanently hangs over the city is starting to thin out. Partly this is because there's less people on the roads, fewer cars and trucks. If the pandemic had brought anything positive to the city it was the realization that it didn't have to force its whole self out into the streets every rush hour until it ground to a frustrated, paralyzed halt.

But Zawadi also knows there's something else going on, something bigger than just people working from home more – something playing out on a scale wider than just her city. The whole world was changing – faster in some places than others, sure, but with everyone moving roughly in the same direction, and in ways Zawadi couldn't have

imagined just five years ago. The world had seen the brink, got a glimpse of just how bad things could get, and how fragile they were. Somewhere amongst the chaos and the millions of sick and dead it had come together to demand better than 'the new normal', better than a return to the status quo, and a chance to clean up and rebuild in ways that didn't just work better, but felt more just.

Zawadi stares down at her phone, unlocks it with a swipe of her thumb, and starts to scroll. There was a long time when she couldn't even look at social media, where she had to delete the apps from her phone, add the websites to her block list. When she didn't it would take just minutes before the anxiety set in, until her jaw started to throb with stress and her temples felt like they were being crushed in a vice. Too much outrage and false information, too much anger and hatred. But like everything else, that was changing too. The biggest social media platforms had been transformed and increasingly decentralized so that now Zawadi's timelines felt more welcoming, more intimate – people she actually knew, things she actually wanted to read or watch. Soccer scores from last night. Recipes for food she might actually make. Friends dancing and grinning in bars and clubs. Photos of dogs dressed as pop stars. She giggles. It still all seems like a meaningless distraction, but at least in ways she wants to be distracted, and on a scale she can handle and control herself; no unseen algorithm desperate to steal her attention through any means it can.



At her stop she hops off the bus, ducking into the shady side of the street for the last few blocks' walk to her work. She passes a delivery driver wearing one of those new spindly, robotic exoskeletons, and watches him effortlessly lift huge boxes from the back of his truck. Parts and components for one of the repair shops that sprung up during the worst of the supply chain crisis, she imagines. She notices the logo on his t-shirt, realizes he's a gig worker, but for one of the platform co-ops that organized after the pandemic ended. It seemed revolutionary at the time, all the workers came together and forced the big brand companies to improve pay and conditions, to guarantee them hours and benefits. Hence the shiny new exosuit, Zawadi guesses. She remembers her time trying to scrape a living during lockdown, delivering food and packages to those that could still afford them, and just the memory is enough to make her lower back groan in pain.

She gently rubs it as she steps into the foyer of her workplace, thinking about the packages she used to deliver and how she came here less and less as the lockdowns dragged on, and it started to empty out. An army of boardroom warriors left, never to return to their battlefield, as whole floors of the skyscraper were left abandoned. She remembers staring down empty hallways lined with grey carpet and white ceiling tiles, tendrils of unused network cables exploding from hastily evacuated desks.

Somewhere amongst the chaos and the millions of sick and dead it had come together to demand better than 'the new normal', better than a return to the status quo, and a chance to clean up and rebuild in ways that didn't just work better, but felt more just.

Now the building is full of activity again, and as Zawadi takes the elevator up to the twentieth floor she can almost feel it reverberating with the buzz of light industry, its purpose shifting as the economy around it reinvents itself. Heading to her office she pauses to look through a window into the production line; the constantly spinning centrifuges, the white overall-clad workers, the endless procession of thousands of vaccine vials shuffling along conveyor belts like the crowds that used to flood the city at rush-hour. On this and the next three floors it is vaccine and pharma production, two further floors up it's PPE, masks, and other medical supplies. And filling the gaps between all of them a dozen or so micro factories, semi-automated production lines able to churn out small runs of whatever might be needed that week, from pens and paperclips to electronic components and machinery parts. Anything and everything that for decades they'd been reliant on factories two continents away for, now made right here, so that the city never gets caught out again.

Zawadi drops her bag at her desk and starts to head to the kitchen to grab a coffee, but decides to check her email first. Good job too. Her inbox is full of urgency; a new coronavirus strain emerging in Europe has been formally identified by the WHO network. Even though there's only been a handful of recorded cases so far, the global co-operative that manages pharmaceutical responses has already tweaked not only an existing vaccine but also a whole suite of antiviral medicines to counter it. The email even has details of how to access inexpensive rapid tests that can spot the new variant. Five years ago this city would have had to wait months to see even a single vial or testing kit, as they sat unused and decaying in the warehouses of other, richer places. Right now the instructions for how to make this one are sitting in Zawaldi's inbox, before the city has reported a single case. She sighs, forgets about the coffee, stretches her back, and starts to download and forward PDFs to the production line managers. Time to get to work.

Scenario 2: I Love You, I Hate You

Six years after the COVID-19 outbreak, the virus, through multiple mutations and unpredictable, uncontrolled outbreaks, manages to persist and become part of our lives. Humanity keeps up, but the long-lasting impacts of the pandemic on health care systems, economies and the environment start becoming increasingly visible across the world.

Key Assumptions

01 **Protracted pandemic with continuous virus evolution.**

02 **Immunity levels vary depending on age group and health status.**

03 **Vaccines are playing catch-up, but efficacy levels are high, and access is widespread.**

04 **Stricter elimination and mitigation public health measures are implemented based on season and/or regional strategies.**

05 **Some health care systems adapt well to the surges of the virus, but others struggle, creating a backlog of treatment.**

06 **Trust in governments and public institutions varies significantly across different parts of the world.**

07 **Health care innovation is happening at a rapid pace, but diffusion of benefits is limited to certain nations and regions.**

08 **Economies worldwide experience a mid-term pause, with some of them recovering only partially.**

09 **Climate change mitigation remains sluggish and extreme weather events become more frequent.**

10 **Humanity (just about) keeps up.**

Scenario Narrative

The year is 2026 and COVID-19 is still here and evolving. The pandemic persists through unpredictable local and regional outbreaks, as well as ongoing incremental mutations caused by herd immunity or sub-optimal vaccination rates in some parts of the world. COVID-19 has become a permanent part of our lives.

Humanity has gradually learned to live with the virus, albeit still clinging to pre-pandemic behaviours. Immunity and vulnerability levels vary depending on age group and health status. Variants of Interest (VOIs) and Variants of Concern (VOCs) keep appearing with increased frequency across different geographies. Since the first generation of vaccines is no longer effective, a seasonal, influenza-like approach is now in place with efficacy levels varying from season to season. Signs of vaccine nationalism are present but do not significantly affect vaccination initiatives. Alongside vaccines, other prevention and treatments options are also developed and provided in most parts of the world, although equitable access is not always possible. This is due to the persistent lack of a global regulated framework for vaccine and treatment distribution. Oversupply distribution of vaccines to countries with limited supply is happening slowly. Globally, mortality rates are low across high income regions but vary significantly elsewhere. The risk of long-COVID symptoms is present across all age groups and poses a considerable public health concern. Remote working models and continued physical distancing persist.

In the period between 2021 and 2026, WHO managed to prevent several potentially threatening additional pandemic outbreaks. This was a result of the ongoing battle with the COVID-19 pandemic, which also resulted in an increase in stricter public health measures, both aimed at mitigation and elimination. Locally and nationally, diagnostics, surveillance and tracking are performing well, with widespread use of testing kits, rapid detection and contact tracing. Affordability and reliability of rapid tests are still an issue.

Efforts to tackle health illiteracy are underway in many nations with health courses introduced in schools. However, regional, or global cooperation remains limited, resulting in insufficient sharing of information and know-how. Movements of people between urban and rural settings within countries poses a challenge on the capacity of infrastructure systems to cope. Production of Personal Protective Equipment (PPE) and Polymerase Chain Reaction (PCR) testing is still highly centralised and access is directly linked to a nation's purchasing power.

In some regions, health care systems adapt well to the continued surges of the virus, but others struggle, particularly with staff shortages and a growing backlog of treatment. Governments around the world, through meaningful engagement with younger generations, are performing well in containing mis- and disinformation surrounding COVID-19. However, some groups, platforms and regions still generate waves of false information every time a new variant appears. Trust in governments and public institutions varies significantly across the world, with citizens in some countries attributing the protracted nature of the pandemic to the inability of their leaders to make rapid, informed, and inclusive decisions. Demonstrations and civil unrest are a common phenomenon that nations struggle to contain.

With the pandemic ever present in the public discourse, high income nations take action to battle health inequalities. However, low and lower-middle income nations struggle to manage the protracted nature of the virus and see significant health and intersectional inequalities. A similar pattern is visible in the field of health care innovation (CRISPR technology for instance) and digital health; it is happening at a rapid pace, but its benefits are limited to certain nations and regions. Technological advancements in the fields of Virtual Reality (VR) and Augmented Reality (AR) are used to accommodate the increasing needs of a world where the boundaries between digital and physical environments are blurred with hybrid ways of working, meeting and learning becoming the norm.

The persistent nature and long-term economic burden of COVID-19 has forced economies around the world to maintain a defensive stance. Occasional lockdowns, lack of solidarity between nations and some increased economic protectionism paint a socioeconomic landscape characterized by disparities. This resulted in a mid-term global economic pause after which some economies could only partially recover.

In some countries and regions, health care systems adapt well to the continued surges of the virus, but others still struggle, particularly with health care staff shortages and a growing backlog of treatment.

Economic recovery has not necessarily meant a radical rethinking of production systems. Reliance on fossil fuels continues and deforestation has not met desired targets. Although ecosystem degradation shows signs of slowdown, diminishing biodiversity plays a key role in the emergence of new pandemics. Extreme weather events are frequent and intense.

Although political systems show signs of fracturing, global cooperation is somewhat effective but public-private partnerships are only strong in some regions and the role of the private sector in managing the pandemic globally is not entirely clear. Some private institutions and pharmaceutical companies dictate the public policy and decision-making agenda. The African region displays impressive regional efforts in managing the pandemic and intraregional solidarity is remarkable. Other regions do not enjoy the same levels of collaboration and lack equitable access to supply chains.

Reliance on systems and approaches partly responsible for the inadequacies in the public health response during the first two years of COVID-19 seem to justify the state that the socioeconomic landscape has come to. This includes loose regulations, lack of transparency in international relationships and global partnerships, prioritisation of economic power instead of pandemic vulnerability, lack of preparedness and accountability, binding commitments and decisive implementation.

During this prolonged period of COVID-19, the world is experiencing fatigue. Humanity is only just about managing to maintain a fragile balance within which it keeps up.

A Day in the Life: Unevenly distributed

Meet Maria, a history professor adapting to new ways of working and teaching in a world still coming to terms with the pandemic.

The lecture hall is about a third full, at a glance. It reminds Maria of giving classes back during the pandemic, standing in her tiny kitchen, an improvised green screen pinned to the wall behind her, as she spoke to a monitor full of empty black squares. Each black square a student, their video feed off, their once familiar faces fading from Maria's memory.

It was tough back then, standing up and talking for a full hour to an empty kitchen, the only feedback coming in in the form of an occasional question or comment in the chat feed. She wasn't sure what she hated more – the emojis that stood in for acknowledgement in the same way the disabled video feeds stood in for faces, or the fact that she found herself craving them, each simple cartoon heart and thumbs up standing in for some sense of validation and connection.

It's easier now, but not always by much. Today is a good example. Maria double taps the side of her glasses and the interface instantly fades back in, and most of the empty seats start to fill with avatars. She's always – even now, a few weeks into the semester - a little bit overwhelmed by their sheer variety at first, but she's starting to understand what they represent, why there's so much inconsistency between them. Some appear as photorealistic avatars cosmetically tweaked to celebrity perfection, others flaunting the college's rules by presenting themselves as video game or cartoon characters. And then there's the rest of them, manifesting as nothing more than identical, translucent, motionless mannequins – the new equivalent of the empty black windows, like creepy human shaped vessels waiting to have identities decanted into them. For some the anonymity is a choice, one Maria can't fail to understand or respect, while for others it's circumstances outside of their control. Maria watches some of them glitch in and out of existence, and finds herself imagining them hunched over laptops in their distant, crowded homes, trying to share a low bandwidth connection with the rest of their family, or nervously nursing a glass of water as they leech Wi-Fi in coffeeshops where they've outstayed their welcome.

Maria sighs, waiting for the class to settle down. It's better than being back in the kitchen, she whispers to herself. And it is, at least for the students that have made it here in person, or have fast connections in peaceful homes. It's this divide that worries her the most – even just a few weeks into teaching she's starting to feel the disconnect between the remote kids and both her and their in-person classmates. The latter are more engaged, more involved – ask more questions, start more discussions. For a start she can remember most of their names just like that, without having to blink at an avatar and wait for it to be revealed, floating above their head.

And things are better, she reminds herself. During the height of the pandemic she'd try and avoid the news headlines in order to stop the anxiety and worry suffocating her; now she finds herself seeking them out for reassurance. Mortality rates are low across the board, and governments everywhere are working with WHO to keep on top of infections and outbreaks using reliable data. Economies are picking up again, travel is opening up, and a lot of countries - like Maria's – are making real strides to close the gap on healthcare and income inequality.

But she knows that's not the case everywhere, and the rate of progress into this new future isn't evenly distributed. She knows that if she pulls up a class roster and checks where the remote students are from then the familiar patterns will start to emerge – the kids with fancy avatars

could be from anywhere in the world, but more often than not it's some big city with a high-tech economy. The rest of them – the ones with the low polygon counts and even lower bandwidth – will be from places more depressingly familiar. Countries where they're still waiting to get the latest approved vaccines, meaning even if they could get here, they'd not be allowed on campus. Countries where infection rates are so high, and new strains so common, that they're still on the no-travel list. Regions where the politics became so messed up that they don't officially believe the pandemic even happened, or refused to ever re-open their borders. Places hit so hard by supply chain problems that you can't even find a decent laptop or phone, let alone the latest VR/AR gear. Last semester half of Maria's class just vanished for six weeks when the climate storms rolled in, and half a dozen anonymous datacenters were lost to the flood waters.

It's this divide that worries her the most – even just a few weeks into teaching she's starting to feel the disconnect between the remote kids and both her and their in-person classmates – the latter are more engaged, more involved – ask more questions, start more discussions.

Maria sips the last of her cold coffee and steps up to the lectern, the cameras dotted around the walls and ceiling of the hall twitching and turning to focus on her. The college had spent a lot of money on getting the campus updated for this brave new world – Education 3.0, the Dean insisted on calling it – but they hadn't had much choice. Overnight the college's intake of foreign students had vanished, and with it most of its income. They had two choices – lean heavily into remote learning, or go bankrupt.

Like a lot of her faculty colleagues she had doubts about it all – from how the money had been shared out between STEM and arts courses, to which tech companies the college had got into bed with to get all this gear, and how they were paying them back with their students' private data. But Maria tries to not be too cynical – the tech mostly works, and much better than the disparate systems they had to scramble to use during the first lockdowns. And the students are here – whether virtually or in person – and getting an education, however imperfect it might sometimes feel.

Maria touches the air with her fingers, drilling through menus that float in her peripheral vision, and air-types login credentials. Windows unfurl in the space behind her, as high as cinema screens – today's presentation. But before she can even launch the first slide - before she can even open her mouth to speak – a low chime rings out across the colleges PA system, and the virtual screens behind her start to fill with text, red and white on ominous black backgrounds.

HIGH FLEX ALERT
IMMEDIATE SUSPENSION OF ALL IN-CLASS TEACHING

Due to the detection of a WHO designated Variant of Concern, all on-campus learning and gatherings are immediately suspended until further notice. All students and staff (not including Priority A designations) most report immediately to their allocated rapid testing center, before vacating campus.

YOU MUST NOT RETURN TO CAMPUS UNTIL FURTHER NOTICE

Failure to comply can result in disciplinary action.

Classes will continue as normal, as per fully remote contingency plans. Check departmental websites and social media for details and further updates.

Maria sighs and reaches up to touch her glasses, but most of the avatars have vanished before she can even take them off. She packs up her bag as she watches the in-person students file out, thinking she'll wait a while for the corridors to quieten down before she goes and joins them in the lines for a rapid flow test. And then? Well, then it's back to class, back to the kitchen.

Scenario 3: Heartbreak Hotel

The virus has evolved to become even more infectious. Nations across the world react in different ways, and the lack of a global, unified front against the pandemic results in a two-speed world characterized by increasing socioeconomic, technological, environmental and political disparities.

Key Assumptions

01 **The virus evolves to become even more infectious; human transmissibility levels record new highs.**

02 **New variants emerge, vaccines lose efficacy.**

03 **COVID-19 causes a wider symptom range and wider age brackets are impacted; long COVID rates increase.**

04 **Diagnostics, surveillance and tracking vary significantly in quality and reach across nations.**

05 **Health care systems globally struggle to keep up with the surge in infections.**

06 **The infodemic surrounding the pandemic is once again thriving and hard to control.**

07 **Economies are suffering the consequences of long-term pauses; recessions and economic hardship increase.**

08 **The fight against climate change is not yielding the expected results and the pressure to adapt increases.**

09 **Regional and cross-country cooperation is inconsistent, with only selective support and cooperation.**

10 **Collective failure, humanity plays catch up again.**

Scenario Narrative

The year is 2026. The COVID-19 pandemic is not over, and the virus has evolved to become even more infectious. Human transmissibility levels record new highs. New, more threatening variants emerge frequently leaving vaccine manufacturers struggling to keep up. Equitable vaccine access initiatives such as COVAX do not meet their desired goals as high income nations redirect their production capacity to domestic booster shots.

Despite significant investments, no widespread and fully effective treatments for COVID-19 have emerged. New variants cause a wider range of symptoms and impact a wider age bracket, especially in countries and settings where the vaccine uptake is not high.

Long COVID symptoms are the norm for almost everyone who gets infected, putting a significant strain on economies, productivity and health care systems. Society is increasingly fearful of the virus while being hesitant about vaccines. A broader range of people are shielding, refraining from social contact and not fully engaging in society. Pandemic fatigue and mental health issues are on the rise and the world feels like it is in constant crisis mode, balancing the impacts of COVID-19 with other health risks, including child and maternal health, economic hardship, transgenerational trauma and the rapidly increasing impacts of climate change.

After almost five years of a rapidly evolving pandemic, different nations choose to focus their efforts on different fronts. Some countries prioritize the increase of stricter elimination and mitigation public health measures, some focus their efforts and financial investments on strengthening their haemorrhaging national health care systems, which struggle with staff and equipment shortages and a significant backlog of critical and non-critical treatment. Others make significant investments in health care innovation but without diffusing the benefits widely.

Globally, societies increasingly struggle with the infodemic that continues to accompany the COVID-19 pandemic. It is now thriving along with growing civil unrest and discontent. Multiple platforms and groups generate and spread false information about COVID-19 and its evolution, causing confusion and contributing to an increasing lack of trust between citizens, their governments and public institutions. Heavy focus lies on domestic political priorities with some political leaders promoting the divergence between science and politics and working against the scientific consensus. The sharing of complex, evolving information is not happening in a clear, inclusive, or accessible way, resulting in increasingly polarized behaviours.

Vaccines are the only treatment and prevention option but access to them depends on the region and country. A large part of the global population is still unvaccinated, vaccine nationalism and vaccine distribution bias against key minority groups are on the rise. Overall, regional and cross-country collaboration is fragmented with selective support and cooperation. As a result, the sharing of information, data, technology, licences and resources between nations and regions is limited with an obvious, negative impact on the widening health inequalities and intersectional inequalities within and across countries and regions.

The efficiency of public-private partnerships is under question and global supply chains are driven only by political influence. Although adequate scientific research was conducted prior to the COVID-19 pandemic, it was not used effectively in the years that followed the outbreak. What is more, the world is suffering from the lack

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of a unified front to battle the worsening climate emergency – ecosystem degradation is happening at an accelerated pace and extreme weather events occur with increasing frequency and intensity. WHO and UN are no longer a forum of transparent discussion and collaboration.

Many countries are not able to achieve their net zero targets within the desired timeframes, while others completely abandon their commitments and choose to focus on managing the pandemic and salvaging their economies. Conflict-laden countries and regions experience new, higher levels of unrest with some, but not enough, global intervention and support. The world wants to work as one but shifting priorities and lack of strategic collaboration result in a highly fragmented landscape of global governance. Trust in WHO and its neutrality is dissipating, undermining the Organization's ability to form a global alliance.

Many countries are not able to achieve their net zero targets within the desired timeframes, while others completely abandon their commitments and choose to focus on managing the pandemic and salvaging their economies.

A Day in the Life: Retail anxiety

Join Marc, an unemployed hospitality worker turned full-time caregiver, as he tries to track down groceries and supplies for his long COVID stricken family.

Marc keeps his eyes forward as he slowly edges the car through the crowd of protesters. Head front, avoid eye contact. That's the golden rule. It doesn't stop the protestors from slapping the car though, each hit on the roof or the windows fraying his nerves, making him flinch. At one point a woman hits the driver-side window so hard that he can't help but snap his head round to look, and instantly regrets it. Past her contorted, screaming face he sees something far more unsettling – a glimpse of black metal in the crowd, a large-set man in combat fatigues studded with patches and flags, the unmistakable bulk of an assault rifle cradled in his arms.

Marc looks away instantly. Head front, avoid eye contact.

Eventually the hammering on the roof and windows stops, the crowd parting to let him slip through. One of the store's security guards – barely a kid, looking frayed and exhausted – waves him through the security gate, not even glancing at the vaccination card Marc flashes at him through the windshield.

Marc doesn't have any trouble finding a parking spot right near the superstore's entrance – past the chaos of the protest, the lot is basically empty. Walking to the door he pushes his hand into his pocket and pulls out two heavily crumpled items – the first is a counterfeit N95/FFP2 mask, a few days past its best. He puts it on. The second is his shopping list, which he just puts back in his pocket without even looking at it. He knows what's on it, he's been staring at it for days. He tried six places yesterday, and this is the third today. It took him over an hour to dive here. Maybe this time he'll get lucky.

His heart drops when he gets inside though. It's the same story as before – the store looks like a riot just rolled through it. The floor is dirty, there's random debris and packaging materials scattered in the aisles, and even without venturing too far in, Marc can see that so many of the shelves are empty. It's also eerily quiet, as empty of customers as the parking lot is of cars. The official reason from

the store's owners is that everyone is shopping online due to the continuing lockdowns, but Marc isn't convinced. He thinks a lot of people have just given up. Plus ordering online is just as unreliable as coming to the store – in some ways it's even more frustrating, endlessly scrolling lists of things you need or want, all sitting there with their little photos and customer reviews – but all marked Currently Unavailable in red text. The last two times Marc found stuff in stock online it never got delivered, and he just wasted another afternoon arguing with anonymous chatbots about getting a refund.

If the news and stories he reads online are to be believed – and he seriously doesn't know what should and shouldn't be anymore – any new stock that arrives at the big online retailers just gets bought up by scalpers instantly. A whole dark supply chain existing in the shadows of the infinitely complex legitimate ones, networks of scalpers using bots and algorithms to find any new stock the nanosecond it appears. Someone described it to Marc recently as an arms war – rival gangs of black marketers using competing AI programs to try and beat each other to any shipments that manage to make it through the congestion at the ports and distribution centers. He read an article last week claiming that the bots being used for this were being created by the same coders that used to write high frequency trading algorithms for hedge funds. He has no idea if it's true, but somehow it sounds likely. But then, so many stories do now, even the weirdest ones.

And anyway, if Marc is honest with himself, one of the reasons he likes shopping in person as opposed to online is that it gets him out of the house. He half-laughs to himself as he thinks this,

Marc doesn't have any trouble finding a parking spot right near the superstore's entrance – past the chaos of the protest, the lot is basically empty.

but it's true. Things are tough at home. Tough and exhausting. He's been caring for his mum and uncle for nearly two years now, their long COVID symptoms apparently unending. It's left the former bed-ridden, and the latter with what looks a lot like early onset dementia. And it's very early – his uncle is barely in his 50s. And then about nine months ago his sister and her three kids moved in, after she lost her job and they got evicted. The eldest one cries all day, the youngest cries all night. As depressing as all this is right here, he's secretly happy to just get a break from them all.

He's two thirds of the way around the store's aisles when he decides to give up. They haven't got any of the stuff he needs. No painkillers, no diapers, no toothpaste, no cleaning products. Certainly no masks. They've not even got that candy his mum likes. Maybe it's the supply chain disruptions, maybe it's the scalpers, maybe it's the internet driven panic buying. Maybe it's all three. Who knows? He read a post in a private social media group last week claiming that panic buying was the prime culprit now, and that it's being driven by manufacturers and retailers, using bot networks to whip people into a frenzy. It sounded like another harebrained conspiracy theory, but staring at the empty shelves now he's not so sure. Nobody can be making money from this, he thinks, and the companies and corporations must be getting as desperate as their customers.

Out in the car he sits for a while, briefly relishing the quiet and solitude, until he finds himself sobbing uncontrollably.

When he's finished, he composes himself, tries to decide what to do. He could give up, head home. But the thought of coming back empty handed, of having to try and explain it again to his uncle and sister, haunts him. Reluctantly he pulls his phone from his pocket, logs in to the private social media group again, and scrolls until he finds the post he saw this morning. He taps the link, and lets it open up a map.

The drive takes 40 minutes, and he spends every one of it furtively glancing at the fuel gage, freaking out that he might not have enough gas to get home. Filling the tank yesterday was a long enough struggle, he doesn't relish yet another wild goose chase.

When he finally reaches the scalpers' market its pretty much as described in the post, to his relief. It's at yet another abandoned strip mall, in the underground parking garage of a department store chain that went bust during the first lockdowns. He has to park the car outside and walk down the service ramp, and inside it's busy. More shoppers than he's seen at a legit store in months. And certainly more stock.

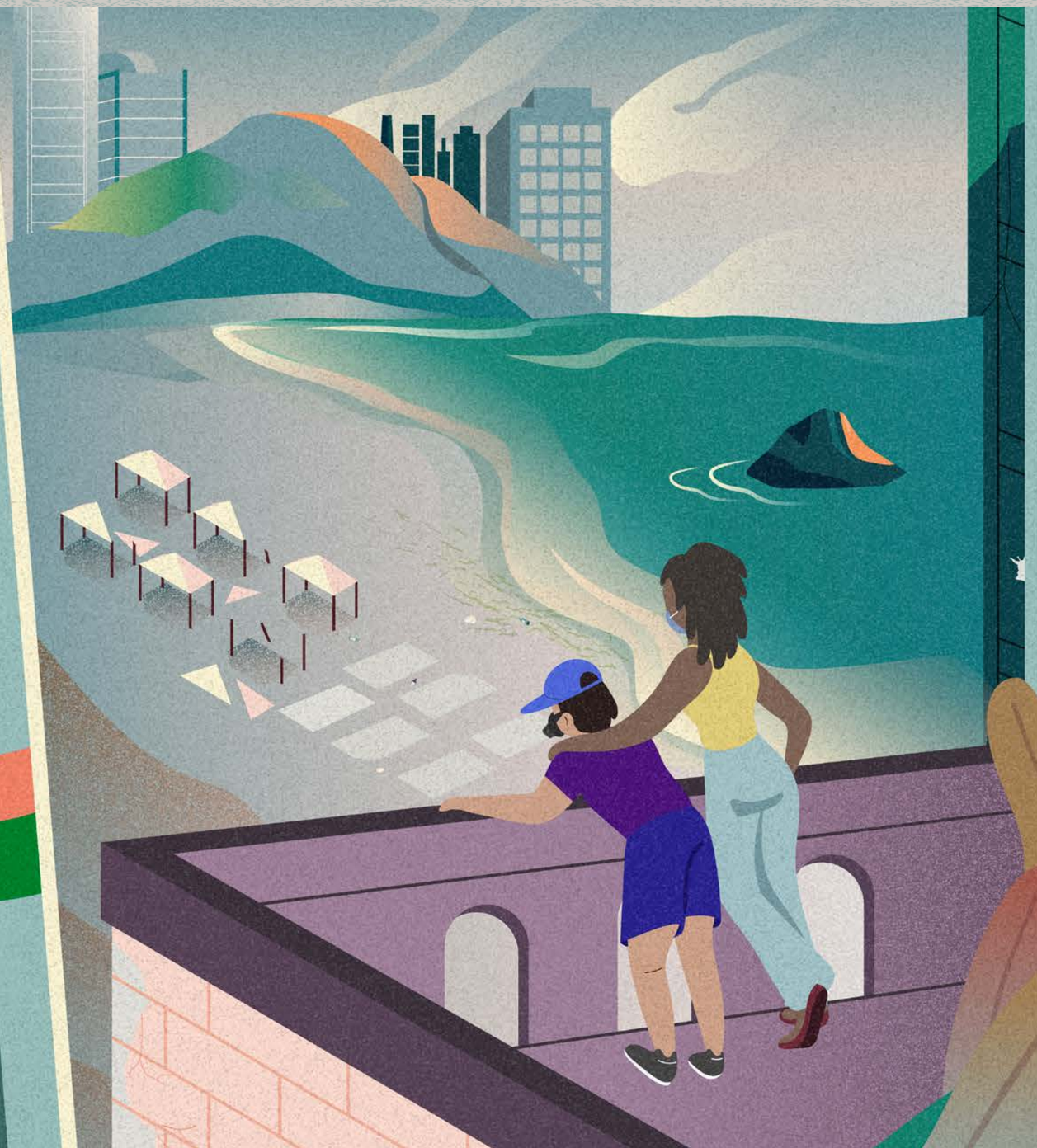
He can't quite believe it at first. It's all here. Pallets of toilet paper, rubbing alcohol, baby formula… stuff he's not seen for months, stacked up to the ceiling. Guys running little stores straight out of open shipping containers, boxes of everything from coffee to smartphones piled up behind them. He suddenly feels like a kid at Christmas, overwhelmed by the choices on offer. He starts to grin behind his mask.

And then he sees the prices.

He stops dead in his tracks, feeling like the floor is falling away from beneath his feet. He thrusts a hand in his pocket, pulls out the crumpled shopping list again, and drops it to the floor. Tries another pocket and pulls out more crumpled paper - a handful of banknotes. Cash only at the scalpers market, as the angrily scrawled sign at every stall points out. He stands there for two long minutes, counting what he has, flattening out the crumpled notes, making desperate calculations in his head. Just enough to buy some painkillers, one pack of diapers, and a tube of toothpaste for the whole house to share. All at a 400% mark-up. His mum's candy will have to wait.

Scenario 4: Here Comes Trouble

In addition to a worsening COVID-19 pandemic, a new pandemic emerges. Nations are unable to handle the additional burden of a double pandemic. Public health measures are contradictory, national economies collapse, ecosystem degradation accelerates, extreme weather events are frequent and intense. Humanity is exhausted and struggles to manage.



Key Assumptions

01 **Another pandemic emerges, in addition to a worsening COVID-19 pandemic, with distinct regional characteristics.**

02 **Some vaccines seem to be working while others are not. Access to vaccines depends heavily on income and citizenship.**

03 **Tropical zones are first to suffer the impact of a double pandemic as new Zika strains render the COVID-19 public health response ineffective.**

04 **Diagnostics, surveillance and tracking systems struggle to cope with two pandemics at the same time.**

05 **The double pandemic threat has left many health care systems in peril, with low resilience and a growing backlog of treatment.**

06 **Efforts to tackle health inequality and intersectional inequality are severely hindered.**

07 **Economies globally experience a protracted pause, leading to eventual collapse for some.**

08 **Tackling the climate emergency is no longer at the top of many nations' agendas.**

09 **Breakdown of global collaboration coupled with severe conflict and unrest.**

10 **Humanity struggles to manage.**

Scenario Narrative

It is the year 2026. Everything that could go wrong with COVID-19 has gone wrong. In addition to a worsening COVID-19 pandemic, the world has experienced an outbreak of a new disease. The second pandemic, caused by a Zika-like vector-borne virus established in mosquitos, is expressed through multiple, regional outbreaks which are geographically restricted, but place a large part of the global population at risk. Although the new virus is hard to detect early and its symptoms are mild, the risk of congenital malformations, complications of pregnancy and neurological complications is increased. Nations struggle to establish public health measures that do not contradict each other and there is widespread confusion around how to protect populations from this double pandemic.

This double pandemic has distinct regional characteristics. In Africa, for example, where Zika-like viruses have already been present for decades, WHO has put in place response systems, frameworks and infrastructure. However, additional pressure from terrorism and regional conflict renders the overall public health response ineffective. For less vulnerable regions, the new pandemic presents only a seasonal threat, yet the worsening COVID-19 pandemic continues to consume time and resources.

With governments proving incapable of effectively leveraging early warning systems or providing clear, scientific, and consistent guidance, the lack of trust between citizens and public institutions reaches a new high. Most individuals choose alternative sources to inform themselves about the double pandemic. Science is heavily politicized, with intentional and unintentional political missteps frequent. While there is a widespread commitment to return to business as usual, willingness to fundamentally change the conditions that led to the double pandemic are absent. As a result, misinformation dominates the public dialogue and social media, resulting in highly divided societies. Continuous lockdown measures have a significant impact on local and national economies. Nations hoard resources and capital. Solidarity is limited and protectionism rises. While for some high income countries the impacts of the double pandemic are merely destabilizing, for low income countries they become an existential threat.

Most countries impose strict movement, travel and border restrictions. As a result, the aviation industry collapses and related sectors follow suit. Countries that depend heavily on international tourism suffer catastrophic recessions and there are severe implications for population movements and migration away from equatorial climate zones to avoid exposure to mosquitos.

Some economic sectors manage to adapt by leveraging lessons learned during the first two years of the COVID-19 pandemic. However, city centres experience another period of reduced activity and remote work is once again the norm. Office spaces remain empty, triggering a real estate crisis which has knock-on effects on other sectors. Schools also remain closed for prolonged periods and lessons across all grades take place in virtual classrooms.

City authorities reconsider their spatial typologies and overall operations to respond and adapt to the challenge of the double pandemic. Policies aim to encourage and accommodate increased active travel, reduced traffic and footfall, and flexible use of indoor and outdoor spaces. Economic fallout leads to strikes and demonstrations which leave city centres ravaged. At the same time, low-risk zones witness waves of immigration, which put pressure on their systems and infrastructure, catalysing conflict.

Health care systems around the world are unable to cope with the surge in cases of COVID-19 and the new virus. There are staff shortages, lack of equipment due to market failures and a growing backlog of treatments. The impact on mental health and well-being is profound. Vaccine rollout has been compromised by the massive mosquito control efforts. New variants of COVID-19 show low susceptibility to vaccines.

The health and intersectional inequalities that were brought to the fore at the outbreak of COVID-19 are now more pronounced, with widening gaps and disparities. Although ecosystems benefit

from the slowdown in human activity and consequent reduction in carbon emissions, overall environmental degradation is accelerating and the risk of new pandemic diseases is increasing. Species go extinct and those that tend to survive and thrive (rats and bats for instance) are more likely to host potentially dangerous pathogens. While the climate change agenda intersects with epidemic control, government responses around the word are focused on defensive, emergency measures that deprioritize measures aimed at tackling the climate emergency. Extreme weather events are frequent and intense leading to humanitarian crises. Coupled with the disruption of supply chains, some nations suffer from food insecurity and malnutrition. Conflict occurs more often.

Countries that depend heavily on international tourism suffer catastrophic recessions and there are severe implications on people movement and migration away from equatorial climate zones towards low-risk zones to avoid exposure to mosquitos.

In this dire landscape, some see an opportunity to capitalize on global fear and uncertainty, and populism and nationalism are on the rise as surveillance state types emerge. However, activism and civil society also strengthen, with community-led initiatives to improve behaviours and risk assessment at the individual level. These have a positive impact but are not enough. Overall, community resilience is low due to pandemic fatigue. Tolerance to yet another set of restrictions is also low. Active boycotts, threats to scientists and health professionals and burnout of health workers are common.

The world is tired, collaboration between nations is fragile and local partnerships are limited. Low compliance with international agreements for health regulations is widespread, apathy and lack of solidarity is now considered normal. Many of the negative trends and outcomes observed during the double pandemic such as insecurity and instability, lack of trust, reduced health care capacity, hindered public health response, supply chain disruption, and conflict and civil unrest feed one another, resulting in a vicious feedback loop. Humanity struggles to manage.

A Day in the Life: The wrong way

Follow Amir, a gig-economy delivery driver, as he attempts to navigate a heavily balkanized city in an increasingly fractured world.

Amir helps one of the warehouse workers load the last few packages into the back of the van. He remembers when this micro-distribution center used to be a noodle place - like a lot of places it had barely survived the COVID lockdowns, and by the time the new Zika-like outbreak rolled through, the owners sold it to the big online retailer that had been buying places up all over the city.

He coughs as he stands up straight, wheezing into his mask, and the guy from the distribution center shoots him a concerned look, throws his hands up and backs away. Amir brushes him off with a wave, says its fine, and climbs into the van. He pulls off his mask and checks his face in the rear-view mirror –sweat forming on his forehead, swollen lids above bloodshot eyes, clammy beads of sweat collecting on his forehead. "You're fine", he tells himself, "you're just tired, been working too hard".

He pulls the unmarked jar of pills out of his inside jacket pocket, and swallows three with the flat, lukewarm dregs of a day-old can of soda. Amir has no idea what they are, just some anonymous tablets he bought off a guy in his building, who said he got them from his cousin, who he claims is a vet. Cow pills, he called them, but they work super well on humans. "Get your temperature down, get you through the checkpoints. It's what the cops use". He stares into the mirror again, straight into bloodshot eyes. "You're just tired. Need a day off".

Well, it won't be today. He's barely started the van up and the app is already nagging him, his phone projecting a map onto the inside of the windscreen as it reels off locations and target times. Going to be tight today, but then it always is.

The first checkpoint is a breeze, but then he's going the right way. Or should that be the wrong way? Depends who you are, Amir thinks, like so much in this city. He's exiting an Amber zone for a Red zone, so nobody really cares – he knows the cameras scan his face and license plate as he sails through, past the unmoving line of trucks and cars trying to go the other way, but nobody stops him,

and he hardly slows down enough to read the disclaimers and warning signs.

He keeps the speed up, the van creaking as it shifts through gears. It's only a few minutes to the next checkpoint, and he doesn't want to mess around. It's not just the app's constant nagging about time targets – driving through here always puts him on edge. It's one of the city's biggest camps – everywhere he looks there are tents, on the sidewalk, under flyovers, in the parking lots of long-abandoned stores. Bodies lie and sit here and there, some moving, others not. It's one of those places you end up when you can't get into an Amber or Green zone. Amir shudders. Like everyone, he's heard the stories of people leaving work in one Green zone, passing through a Red, but never making it out the other side – never making it to their home – because they couldn't get through the checkpoint. Those people live in places like this now, the stories say. Amir shakes his head. Even if you weren't really infected when you got stranded here, it wouldn't be long until you were.

Amir's heart drops as he approaches the next checkpoint. The line is longer than he hoped, but he's not surprised – he's trying to get into a Gold zone, one of the city's most exclusive enclaves, so security is tight. He enviously watches cars zip through in the express entry lane – all high-end saloons and self-driving limos. That guy in his building claimed he could sell him a pair of Gold zone approved license plates, but they'd be expensive. And risky. Get caught faking that and you are going straight to jail, to await a trial you'd be lucky to survive long enough to see. If there was one place where the infection rates were higher than the Red zone camps, it was the prisons.

Amir's heart drops as he approaches the next checkpoint. The line is longer than he hoped, but he's not surprised – he's trying to get into a Gold zone, one of the city's most exclusive enclaves, so security is tight.

Amir is second in line now, almost there. He coughs phlegm into his fist and wipes sweat from his brow, his eyesight blurring momentarily, like fogged up glasses. He dry swallows another two cow pills and stares at the unmoving car in front of him. What's taking so long?

Suddenly there's activity, shouting. Amir leans forward, over the wheel and dashboard, to try and see better. Two guards – corporate security, from one of the big private armies – are pulling the driver from the car. Compulsory testing, Amir guesses. From the driver's reaction it seems to be a foregone conclusion. He looks terrified, and tries to resist, to pull back, get back in the car. Amir has seen it all before, and he knows what's coming, but the clikclikclik of the taser still makes him flinch as the driver's body crumples to the floor.

Another guard steps forward in front of Amir's van, signals for him to pull over into the next lane, and then steps over to Amir's window, gestures for him to roll it down. He leans in as Amir holds his phone up to his face – or to at least where his face should be, the guard's head is completely wrapped in military grade technology: Kevlar helmet, bioweapon grade breathing apparatus, some kind of AR headset studded with micro-cameras. He stares silently at Amir's phone, something in the headset translating the QR code on its screen. The guard, still not speaking, unhooks the temperature scanner from his belt, pokes it through the car window as Amir rolls back his shirt to expose bare wrist. The scan seems to take impossibly long, seconds feeling like hours, as the two men wait there in complete silence. It's all Amir can do not to panic, watching his fingers tremble, feeling the cold trickle of sweat drops running down the back of his neck. Out of the corner of his eye he can see the driver from the car in front of him lying face down on the tarmac, his arms bound behind his back with plastic zip ties. And then it's all over, the guard – still silent – backing away from the van and waving him through the gate, the cameras on either side watching him go.

Amir's first drop is at another micro-distribution center, one that used to be a bookshop. From here the packages will be loaded into little six wheeled delivery robots, that'll run them along the sidewalks, into the condo buildings, and straight up the service elevators to people's doors. Clean, efficient, sterile. He watches one of them scoot out of the distribution center, past his battered van, and along the impossibly clean looking sidewalk. He wonders how long it'll be until they replace him and the other drivers with something similar. No dawdling, no checkpoints, no compulsory testing, no risk of infection. It can only be a matter of time.

Amir suddenly feels weak, like his legs are about to buckle. His eyes go blurry again. "You're fine, you're just tired, been working too hard". He half-stumbles across the road, and sits on a bench in the shade of a massive condo block – 40 stories of pristine glass and steel, occasional bursts of lush green erupting from balcony gardens. He stares up at it and smiles, taking a deep breath. Closes his eyes, just for a few seconds. "You're just tired. Need a day off".

An angry chiming awakes him, and he finds himself staring into what at first looks like the faceless mask of the checkpoint guard – but, it's something even worse: the headless face of a patrol drone – a three-foot-long metal box covered in sensors and aerials, carried by four dog-like legs. It's got its front paws up on the bench next to him, simultaneously otherworldly and perfectly canine-like, so it can bring its non-face as close as possible to his, like a dog sniffing his breath for food smells. From an unseen speaker a calm, synthetic voice speaks.

A SCAN HAS REVEALED YOUR BODY TEMPERATURE IS IN EXCESS OF LIMITS REQUIRED FOR GOLD ZONE ACCESS. AS YOU ARE NOT REGISTERED FOR GOLD ZONE RESIDENCY YOU MUST PROCEED TO A TESTING CENTER IMMEDIATELY. THIS IS COMPULSORY, AND FAILURE TO COMPLY COULD RESULT IN ARREST. A LIAISON UNIT HAS BEEN DISPATCHED TO ESCORT YOU. THANK YOU FOR YOUR COOPERATION.

Amir tries to stand, but his legs fail him. He sits back down on the bench, the world spinning around him, and the last thing he sees before he blacks out are the two security guards jogging across the plaza towards him, tasers and zip-ties in their hands.

Scenario indicators*

Methodology

1. GDP growth
This indicator shows the world gross domestic product (GDP) growth rate in real terms. Projections for this indicator are based on reviews of historic and forecast GDP growth figures prepared by leading international organizations – European Central Bank, International Monetary Fund (IMF), Organisation for Economic Co-operation and Development (OECD) and the World Bank.

Arup's baseline is in line with pre-pandemic projections prepared by the OECD in 2018, which put the world GDP growth at around 3% per year for the 2021 to 2025 period. As the world economy bounces back from a lower level in 2020 than the baseline, world GDP growth in 2021 and 2022 is therefore likely to be above the baseline. World GDP growth projections for 2021 (5.5 – 5.9%) and for 2022 (1.5 – 6.3%) depending on the scenario, are in line with the Autumn 2021 forecasts from the IMF, the OECD and the World Bank.

From 2023 onwards, the central scenario converges to the pre-pandemic GDP growth levels at 3% per year, and the upside and downside scenarios deviate from the central scenario by a magnitude of around +/- 1.5 percentage points, with a further reduction of around 1.5 percentage points in the case of a double pandemic scenario (downside+ scenario).

These deviations from the central scenario are in line with projections and views set out by the OECD, World Bank and IMF in their Autumn 2021 Economic Outlooks and are based on the likely impacts of vaccination and infection-derived immunity on consumers and investors' expectations; government investment recovery programmes; uncertainty about potential new variants; uneven vaccination rates across the world; supply-chain bottlenecks; and geopolitical tensions. These are the upside and downside factors considered in the scenario projections.

2. Proportion of world population fully vaccinated
This indicator shows the proportion of world population fully vaccinated by 31 December of each year. Arup's baseline is WHO's vaccination targets – 40% of the world population fully vaccinated by the end of 2021 and 70% by mid-2022. From a vaccine production point of view, these targets are reachable. UNICEF estimates that production of approved vaccines will reach 6.9 billion doses in 2021 and an additional 22 billion in 2022. These are enough to fully vaccinate 44% of the world population by 2021; fully vaccinate the world population by 2022 and give boosters to half of the world population also by the end of 2022. Considering both vaccines that are approved and those in human trial stage, in 2022 the world could produce as many as 35 billion vaccine doses, enough to give each person in the world as much as four vaccine doses/boosters in 2022.

Nevertheless, WHO targets are considered to be difficult, if at all possible, to meet. This is because, as of 5 October 2021, only 34% of the world population was fully vaccinated and the vaccination rate in LMICs (which account for 85% of the world population) was only 30% (60% in high-income countries).

Projections for the proportion of the world population fully vaccinated follow a county-by-country, bottom-up approach using historic country level data from Oxford University's Our World in Data and data on vaccine distribution through COVAX to LMICs from Gavi, The Vaccine Alliance.

It is assumed that all high-income countries will meet the WHO targets of 40% vaccination rate in 2021 and 70% in 2022, but LMICs will fall behind. The pace at which LMICs catch up on vaccination rates and high-income countries further advance theirs, depends on several upside and downside factors, which justify our different scenario projections. These include global commitments to equitable vaccine distribution; ramp up of vaccine production; vaccine hesitancy; absorptive capacity in LMICs; and new virus mutations.

Evidence and insights from WHO and leading research institutions were used to support the project team's expert judgement and how these factors impact the pace of vaccination from 2022 to 2025, across high-income and LMICs across the various section.

The approach used projects the proportion of the world population fully vaccinated to reach between 34% and 36% in 2021. In the upside scenario, 76% of the world population will be fully vaccinated by the end of 2023 and 87% of the world population will be fully vaccinated by the end of 2025. In the central scenario, 73% of the global population will be fully vaccinated by 2024, which will go up to 80% in 2025. Only 66% of the world population will be fully vaccinated by 2025 in the downside scenario, and in the downside+ scenario this figure will be only 55%.

3. COVAX doses distributed
This indicator shows the cumulative number of vaccine doses distributed through COVAX by the 31 December of each year.

Arup's baseline is the likely demand for COVAX doses so that LMICs reliant on COVAX reach 70% of their population fully vaccinated. A bottom-up, country-level approach was used to estimate that COVAX will need 3.3 billion vaccine doses so that LMICs reliant on COVAX can fully vaccinate 70% of their population. This is a reachable milestone, as vaccine production is estimated to be sufficient to give the world population three vaccine doses in 2022.

Country level data on number and percentage of people fully vaccinated from Oxford's University's Our World in Data was used for the estimates. A country was considered to be reliant on COVAX for vaccine supply if (a) it is a low/middle-income country, as defined by the World Bank and (b) Gavi, The Vaccine Alliance lists it as a country that COVAX has provided vaccines to.

It is considered difficult, if at all possible, for COVAX to reach 3.3 billion doses (or a 70% vaccination rate in LMICs reliant on COVAX) by 2022. This is based on that fact that, as of October 2021, COVAX had only distributed 337 million doses and only 16% of the 2.8 billion people living in LMICs reliant on COVAX were fully vaccinated. In addition, Gavi's projects that COVAX will miss its target of 2 billion doses for 2021.

The projections for COVAX doses distributed by the end of 2021 are in line with Gavi's projections as of September 2021 and range from 1.2 billion to 1.4 billion, depending on the scenario.

The extent to which COVAX will reach/surpass the 3.3 billion doses needed to reach the 70% vaccination rate and at what pace this will occur depends on several upside and downside factors. These include global commitments to equitable vaccine distribution, a ramp-up of vaccine production, vaccine hesitancy, absorptive capacity in LMICs, and new virus mutations.

Arup's expert judgement was used to form a view on how these factors are likely to impact COVAX doses in the different scenario projections from 2022 to 2025. The expert judgement is based on evidence and insights from WHO and leading research institutions.

*conducted independently by ARUP

The approach used results in projecting that COVAX reaches 3.3 billion doses (70% vaccination in LMICs reliant on COVAX) by 2023 in the upside scenario, by 2024 in the central scenario and beyond 2025 in the downside and downside+ scenarios. It also projected that by 2025 the amount of COVAX doses distributed reaches 4.1 billion (or 84% vaccination rate in LMICs reliant on COVAX) in the upside scenario; 3.6 billion (75% vaccination rate) in the central scenario, 2.8 billion (61% vaccination rate) in the downside scenario and 2.2 billion (50% vaccination rate) in the downside+ scenario.

4. Number of daily new COVID-19 cases

This indicator shows the daily number of new COVID-19 cases reported in the world. The average number of daily new cases is projected for each year within the projection period of 2021 to 2025. Additionally, an average is also projected for the seasonal winter-summer peaks and troughs pattern.

The scenario projections for the daily number of new COVID-19 cases are based on the view that COVID-19, like influenza and other coronaviruses, is likely to become endemic. Endemic diseases can be controlled with vaccines and other medications but not eliminated. Following an extensive literature review, this has been found to be the prevalent view in the growing scientific literature in the field. Indeed, to date, only one human disease, smallpox, has ever been wholly eradicated.

Endemicity means that new COVID-19 cases will rise and fall over time. Nonetheless, the transmission will become stable and predictable as the world population builds up some immunity to COVID-19, similar to other viruses such as influenza. However, scientists have yet to determine the steady rate of COVID-19 infections and the pace at which a steady rate will be reached. Hence, the steady-state for COVID-19 infections is impossible to predict at this point.

In the central scenario, the daily number of new cases in the world for the projection period of 2021 to 2025 will remain, on average, flat. According to data from Oxford University's Our World in Data, the daily number of new cases will be at the same level seen from January to October 2021, just under 550 000 cases/day.

The extent to which the average of new daily cases in the world will be smaller or greater than in the central scenario depends on global vaccination rates, build-up of infection-driven immunity, the durability of both vaccine-driven and infection-driven immunity, impacts of the Delta variant, potential new virus mutations and vaccine hesitancy.

The views taken on how these factors are likely to impact daily cases across the scenarios were based on forecasts prepared by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. The team's expert judgement was used to calibrate the IHME's forecasts to reflect the effects of each downside and upside factors identified in the scenarios. The expert judgement was based on evidence and insights from WHO and leading research institutions.

The approach used has resulted in upside projections of daily cases recorded in the world decreasing from just over 500 000/day in 2021 to just over 180 000/day in 2025, which is about one-quarter of the peak recorded in April/May 2021. In the downside scenario, it was observed that daily cases recorded in the world reached just under 950 000/day by 2025, which is higher than the peak of over 800 000 daily cases seen in April/May 2021. The reason for this is that the downside scenario assumes lockdowns will be less effective and new variants will evade vaccines and treatments. In the downside+ scenario, where a Zika-like pandemic alongside COVID-19 puts extra pressure on health care resources in most LMICs, world cases may reach over 1 million/day by 2025.

5. Number of deaths

This indicator represents the number of deaths with COVID-19 reported each day in the world. The projections for the COVID-19 mortality rate in the world are easily derived from this indicator, which is done by dividing the projections for daily deaths by the world population.

The scenario projections for COVID-19 daily deaths are based on the view that COVID-19 is likely to become endemic, such as influenza and other coronaviruses. This was found to be the prevalent view in the growing scientific literature in the field through literature scanning.

However, scientists diverge on what the COVID-19 steady death rate will be and when this will be reached. Some scientists believe that it will be higher than that of influenza, which kills 291 000-646 000 people annually worldwide, equivalent to 797-1770 people every day. Others suggest it will be closer to coronaviruses like SARS, which has a much lower death toll at less than 1000 people annually worldwide at its peak in 2012-2013 (or about two people every day). Other scientists suggest it will be something in-between these two. Therefore, it is impossible to predict what the COVID-19 deaths baseline will be in steady state at this point.

In the central scenario, the daily number of deaths with COVID-19 reported in the world will remain, on average, flat at a similar level seen from January to October 2021, based on data from Oxford University's Our World in Data.

The extent to which the average daily deaths with COVID-19 reported in the world will be smaller or greater than the central scenario depends on progress in global vaccination, natural immunity build-up, durability of immunity acquired through both infections and vaccines, success of new treatments, impacts of the latest variants, potential new virus mutations and vaccine hesitancy.

The views are based on how these factors are likely to impact daily deaths in the different scenarios on forecasts prepared by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. The team's expert judgement was used to calibrate the IHME's forecasts to reflect the effects of these factors in each of the scenario. The expert judgement was based on evidence and insights from WHO and leading research institutions.

The approach used results in upside projections of deaths recorded in the world reaching 1,800/day, which is in line with the daily death tool of influenza worldwide. In the downside scenario, daily deaths recorded in the world could reach just over 18 000/day by 2025, which is higher than the pick of over 14 500 daily deaths recorded in January 2021. This is because the downside scenario assumes lockdowns will be less effective and new variants will evade vaccines and treatments. In the downside+ scenario, where a Zika-like pandemic alongside COVID-19 puts extra pressure on healthcare resources in most LMICs, world deaths could reach over 20 000/day by 2025.

Projections

GDP growth
World gross domestic product (GDP) growth rate, in real terms.

+ Upside scenario	- Downside scenario	-- Downside + scenario
• Faster progress in global vaccination and infection-driven immunity consolidates economic reopening, consumer spending and private investment • Government investment recovery programmes (e.g., in the EU, UK and USA) kick off in 2022 at speed	• New virus mutations force further containment measures • Geopolitical tensions worsen supply bottlenecks • Public debt and raising inflation lead to withdrawal of pandemic-led government support • Inflation overshooting leads to tighter monetary policies	• Aformentioned • Zika-like pandemic alongside COVID-19 depresses investors and consumers' expectations and spend, disrupts global production further and prolongs supply bottlenecks

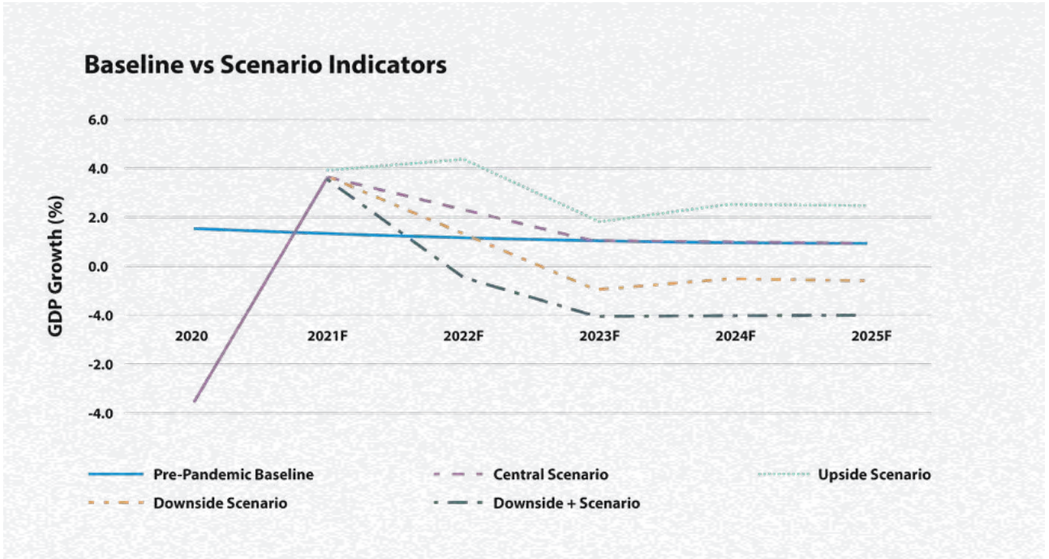


Fig. A1 GDP growth projections graph

Proportion of world population fully vaccinated
Proportion of world population fully vaccinated by 31 December of each year.

+ Upside scenario	- Downside scenario	-- Downside + scenario
• Greater global commitment to more equitable vaccine access by countries with low vaccination rates • Ramp up of vaccine production accommodates both boosters for fully vaccinated and full vaccination of unvaccinated populations	• Vaccine hesitancy remains an issue • Vaccine absorptive capacity in low- and middle-income countries remains a constraint to vaccine distribution • New virus mutations require development of new/enhanced vaccines aggravating vaccine inequality between high- and middle/low-income countries	• Aformentioned • Zika-like pandemic alongside COVID-19 puts extra pressure on health care resources in most low/middle-income countries (largely located in Zika-prone regions), hindering their vaccine absorptive capacity further

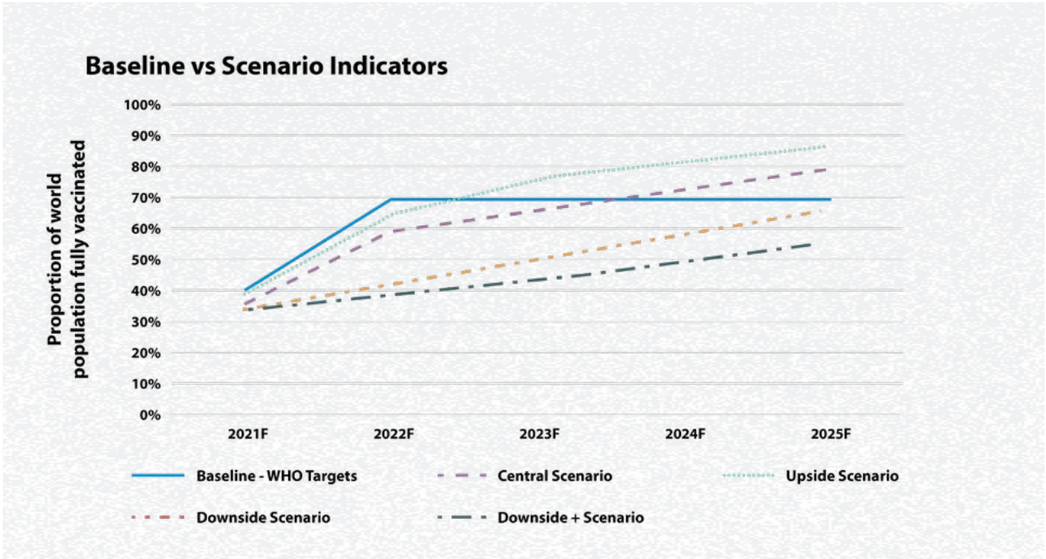


Fig. A2 Proportion of world population fully vaccinated

COVAX doses distributed
Cumulative number of vaccine doses distributed through COVAX by 31 December of each year.

+ Upside scenario	- Downside scenario	-- Downside + scenario
• Greater global cooperation to reduce vaccine inequality between high- and low/middle-income countries, with more funds available and more vaccines donated to COVAX • Ramp up of vaccine production smooths out export restrictions and other trade barriers affecting COVAX • COVAX has resources to build a vaccine buffer for boosters, outbreaks and humanitarian usage	• Vaccine absorptive capacity in low- and middle-income countries remains a constraint to vaccine distribution • New virus mutations require development of new/enhanced vaccines aggravating vaccine inequality • Geopolitical tensions worsen vaccine supply chain and logistics bottlenecks currently affecting COVAX • Vaccine hesitancy remains an issue	• Aforementioned • Zika-like pandemic alongside COVID-19 aggravates vaccine supply chains and logistics bottlenecks further and hinders funds and vaccine donations to COVAX

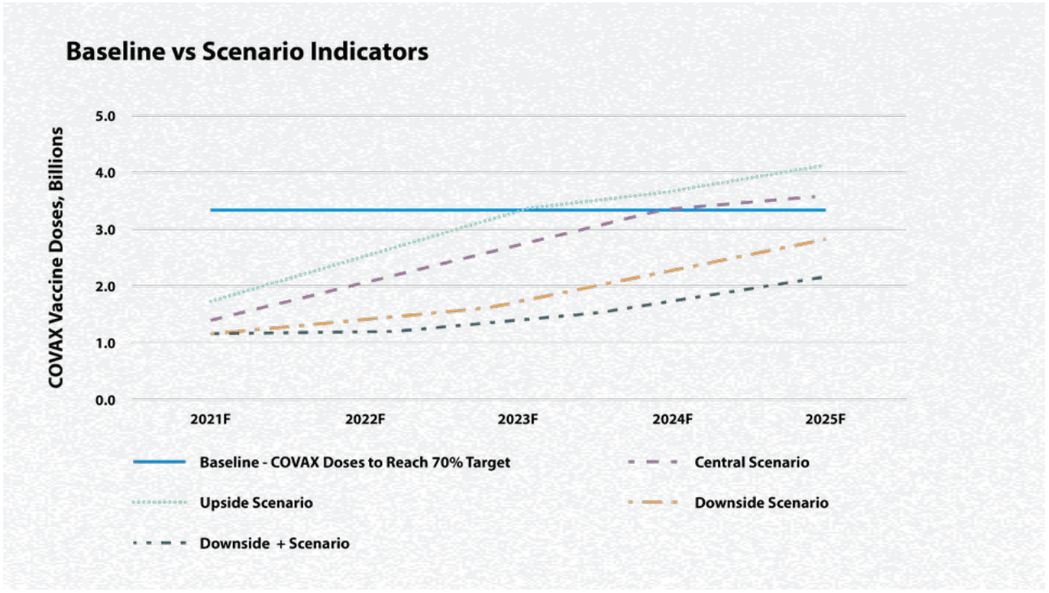


Fig. A3 COVAX doses distribruted

Number of daily new COVID-19 cases
Number of new COVID-19 cases reported in the world. We project the average number of daily new cases and thereby we average out the seasonal winter and summer peaks and troughs pattern.

+ Upside scenario	- Downside scenario	-- Downside + scenario
• Greater global commitment to more equitable vaccine access speeds up global vaccination rates • Infection-driven immunity builds up, namely in low/middle-income countries • Ramp up of vaccine production accommodates both boosters and vaccination of unvaccinated populations • Greater understanding of antibodies prevalence and immunity duration drives targeted preventive boosters for vulnerable people	• New virus mutations wane down existing immunity faster thereby accelerating infections • New virus mutations require development of new/enhanced vaccines and slows down worldwide vaccination rates • Low acceptance and adherence to further containment measures to constrain infection outbreaks • Vaccine hesitancy remains an issue	• Aforementioned • Zika-like pandemic alongside COVID-19 puts extra pressure on health care resources in most low/middle-income countries (largely located in Zika-prone regions), hindering their vaccine absorptive capacity further

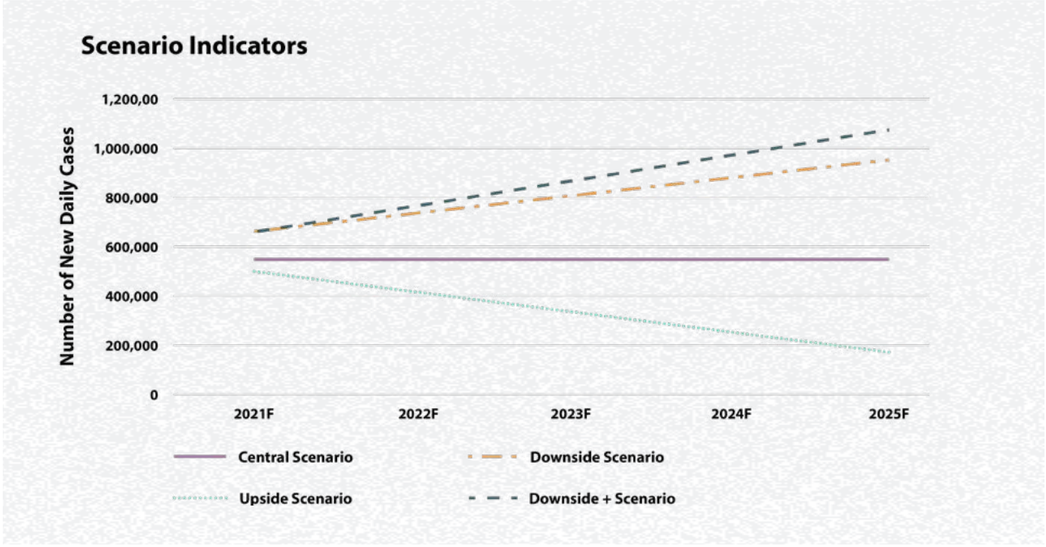


Fig. A4 Number of daily new COVID-19 cases

Number of daily deaths with COVID-19
Number of COVID-19 deaths reported in the world. We project the average number of daily deaths. By dividing our projections for daily deaths by the world population we reach projections for mortality rate

+ Upside scenario	- Downside scenario	-- Downside + scenario
• Greater global commitment to more equitable vaccine access speeds up global vaccination rates • Ramp up of vaccine production accommodates both boosters and vaccination of unvaccinated populations • Greater understanding of antibodies prevalence and immunity duration drives targeted preventive boosters for vulnerable people • New COVID-19 treatments weaken the link between infections and deaths	• New virus mutations wane down existing immunity faster thereby accelerating infections and deaths • New virus mutations require development of new/ enhanced vaccines and slows down worldwide vaccination rates • New virus mutations require development of new/enhanced COVID-19 treatments • Low acceptance and adherence to further containment measures to constrain future infection outbreaks • Vaccine hesitancy remains an issue	• Aforementioned • Zika-like pandemic alongside COVID-19 puts extra pressure on health care resources in most low/ middle-income countries (largely located in Zika-prone regions), hindering their vaccine absorptive capacity further

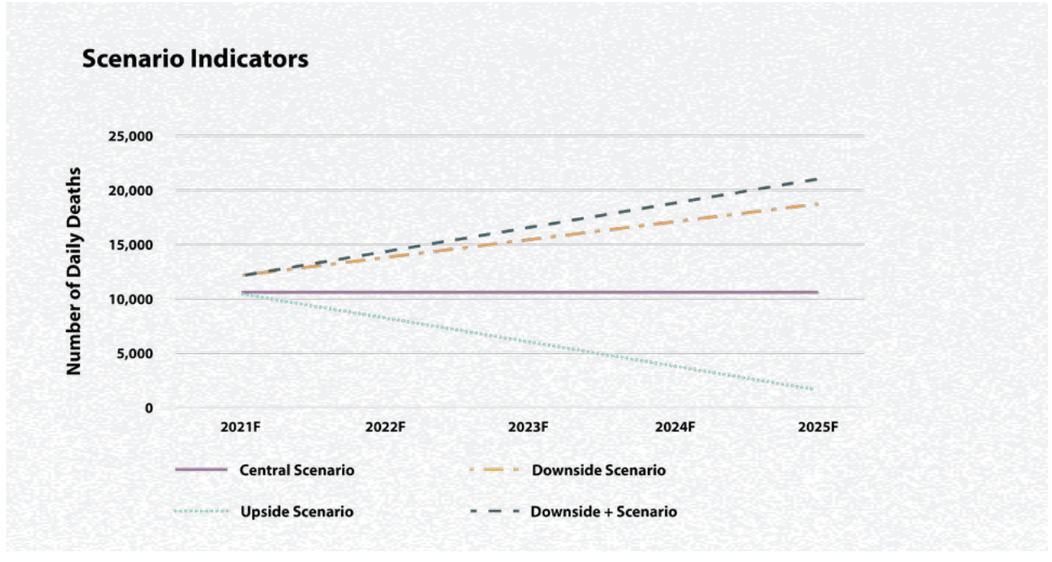


Fig. A5 Number of daily deaths with COVID-19

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