DHL WHITE PAPER

REVISITING PANDEMIC RESILIENCE

THE RACE AGAINST THE VIRUS: WHAT WE'VE LEARNED ONE YEAR INTO COVID-19 AND HOW THE WORLD'S HEALTHCARE SUPPLY CHAINS WILL BE READY FOR THE NEXT PUBLIC HEALTH EMERGENCY

MAY 2021

FOREWORD

COVID-19 has turned out to be the largest global health crisis in 100 years. The disruptions to every aspect of society have been profound. Nearly everyone has experienced the impact of COVID-19 in myriad ways.

Undeniably, the novel coronavirus got off to a sizable head start, but we are closing the gap in this race toward normalcy. Fueled by the many successes and lessons learned thus far – along with our understanding that we belong to one global community – we are gaining speed and now are in a position to finally take the lead.

The specific impact of the pandemic continues to vary by region, and every day seems to bring new realities. Still, the science is quickly being established, and there are some universal truths, including the fact that access to life-saving medicines and supplies is a critical element of ending this pandemic.

Now that we know what our fellow global citizens need, it is up to us to commit to the task of ensuring that they actually *get* what they need. A reliable, forward-looking supply chain with sufficient safeguards is the backbone of this access, and we have important insights to offer to help us get there.

Together we can win this one, but we are not yet at the finish line. Just as importantly, when we do win, we need to prepare for the next race to avoid being caught off guard again. Let's work together to ensure access, protect each other, and return back to normal.

Sincerely yours,

Frank Appel
CEO, Deutsche Post DHL Group

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EXECUTIVE SUMMARY

Logistics and supply chain management play a key role in pandemic management because they ensure the availability and distribution of key pandemic management tools. This paper takes stock of the lessons learned and achievements one year into the race against COVID-19 and refreshes our view on how to best manage the crisis from this point forward. Moreover, it provides insight as to what will best prepare us to handle future public health emergencies.

OUT OF THE STARTING BLOCKS: 10 KEY ACHIEVEMENTS OF THE GLOBAL COMMUNITY

Although the past year has been demanding and full of challenges, there are several achievements across R&D, production and supply chain management, and policy that will help us get through this humanitarian crisis as a global community. For example, the vaccine was developed 5x faster than any other in history and its production was ramped up in record time, quadrupling pre-COVID-19 vaccine production capacity. The supply chain not only met unprecedented cold-chain requirements with -70°C temperature needs, but was also rolled out 3x faster than usual. Moreover, multilateral action was taken to ensure global access to vaccines, and the newly developed vaccine platforms are likely to help tackle other diseases, too.

IT'S A MARATHON, NOT A SPRINT: GOING FROM 4 TO 220 COUNTRIES AND TERRITORIES WITH RESILIENT VACCINE DISTRIBUTION

With the increasing risk of viral mutations, a global vaccination campaign is not only a social obligation, but also a prerequisite to end the pandemic. To successfully manage peak vaccine supply flows, which are growing 30 to 80 percent per quarter in 2021 and will double from the second to the fourth quarter, emphasis needs to be placed on:

Fostering collaboration. All sectors, industries, and nations must work together to successfully end the acute phase of this pandemic, forming strong partnerships and leveraging the support of data.

Securing inbound flows. More than 95 percent of global COVID-19 vaccine doses are produced in just 8 countries and need to be delivered worldwide. Action is required for both transportation and packaging.

Setting up the last mile for success. Last-mile vaccine rollout is the largest logistical challenge, given its unprecedented scale and speed: the aim is to distribute and administer about 10 billion doses by the end of 2021. Getting vaccines from the airport to the patient will require synchronization of the flow of goods, and vaccination points and storage that are specific to the local context.

Maximizing demand for vaccines. To increase the global willingness to be vaccinated to the levels needed to contain the COVID-19 pandemic, education and targeted communication on vaccines, a user-friendly process, and clear incentives need to be prioritized.

THE HOME STRETCH: 7 BILLION TO 9 BILLION ADDITIONAL SHOTS PER YEAR TO END THE PANDEMIC

The COVID-19 pandemic is a dynamic situation, as is the virus that causes it. With this in mind, it is not only imperative to vaccinate the world as quickly as possible, but to ensure immunization is sustained in the years to come. As a result, the COVID-19 supply chain and logistics setup in 2021 will remain important going forward.

In 2022 to 2023, around 7 billion to 9 billion vaccine doses and corresponding ancillary supplies are expected to be distributed annually. To ensure success, all actors need to remain prepared for high patient and vaccine volumes, maintain logistics infrastructure and capacity, and plan for seasonal fluctuations. Only then can the supply chain system that is currently being rolled out provide a well-equipped platform for the years to come.

GETTING READY FOR THE NEXT RACE: ENSURING SYSTEMATIC PREPAREDNESS FOR THE NEXT PUBLIC HEALTH EMERGENCY

In the same way that runners train between races, we must maintain a level of conditioning that keeps us prepared for the next global health event. Learning from the COVID-19 pandemic, governments should expand and institutionalize virus containment and countermeasures (e.g., early-warning systems, digital contact tracing, and national stockpiles) to ensure strategic preparedness and more efficient response times in the future. As respiratory viruses are prone to pandemic spread, public, corporate, and nongovernmental entities need to plan and prepare for early identification as well as for efficient medication development and rollout to save lives in the next outbreak.

INTRODUCTION

Pandemic management is a combination of infection prevention, monitoring, and countermeasures. Logistics and supply chain management play a key role in this effort because these are the processes that ensure the availability and distribution of key pandemic management tools: medicines and medical supplies, such as vaccines, test kits, ancillary supplies, treatments, and personal protective equipment (PPE).

Last year, we provided our perspective on the logistics and supply chain challenges that emerged early in the pandemic management effort and suggested approaches to both tackle and prevent those challenges. At that point, PPE was the category of supplies at the heart of the supply chain problem, while vaccines were still being developed. Today, vaccines have quickly become the most critical asset on which pandemic management depends.

Building on 8 months more experience, this article takes stock of the lessons learned and achievements from the yearlong race against COVID-19. It refreshes our view on how to best manage the current crisis and provides insight, from our perspective, as to what will best prepare us to handle future public health emergencies. With each chapter, this article explores pressing questions on the minds of governments and public health professionals:

- **Out of the starting blocks:** What have we achieved in the fight against COVID-19, and where do we stand today? (Chapter 1)
- **It's a marathon, not a sprint:** How do we build a strong, agile supply chain that stands up to the pressure of peak vaccine volumes and an accelerated rollout pace? (Chapter 2)
- **The home stretch:** What is our "post-peak" plan for keeping the virus and its mutations in check in the long term? (Chapter 3)
- **Getting ready for the next race:** Is it possible to prevent another outbreak and, if not, how do we keep one from turning into another pandemic? (Chapter 4)

Together, we hope the answers to these questions support the continued dialogue between governments, pharmaceutical manufacturers, life sciences institutes, and the logistics industry, as these are the players that – with their collective power – will need to prepare for and manage the inevitable next public health event.

OUT OF THE STARTING BLOCKS

10 KEY ACHIEVEMENTS OF THE GLOBAL COMMUNITY

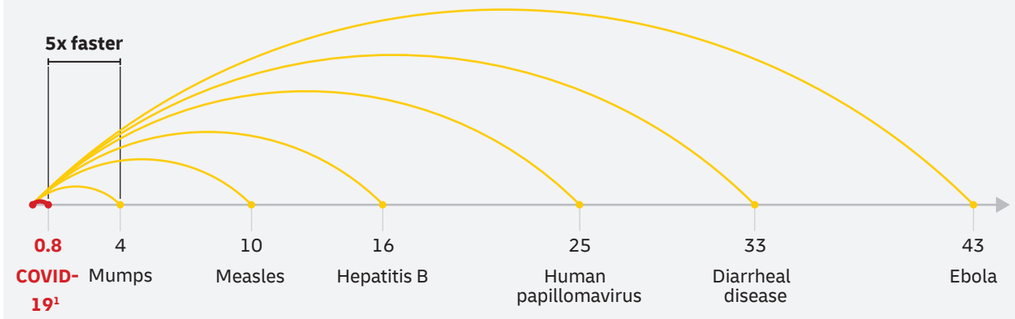
The past year has been demanding and full of challenges. However, when taking stock, it becomes clear that there are several achievements across R&D, production, supply chain management, and policy that will help us get through this humanitarian crisis as a global community.

1. COVID-19 vaccine development occurred 5x faster than any other vaccine in history

Moving away from traditional, sequential vaccine development processes that take many years, parallel processes and an unprecedented push from the scientific community allowed the COVID-19 vaccine to be created in about 9 months – 5x faster than the creation of the mumps vaccine, which was developed in 4 years (Exhibit 1). However, it is important to note that the clinical and regulatory standards and hurdles for the approval of the COVID-19 vaccine are the same as those for prior vaccines. In addition, global collaboration spurred the development of the various vaccines, with researchers around the globe conducting many processes simultaneously and sharing their coronavirus-related data with other scientists. Finally, regulators have collaborated seamlessly with researchers to enable swift approval, by using rolling review processes or granting Emergency Use Authorizations, for example.

VACCINATION INNOVATION

TIME FROM INFECTIOUS AGENT IDENTIFICATION TO VACCINE APPROVAL IN THE US, YEARS — EXHIBIT 1



[1] COVID-19 vaccines have received emergency use approval, whereas the other vaccines have received biologics license application approval in the stated time

Source: Bernadeta Dadonaite, Max Roser, and Samantha Vanderslott, "Vaccination," Our World in Data; "COVID-19 vaccines," US Food & Drug Administration, February 5, 2021, fda.gov

2. 2 new vaccine platforms, that can tackle diseases beyond COVID-19, have emerged and begun to mature

In just the past year, viral vectors and mRNA have been fully established as new vaccine platforms. Their capabilities will quite likely prove valuable over time against other diseases as well. While most other vaccines use weakened or inactivated versions or components of the disease-causing pathogen, viral vectors and mRNA work differently (please refer to the information box below for further details).

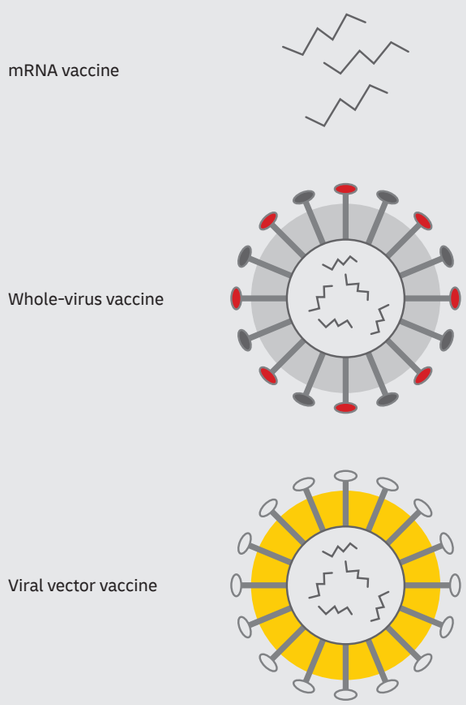
With mRNA and viral vectors now achieving market maturity, 30 and 50 years of research, respectively, have culminated in a new gateway to fighting additional diseases. Currently, there are more than 440 clinical trials active with mRNA and 140 clinical trials with viral vectors, which will all benefit from the scientific progress and upscaling of manufacturing capacity achieved in the past year. Therefore, the acceleration of these 2 technology platforms over the course of the COVID-19 pandemic is expected to also benefit patients suffering from a number of different diseases.

Background reading: mRNA and viral vector technologies

mRNA vaccines – the platform on which the Pfizer/BioNTech and Moderna COVID-19 vaccines were built – takes advantage of the process that cells use to make proteins in order to trigger an immune response. In a nutshell, a mRNA vaccine encodes information that provides the human body with instructions to produce certain proteins. These proteins, which in this case resemble the SARS-CoV-2 spike protein, will then trigger an immune response. This bypasses the complexity and expense of traditional therapeutic-protein production. Instead, mRNA gives scientists the power to quickly adapt the protein sequence in response to mutations or new findings once the delivery model or platform is established. What's more, with the theoretical capacity to encode almost any protein with high precision and a flexible production process, mRNA vaccines have the potential to be used to treat a range of different diseases. For example, cancer might be tackled by stimulating an immune response (via tumor-associated antigens) that prevents tumor metastasis. Moreover, the mRNA platform is also considered promising in providing protection against other, so far unresolved disease challenges, such as HIV and multiple sclerosis.

Viral vector vaccines, such as Johnson & Johnson's and AstraZeneca's vaccines, use a modified version of a more innocuous virus to carry the genetic information for the virus spike protein (in the form of DNA) into human cells, which then produce the spike protein and stimulate an immune response against it. This platform had been applied in an Ebola vaccine, but was never put to use on a large scale. Viral vectors can also be used for cell and gene therapy, allowing for defective or missing genes in the body to be repaired or replaced, thereby restoring normal function. Integrating genetic information into the genome is a permanent intervention and requires both precise recognition of the target gene location and high stability of the genetic sequence. With this technology, there is significant potential to cure diseases such as diabetes, cancer, or heart disease.

VACCINE TECHNOLOGIES



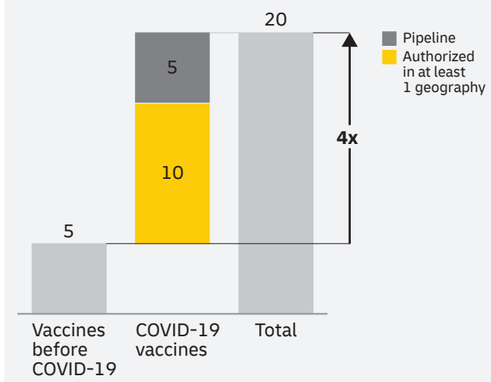
3. Total global vaccine production quadrupled within a year

Vaccine developers have already launched more than 100 vaccine production facilities globally, and that number is increasing steadily. The rollout of manufacturing capacity has been about 3x faster for COVID-19 vaccines than for a typical capacity expansion, such as a technology transfer to a new site. As a result, the total global vaccine production capacity has quadrupled.

Total global vaccine production announced for 2021 is 20 billion doses, including 15 billion doses of COVID-19 vaccines and 5 billion doses of other vaccines – that is, capacity that existed before the pandemic. The announced production capacity of approved vaccines is up to approximately 10 billion doses. If manufacturing commitments to scaling up can be met, global 2021 production output should be sufficient to vaccinate the entire global population. Additionally, if all COVID-19 vaccine innovators are successful in clinical trials, an additional pipeline of around another 5 billion doses could be made available.

As with the development of the vaccines themselves, the huge increase in the speed and scale of production capacity is driven by unprecedented global collaboration and industry partnerships – particularly between vaccine developers and manufacturers in the form of contract manufacturing, for example. Generally, both parties can benefit greatly from the partnership. In the example of Pfizer and BioNTech, who were already engaged in a partnership since August 2018, BioNTech was able to offer promising research in mRNA technology, while Pfizer offered large production capacity and scaling possibilities. This is similar to Moderna and Lonza, where Lonza provided the capacity to scale up production by a factor of 10. The University of Oxford has used the partnership with AstraZene its global development, manufacturing, and distribution capabilities. Bayer, on the other hand, is partnering with CureVac and supporting it primarily in the execution of operational studies and regulatory tasks.

VACCINE PRODUCTION
2021, BILLION DOSES
EXHIBIT 2



Source: UNICEF COVID-19 production tracker with additional assumptions on realization and shipment timing of announced volumes (per vaccine development stage). Pre-COVID vaccine data based on Airfinity

4. The complex global vaccine supply chain was ramped up successfully

Setting up the supply chain for COVID-19 vaccines took just 6 months in some cases, which is approximately 3x the speed of the typical 18-month pre-COVID-19 timeline. As one pharma supply chain executive put it, "Ramping up the COVID-19 vaccine. supply chain felt like building the plane while flying it." Despite the breakneck speed at which it was set up, the supply chain fulfilled the daunting requirements:

- In the 4 months since shipping of the various vaccines began, around 1 billion doses have already been delivered
- Virtually no doses were held up or damaged in transit
- The production-to-injection timeframe can be as fast as 2 days, and in virtually all cases, takes less than a week

<1%

of total vaccination cost is caused by logistics

Comparing the costs of end-to-end vaccine supply chain logistics, which are less than 1 percent of the total vaccination cost (which, in many cases, equals only a couple of cents), to their critical role in the overall vaccination strategy shows that current logistics solutions are highly efficient. Vaccine distribution has included the traditional methods of local cross-docking and warehousing as well as an additional archetype, "direct to dosage," which has not been applied at scale for vaccines until now.

Once again, an unprecedented level of multisector, international collaboration – including logistics and pharma companies as well as the public health and military infrastructures of many governments – is a key driver of this speed. For example, logistics couriers have been allowed to transport vaccine doses on military helicopters or boats to avoid traffic jams and speed up delivery. Regulators and industry associations have revisited limits on the shipment of dry ice, which has facilitated greater volumes of vaccine shipping, and storage capacity has been shared across international borders.

Recent collaborative efforts facilitated the supply chain setup, but necessary preparations by the logistics industry – including sizable investments in transportation and storage infrastructure – were key to the success. This includes early capacity planning, risk taking on the part of logistics players, and the setup of freezing and packaging solutions.

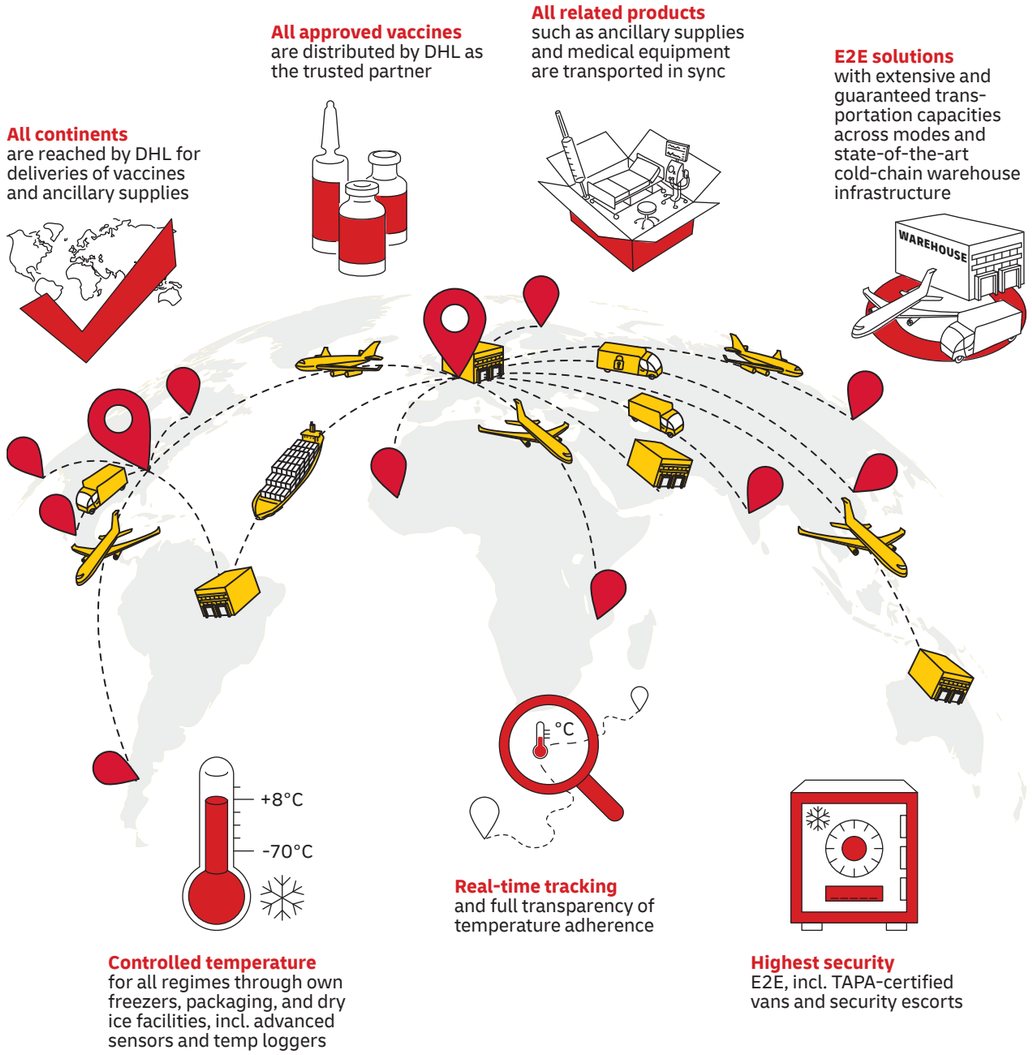
Multisector partnerships are going the extra mile to ensure the correct and timely delivery of COVID-19 vaccines

Image source: Reuters

DHL IS THE TRUSTED PARTNER FOR COVID-19 VACCINE LOGISTICS WORLDWIDE

DHL's contributions to COVID-19 vaccine distribution to date include:

>200 million doses of all approved vaccines distributed internationally	>120 countries served	>9,000 flights operated to deliver vaccines
>350 DHL facilities involved in the process	>50 bilateral and multilateral collaborations with partners in the pharma and public sectors	>10 new and dedicated services introduced



5. Extreme cold-chain requirements were met at scale – flawlessly!

The supply chain setup was not only unprecedented in terms of scale and speed, but it also needed to meet the extreme –70°C cold-chain requirements of the Pfizer/BioNTech vaccine for both transportation and storage (at least in the first few months of the vaccination rollout). Such extreme temperature requirements were previously only needed in small-scale clinical trial settings. Therefore, many practitioners were concerned about whether these requirements could be met a huge, global scale. In transportation, potential bottlenecks from dry ice shipping limits have been tackled successfully, and in storage, the global capacity of –70°C freezers was expanded by 50 percent in a single year. Despite the rapid capacity expansion and introduction of new processes, the cold-chain infrastructure has been successful, with less than 0.01 percent of vaccine doses spoiled or damaged during logistics processes.

<0.01%

of vaccine doses have been spoiled or damaged in logistics

This success can be attributed to 5 factors: critical cooling infrastructure like freezer farms, reliable temperature monitoring equipment at all stages of the supply chain, staff who are well trained in the standard operating procedures of vaccine storage and handling, accurate vaccine inventory management, and innovative packaging solutions with integrated cooling features.

All 5 factors are crucial to ensuring temperature control at every step of the supply chain. To illustrate the complexity, consider the case of temperature monitoring. First, active temperature loggers suited for real-time tracking at –70°C need to be available in large quantities. Second, to ensure seamless tracking from origin to destination, the active loggers need to be approved for use on flights, which requires approval from all involved airlines globally. In the past few months, many airlines have been very adaptive and agile in testing and approving these devices. Finally, to harness the information provided by the loggers – like location, temperature, time, light events, and other environmental information – an analytics platform is needed to generate real-time insights.

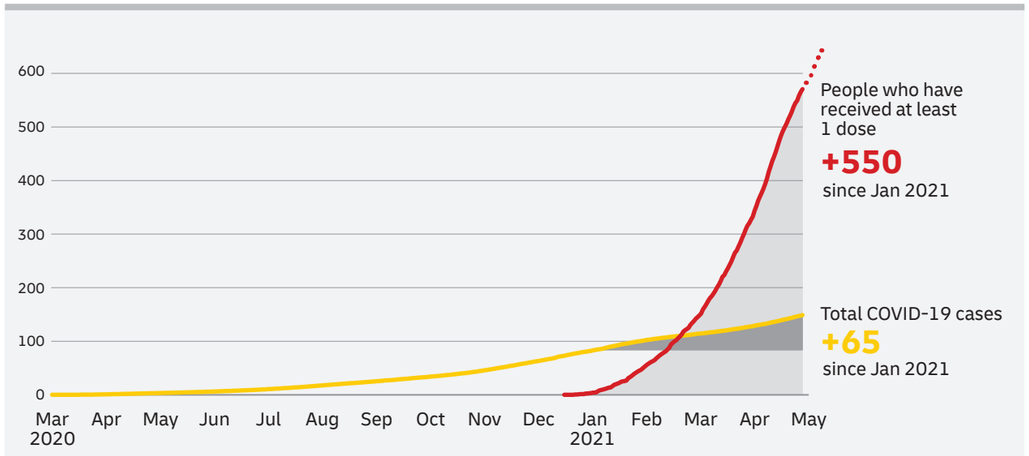
All this flows together in the new direct-to-dosage shipping model that Pfizer/BioNTech has implemented. Utilizing cooling boxes, which get shipped directly to the final location, reduces the number of handling steps in the supply chain and eliminates the need for local cooling infrastructure. Those boxes can, when replenished with dry ice as needed, become mobile ultralow temperature freezers that help maintain the temperature requirements even in regions where permanent low-temperature freezers may not be available.

6. The vaccination rate already outpaces the infection rate by a factor of 9

Achieving high vaccination rates is indispensable for a return to normality. Initial models suggest that 5 billion to 6 billion people will need to be vaccinated to ensure the sustainable management of this virus with minimal mortality rates. Therefore, to end the acute stage of this pandemic as soon as possible, speedy vaccination is of utmost importance.

It only took about 2 months since post-clinical trial vaccinations began for the number of daily vaccinations to exceed the number of daily infections globally, and the vaccination pace is currently about 9x faster than the virus spread since the beginning of the year, about 550 million people have received at least 1 shot (more than 1 billion doses have been administered in total) and approximately 65 million people have been infected. This gap will widen further once higher vaccine quantities become available in the market. Thus, the global community is on track to outpace the virus in months, not years. Still, the pace needs to be accelerated even further to avoid further mutations of the virus that could spread even more quickly.

COVID-19 VACCINATION VS. CASES
MILLION PEOPLE
EXHIBIT 3



Source: Our World in Data COVID-19 data explorer, Apr 28, 2021

7. Multilateral action was taken to ensure global access to vaccines

To end the acute phase of this pandemic, it is not only important to vaccinate as many people as possible, but also to do so across the world. While the initial vaccine rollout appears to be concentrated in high- and middle-income economies, the vaccination campaigns in lower-income economies have also kicked off, with the vaccines produced mostly in Europe, China, India, and Russia. They are expected to grow exponentially as vaccine production capacities continue to rapidly increase. Financial access and the availability of infrastructure will be vital in supporting this exponential acceleration around the world, particularly in low-income and remote locations.

COVAX is a central pillar to enabling broad financial access to COVID-19 vaccines. Its Advance Market Commitment supports low- and middle-income economies with donor-funded safe and effective vaccine doses. Their aim is to distribute 2 billion vaccine doses by the end of 2021. About a month after its first international delivery, COVAX had been able to provide more than 50 million doses to 120 countries. Over 70 of these countries were low- and middle-income economies.

COVAX aims to distribute

~2 bn

vaccine doses globally by the end of 2021

In addition to financial access, inbound logistics and last-mile delivery of vaccines are crucial to ensuring the success of a broad vaccination campaign. Recognizing this unique situation requiring innovative and bold collective action – public, private, and third-sector institutions have risen to the challenge. In December 2020, UNICEF and the World Economic Forum signed a charter, along with 18 shipping, airline, and logistics companies, giving way to public–private partnerships focused on vaccine logistics that advise on last-mile delivery solutions and support in order to resolve bottlenecks and fill potential gaps as needed.

Background reading:
COVID-19 Vaccines Global Access initiative (COVAX)

COVAX is a multinational commitment and risk-pooling mechanism to support equitable access to COVID-19 vaccines. Of the 172 participating countries, more than half (92) are low- and middle-income countries, entitled to financial support for COVID-19 vaccines.

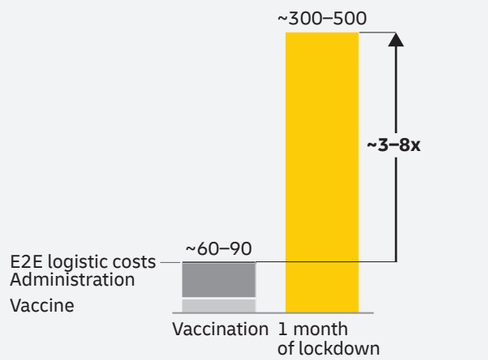
Comprised of 4 organizations with experience in global vaccination campaigns, each adds unique value. The Coalition for Epidemic Preparedness Innovations supports and funds vaccine R&D. Gavi is responsible for raising funds and pooling purchasing power. The UN International Children's Emergency Fund (UNICEF) has been tasked with the procurement and international transportation of COVID-19 vaccines. The UN World Health Organization oversees the allocation of vaccines once purchased. Together, COVAX's 4 members aim to facilitate the distribution of 2 billion vaccine doses by the end of 2021.

8. Vaccine economics work: on a per capita basis; end-to-end costs for vaccination equal just 1 week of lockdown costs

While the safety and effectiveness of vaccines is the major concern for the vaccination campaign, economic viability is also important to ensure a quick, large-scale global rollout. Fortunately, the vaccines are not only safe, but also an economically viable, socially accepted lever toward ending the pandemic.

For a typical industrial nation, the average total vaccination costs are between around EUR 60 and 90 per capita and include the costs of the vaccine itself, the costs of administration, and the end-to-end logistics costs. Compared to the average costs of a lockdown, which ranges from EUR 300 to 500 per capita per month, vaccines are on average 3x to 8x cheaper and therefore not only save lives, but save whole economies.

COST PER PERSON
EUR
EXHIBIT 4



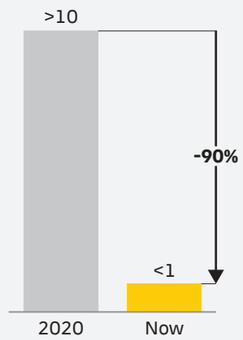
Source: Simplified illustration based on a smple calculation for 3 industrial countries. Lockdown and vaccination costs for the adult population over 18 years. Vaccination costs vary based on used vaccines, as well as points of vaccination in the different countries. Lockdown costs (total economic costs due to the closure of, e.g., shops and restaurants) are based on estimates by independent economic researchers

9. Markets quickly met the surging demand for testing, ancillary supplies, and PPE

The emergence of COVID-19 triggered a massive demand surge for both existing products and not-yet-developed products. Certainly, all of us still remember the days when consumers rushed into supermarkets to hoard groceries like pasta, flour, or toilet paper and hospitals were at risk of running out of PPE. After an initial gap between supply and demand, markets kicked into high gear. Global PPE demand increased by a factor of more than 3x at its peak. However, production reacted fast, which also led to a relatively quick return to normal for PPE prices.

Additionally, more than 350 new rapid-test products have been developed and approved to date, and production was quickly scaled up. For a sample, Germany has secured access to more than 1 billion rapid antigen tests via sourcing contracts, joint procurement with the EU Commission, and potential additional direct orders. Looking beyond protective and diagnostic materials toward ancillary vaccination supplies (such as needles, syringes, and alcohol pads), large-scale development and production has already been set up. To illustrate the uptick in production of ancillary supplies, consider that UNICEF alone plans to deliver up to 2x its normal vaccine volume per month and shipped more than 500 million ancillary items in 2020.

FFP-2 MASK PRICES
EUR
EXHIBIT 5



Source: In Western Europe based on multiple online platforms

10. Large-scale research on therapeutics has been promising

While COVID-19 vaccines will be critical tools for an end to the pandemic, diagnostics, antibody medicines, and other therapeutics will be important complements.

At this time, the ultimate therapeutic has not been identified. However, there are more than 400 candidates in the pipeline for COVID-19 therapeutics, and 11 candidates have already been approved or have received an Emergency Use Authorization. The approved candidates are part of the "virus-directed small molecule," or "virus-neutralizing antibodies" categories. These therapeutic candidates use antivirals or antibodies collected from COVID-19 survivors. For example, Regeneron recently reported an 81 percent reduction in symptomatic infections after subcutaneous injection of its antibody cocktail.

These efforts contribute to preventing severe cases and reducing mortality. As such, they are an increasingly important building block for managing the pandemic and complement the use of vaccines.

THERAPEUTICS PIPELINE

Source: Milken Institute; BioCentury; FiercePharma; FierceBiotech

Moreover, there is hope that further advancements will be made, maybe even with fairly easy methods. Just recently, research provided evidence that patients treated with asthma inhalers were less likely to need urgent medical care or hospitalization and had a shorter recovery time.

IT'S A MARATHON, NOT A SPRINT

GOING FROM 4 TO 220 COUNTRIES AND TERRITORIES WITH RESILIENT VACCINE DISTRIBUTION

By the beginning of 2021, the light at the end of the tunnel had gotten a bit brighter. Vaccination campaigns kicked off in various countries in January, and by the end of April, these campaigns had administered approximately around 1 billion doses globally.

What's more, as many as 15 billion doses will arrive by the end of the year, ifannounced manufacturing capacities are fulfilled and when additional vaccines successfully enter the market. Thus, there is a high chance that there will be enough capacity to vaccinate the world still this year.

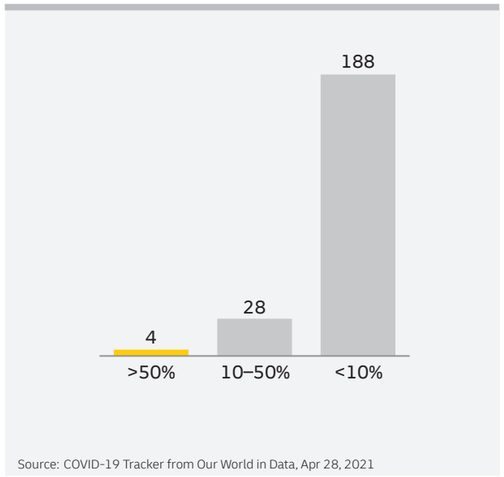
~1 bn of the 10 bn doses

that are globally required to achieve high levels of immunization by the end of 2021 have been delivered

However, for vaccination to succeed, the logistics must also be successful. Therefore, governments, manufacturers, and logistics providers need to ensure that countries and people around the globe get access to vaccines. With the increasing risk of viral mutations, this is not only a moral imperative, but also a prerequisite to end the pandemic – as an executive recently put it, "No one is safe until everyone is safe!" As of the writing of this paper, this notion is sadly exemplified by the explosion of infection rates in India, which are likely caused by a new, more transmissible, mutation.

With only 4 countries thus far having achieved vaccination rates of over 50 percent, the rollout will become increasingly difficult in the future. This is because many of the approximately 188 countries and territories yet to attain significant vaccination progress have less-developed infrastructure, and this leads to logistical challenges that make it more difficult to serve these countries. Moreover, global COVID-19 vaccine production is highly concentrated, with more than 95 percent of doses produced in just 8 countries. The flow of input materials into these production countries is dependent on contributions from a number of other countries. As a result, close international collaboration as well as a high-performing international supply chain are required to enable vaccine production at scale.

VACCINATION PROGRESS BASED ON SHARE OF POPULATION THAT IS FULLY VACCINATED
NUMBER OF COUNTRIES EXHIBIT 6



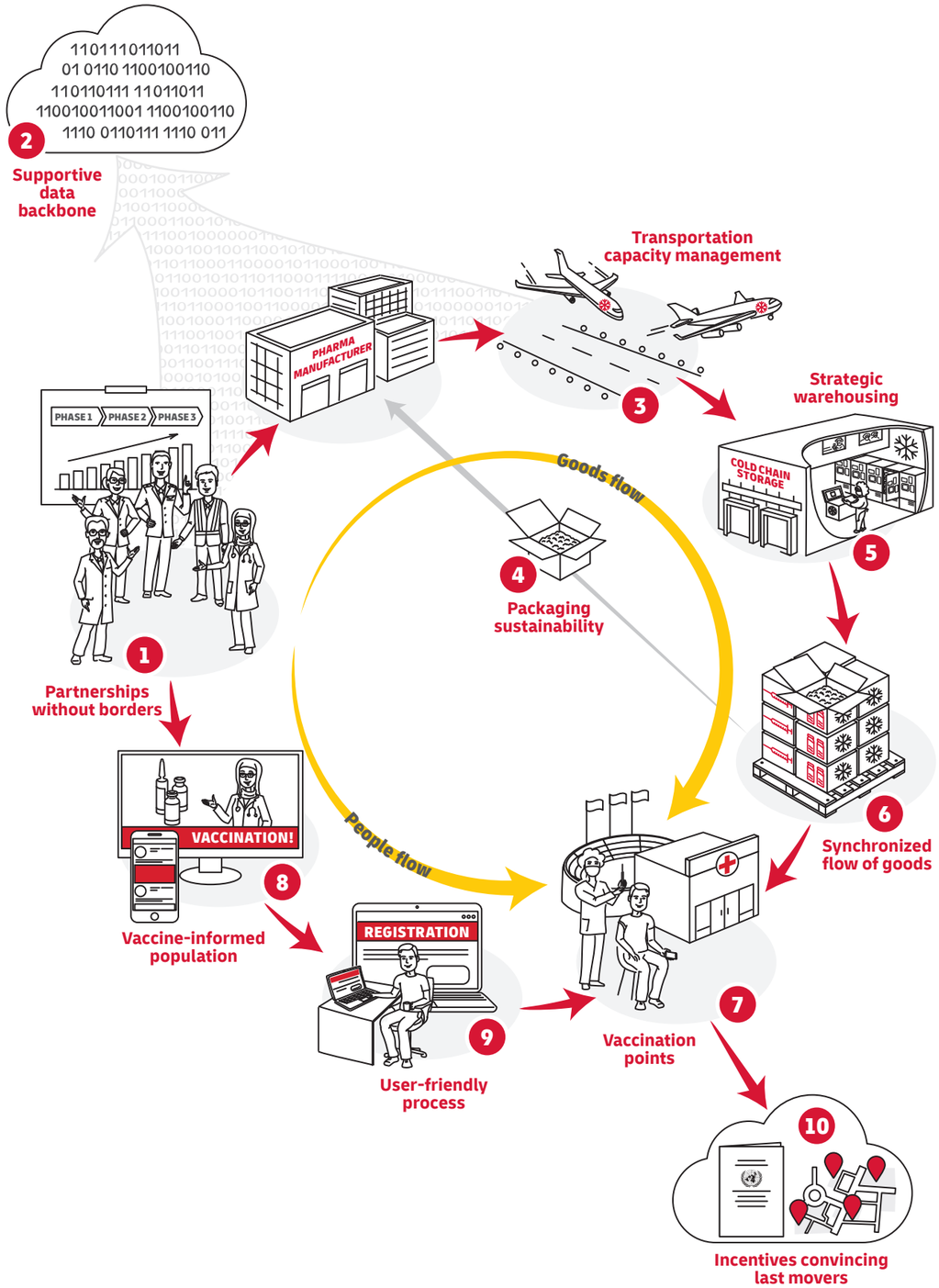
Source: COVID-19 Tracker from Our World in Data, Apr 28, 2021

To manage the challenges ahead, the global community should leverage building blocks that have already proved valuable in the countries that are currently successful in their vaccination efforts, and complement them with additional measures tailored to low- and middle-income countries to achieve a successful global rollout. The following 10 building blocks across 4 areas – collaboration, inbound flows, last mile, and demand maximization – are essential to meeting the challenge of peak vaccine distribution head-on.

>95%

of global vaccine production is concentrated in 8 countries

10 BUILDING BLOCKS FOR SCALING THE SUPPLY CHAIN FROM 4 TO 220 COUNTRIES AND TERRITORIES



Building blocks

FOSTERING COLLABORATION

1. Partnerships without borders. Cross-sector and cross-border partnerships help stakeholders align on the monitoring and delivery of vaccines and ancillary supplies. Specifically, collaborations between pharma players, governments, the military, and logistics players can ensure smooth end-to-end vaccine distribution. While such partnerships have existed for a while to some degree, we are seeing much closer collaboration as partners go the extra mile, seamlessly complement each other's competencies, and provide emergency support to ensure that as many vaccines as possible are administered in the shortest time.

2. Supportive data backbone. End-to-end supply chain transparency can be achieved through a combination of new tools, the interoperability of various systems, and data-sharing protocols. A comprehensive and real-time view of the supply chain enables stakeholders to collaborate seamlessly and respond to bottlenecks faster.

SECURING INBOUND FLOWS

3. Transportation capacity management. Capacity limits (particularly those related to air freight and dry ice) can lead to bottlenecks that delay vaccine delivery, compromise vaccine quality, and even endanger aviation workers. Accurate prediction and management of transportation capacity can ensure the timely and safe delivery of vaccines to destination countries.

4. Packaging sustainability. Many of the vaccines approved today have cold or ultracold storage temperature requirements, for which special packaging systems are required. These can be quite expensive – up to EUR 400 per container. Streamlined return logistics and multisupplier relations can ensure packaging and equipment capacity, sustainability, and circularity, with packaging being refurbished (as needed) and reused.

SETTING UP THE LAST MILE FOR SUCCESS

5. Strategic warehousing. Just-in-time or direct shipping models are not always suited to serving a large number of vaccination points or countries with largely remote populations. At the same time, up to 70 percent of health facilities in low- and middle-income countries do not have the capacity to store large volumes of COVID-19 vaccines at 2 to 8°C or –20°C. Taking into account the time, cost, and utilization of large-scale cold-chain storage and warehousing, national governments should explore the option of setting up appropriate storage at local or regional levels.

Examples

The signatories of the UNICEF and World Economic Forum charter on COVID-19 vaccine delivery have stepped forward to offer pro bono support in the form of specialist logistics personnel for global logistics coordination, and operational assistance for warehousing and cold-chain solutions at regional and national levels. At the same time, many countries have issued vaccine exemptions such as removing import barriers at their borders, speeding up transportation.

Active loggers enable location and temperature tracking of each vaccine shipment in near-real-time. The DHL Quality Control Center predicts shipment schedules, identifies anomalies, and triggers solutions.

The DHL Ice Tracker forecasts and monitors dry ice amounts, adapting the network as necessary to ensure both flight crew safety and product quality.

Well-functioning return logistics can reduce packaging waste by 50 to 60 percent.

Direct shipping to points of use
Pfizer: Vaccines enter the country and are shipped and stored at delivery points. There is no need for cross-docking or repackaging.

Cross-regional hub
Dubai and the UN World Food Programme: Vaccines are stored in a cold-chain warehouse at a regional hub in Dubai. Foreign governments commission vaccines and ancillary supplies for combined shipment. Once these shipments clear customs at the hub and destination country, each point of use receives 1 combined shipment.

Local hub
Rwanda: The country has cold-chain warehousing close to an international gateway. Each point of use receives vaccines and ancillary supplies as needed.

Background reading: Segmenting COVAX countries to identify suitable last-mile setups

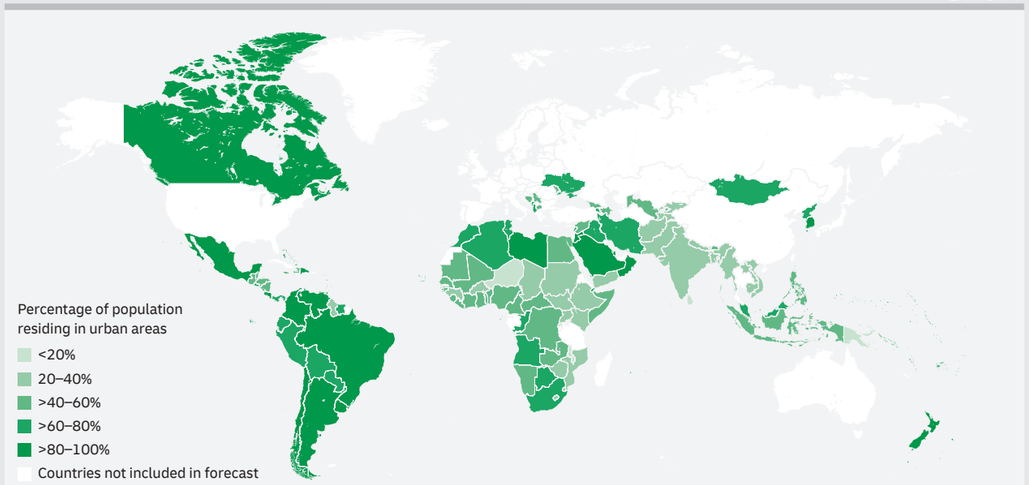
The parameters that account for major distinction between last-mile distribution models are the size and distribution of populations. Based on these parameters, countries tend to fall into 1 of 3 categories:

1. Small population and high concentration: Countries in this category – such as Togo, Djibouti, and El Salvador – will typically need a few dozen or hundred shipments of vaccine doses to just a few central points of use.

2. Large population and low concentration: Countries in this category – such as Bangladesh, Ethiopia, and the Philipines – will likely require a high number of doses with many shipments to many points of use, as vaccination campaigns spread across those countries.

3. Hybrid countries – such as Ukraine and Rwanda – could implement both of the above logistics approaches, beginning with the areas of high population concentration (e.g., capital and major cities) while setting up infrastructure to reach the areas of low population concentration.

POPULATION CONCENTRATION OF COUNTRIES INCLUDED IN CURRENT COVAX DISTRIBUTION FORECAST EXHIBIT 7



Source: UN Department of Economic and Social Affairs; Gavi's most current COVAX Distribution Forecast (Feb 2021, accessed Apr 29, 2021)

Building blocks

6. Synchronized flow of goods. In addition to vaccines, the transported volume of ancillary supplies, such as needles, syringes, diluents, and hazardous waste containers, needs to be ramped up to ensure that enough are available to administer every vaccine. Vaccines and ancillary supplies should be shipped and stored either jointly or separately, depending on the local infrastructure, timeline, IT capabilities, and availability of medical supplies.

7. Vaccination points. A network of vaccination sites – optimized in both number and location at the start of the vaccination campaign – enables easier patient access and allows for easy logistical access, in order to get as many people vaccinated in the shortest possible time. Additional points can be set up as the situation demands.

MAXIMIZING DEMAND FOR VACCINES

8. Well-informed populations. A recent survey by the Africa Center for Disease Control and Prevention of 15 countries on the continent showed that while 79 percent of respondents said they would be willing to get vaccinated, over half considered themselves either not very well informed or not at all informed about vaccine development. Demand for vaccines could be increased through education and targeted communication.

9. User-friendly process. Fast, large-scale vaccine distribution requires a simple and frictionless process for patients. First, this means easy, centralized registration and scheduling based on clearly defined criteria (e.g., vulnerability). Second, it means vaccination locations with minimal barriers to access.

10. Incentives convincing last movers. The promise of personal protection or the public health cause may have driven the first wave of vaccine recipients, but the next wave may need other incentives. For many, the costs associated with getting vaccinated (e.g., transportation costs, taking unpaid sick leave) may seem to outweigh the benefits, and still others just don't feel that invested. Reducing secondary costs and offering "bonuses" may help boost demand.

Examples

In the mountainous kingdom of Bhutan, vaccines and ancillary supplies were combined upon arrival in the country and then delivered to remote locations by foot or helicopter. Over 95 percent of the adult population has received their first shot.

Vaccination success in the US and Israel started with centralized mass-vaccination sites when supply was lower, and grew to include supermarkets and shopping malls as supply picked up.

Rwanda's Ministry of Health launched a successful vaccine rollout with the help of wide-scale communication via Twitter, TV, and radio, personalized updates for vaccination priority groups (including photos), and the influence of community leaders.

In Estonia, all people prioritized for vaccination (e.g., those over the age of 65) can register through the national e-booking system. Furthermore, Digilugu, the Estonian health information system, contacts younger people belonging to high-risk groups directly and links them to the system.

In the UK, fully vaccinated people face fewer travel restrictions. In partnership with local restaurants, Israel gifts snacks and beverages to vaccinated residents. Offering paid sick leave is yet another incentive to boost vaccination demand. The US state of West Virginia, for example, is paying every resident between 16 and 35 years of age USD 100 to get vaccinated.

THE HOME STRETCH

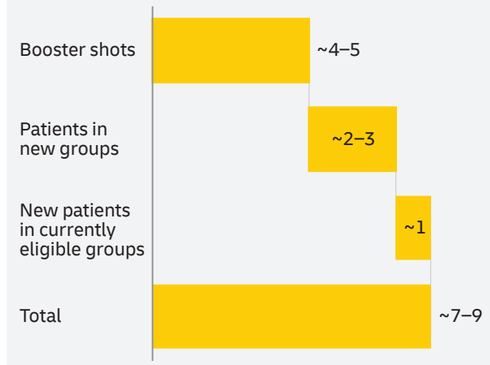
7 BILLION TO 9 BILLION ADDITIONAL SHOTS PER YEAR TO END THE PANDEMIC

The COVID-19 pandemic is a dynamic situation, and so too is the virus that causes it. As we witnessed in India, more transmissible mutations may very well be responsible for the explosion of infections, where the number of new COVID-19 cases per day has increased by a factor of 20 within just 8 weeks from early March to late April. For this reason, it is not only important to vaccinate the world as quickly as possible, but to ensure that immunization is continued in the years to come. This will be the way to keep (re)infection rates as low as possible and also slow down the pace at which the virus mutates.

As a result of continued vaccination efforts, the supply chain will remain of critical importance. In this section, we explain 3 key aspects to bear in mind going forward: remain prepared for high patient and vaccine volumes, maintain logistics infrastructure and capacity, and plan for seasonal fluctuations.

Remain prepared for high patient and vaccine volumes. Once around 75 percent[1] of the global population that is currently willing and eligible to be vaccinated has received their full recommended dosage, the need for an additional 7 billion to 9 billion doses annually will be driven by 3 factors. First, another 4 billion to 5 billion doses will make up the first round of "booster shots," where those who were already fully vaccinated receive a subsequent dose in order to maintain their immunity. Second, another 2 billion to 3 billion doses will be earmarked as initial vaccinations for newly eligible patient groups, such as children under the age of 12 who are currently ineligible but will likely have their turn at the conclusion of current clinical trials. Finally, time will likely turn many in the "currently eligible but unwilling" category into new patients. This category would account for around another estimated 1 billion doses (assuming a 10-percentage-point uptake in willingness to be vaccinated).

ESTIMATED ADDITIONAL VACCINE QUANTITIES FOR 2022 AND BEYOND
BILLIONS PER YEAR — EXHIBIT 8



Source: UN Department of Economic and Social Affairs; Johns Hopkins Center for Communication Program; DHL analysis

Maintain logistics infrastructure and capacity. Supply chain professionals wonder if and how transportation and storage requirements might need to be adapted once vaccine formulas change to tackle mutations. Fortunately, no new transportation requirements are expected. As of today, it is highly likely that these changes will mainly impact the R&D stages of vaccines and their production. The implications for fulfillment, transportation, and distribution are expected to be minimal, as shown in Exhibit 9.

What's more, the elimination of ultracold-chain requirements due to temperature stabilization is expected to reduce the complexity of transportation even further, and these potential advancements could also be maintained when the vaccine formulations are adapted to tackle mutations, as long as blueprint trials and approvals are in place.

Meanwhile, companies and partnerships are even developing alternative vaccine delivery methods, including nasal sprays, injections, and oral vaccines (capsules and tablets), which could result in further relaxation of temperature requirements as well as longer shelf lives.

1 Johns Hopkins Center for Communication Programs, KAP COVID Global Vaccine Acceptance survey, Wave 19, https://ccp.jhu.edu/kap-covid/vaccine-acceptance/.

Background reading: Why we will still need 7 billion to 9 billion doses per year in 2022 and 2023

Booster vaccinations. Most likely, vaccines will decrease in efficacy over time. Since COVID-19 vaccines have only recently been developed the exact duration and long-term levels of protection offered by vaccines and/or past infection is hard to predict. While researchers agree that we will likely need booster vaccination against the same virus strain, the exact time intervals have yet to be determined. Moderna's Phase 3 data shows that "antibody activity remained high" (90 percent efficacy) 6 months after patients received the second vaccine. Similarly, Pfizer/BioNTech's Phase 3 trials show that the vaccine's efficacy remains at over 91.3 percent 6 months after the second dose. On April 15, 2021, Pfizer CEO Albert Bourla stated that a third shot will "likely" need to be administered within 6 to 12 months, followed by an annual booster shot.

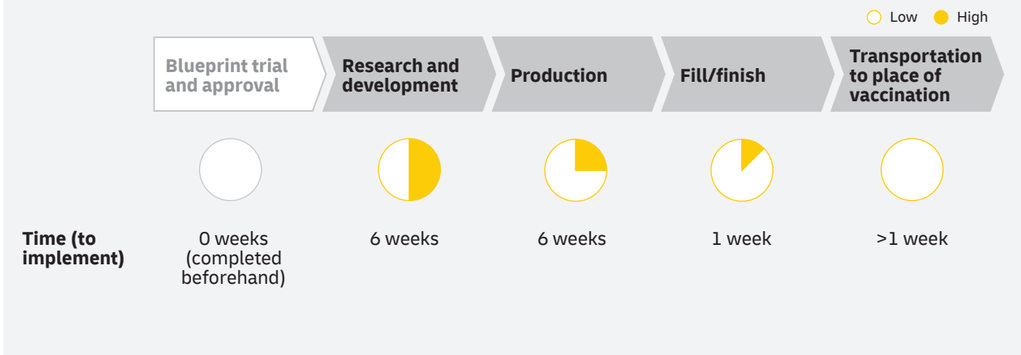
Until further studies reveal the true shape of these efficacy curves beyond 6 months and/or a mutation arises that seriously compromises the efficacy of today's vaccines, experts suggest planning for a vaccination model similar that of the annual influenza shot.

Therefore, we will need to produce and administer booster shots on a regular basis. Based on the current level of willingness to be vaccinated, we expect between 4 billion and 5 billion booster shots to be administered globally in 2021. In later years, this number could go up to 6 billion to 7 billion booster vaccines as more individuals and groups (e.g., children under 12) get vaccinated. The same vaccine volume would apply should we need vaccines to be adapted slightly in case of mutations. However, should we see new mutations emerge that are radically different, we may need a new double-dose vaccine, which would require a global vaccine volume of 12 billion to 14 billion.

Expanding vaccinations to new groups, including children. Promising studies are being run on vaccinating children over the age of 12 with the currently approved vaccines. Hence, this age group is likely to become vaccine-eligible in the coming months, and we assume that many of the 12- to 18-year-olds will be vaccinated in 2021. Approval for children under the age of 12 is less certain and expected to take more time. However, should COVID-19 vaccines be approved for young children by 2022, an additional 2 billion to 3 billion doses would be required.

New patient vaccinations. As the prevalence of COVID-19 continues, it seems plausible that the willingness to be vaccinated will increase over time. This could be because global levels of trust in the efficacy and safety of vaccines will increase and/or targeted and proactive communications reach more remote communities. Furthermore, when new variants emerge that may be even more transmissible than today's dominant B.1.1.7 variant, there will be greater pressure for people to be vaccinated to avoid another acute pandemic. Therefore, it seems plausible that in the next 1 to 2 years, about 500 million additional people could be vaccinated per year, which would require about 1 billion doses.

EXPECTED LEVEL OF CHANGE REQUIRED TO ADAPT THE VACCINE TO A MUTATION EXHIBIT 9

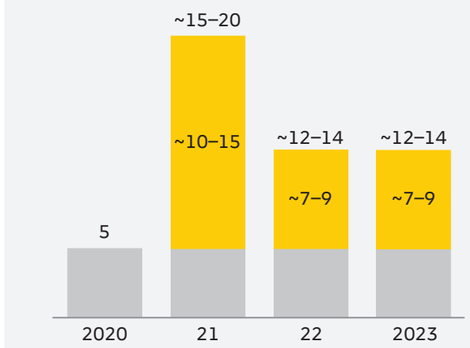


Plan for seasonal fluctuations. While several trials to determine the long-term efficacy of vaccines are underway, experts currently suggest planning for an annual COVID-19 shot similar to the influenza vaccine. The annual flu shot stimulates an immune response to one or more of the prevalent seasonal flu variants. It is developed twice a year – once for the northern hemisphere and once for the southern hemisphere – and the composition of the vaccine is based on dominant flu variants as determined by international experts and data gathered by the Global Influenza Surveillance and Response System.

Therefore, the production, logistics, and administration of COVID-19 booster vaccines are expected to be highly predictable. If we assume that vaccines will need to be administered globally once a year, the quantities can be produced, transported, and stored in advance. Due to the predictability, it is plausible that over time, sea freight will become the preferred mode of transportation for some of the volume. Furthermore, depending on the readiness and capacities of national and regional (ultra)cold-chain infrastructure, vaccines may be able to be stored longer than they can be today. Due to the current high demand, COVID-19 vaccines are administered immediately or only stored for a few days, while flu vaccines are stored for up to 3 months.

In summary, these analyses show that the COVID-19 vaccine supply chain remains critical going forward, as an additional 7 to 9 billion doses of COVID-19 vaccines and corresponding ancillary supplies are expected to be distributed in 2022 and 2023. As a result, the global demand for vaccine shipments will stay at 2x to 3x its precrisis level. However, once the 2021 peak volumes have been distributed successfully, the global supply chain will provide a well-equipped platform, as we expect only 70 percent of 2021 volumes, more predictable demand flows, and relaxed temperature requirements.

PROJECTED GLOBAL VACCINE SHIPPING VOLUMES
BILLION DOSES EXHIBIT 10



Source: Airfinity and UNICEF Data; DHL analysis

GETTING READY FOR THE NEXT RACE

ENSURING SYSTEMATIC PREPAREDNESS FOR THE NEXT PUBLIC HEALTH EMERGENCY

In the same way that runners train between races, we must maintain a level of conditioning that keeps us prepared for the next global health event. Therefore, the need to plan and prepare in order to ensure early identification, efficient containment, and effective remedies is imperative. History has shown that respiratory viruses are the most prone to pandemic spread, so the next public health emergency could be quite similar to the current one. This means that maintenance of the infrastructure we are building to tackle COVID-19 could be useful in the future. Furthermore, the costs associated with the setup and maintenance of a targeted, fit-for-purpose supply chain are much lower when compared with the ad hoc and auxiliary costs of a reactive emergency supply chain.

To this end, this section sets out 10 key strategic actions across the 3 key categories of public health emergency management: prevention and early identification, containment and countermeasures, and medication rollout capacity. While several of the strategic actions (e.g., early-warning systems, digital contact tracing, and national stockpiles) might have already been set up in some countries in response to the COVID-19 pandemic, it is important that these become expanded and institutionalized to ensure strategic preparedness. As this public health crisis has shown, institutionalizing preparedness in the public health space, especially around containment and countermeasures, can save lives. Therefore, we believe that the sum of these measures will help the public sector and health service providers ensure systematic preparedness and efficient response times for public health emergencies in the future.

10 STRATEGIC ACTIONS THAT GOVERNMENTS AND OTHER STAKEHOLDERS SHOULD CONSIDER PURSUING NOW

Prevention and early identification

1. Institutionalize active partnerships and systems
2. Double down on global early-warning systems
3. Create and follow through on an integrated epidemic-prevention agenda
4. Invest in targeted R&D to improve diagnostics, therapeutics, and vaccines

Containment and countermeasures

5. Implement national containment and escalation plans
6. Leverage digital contact tracing and monitoring apps
7. Establish emergency stockpiles and an associated “supplies and logistics” emergency system

Medication rollout capacity

8. Maintain “ever-warm” manufacturing capacity
9. Define blueprint research, production, and procurement plans for diagnostics, therapeutics, and vaccines
10. Maintain and expand rollout capabilities for diagnostics, therapeutics, and vaccines

Prevention and early identification

1 **Institutionalize active partnerships and systems**

It's important to conduct regular outbreak simulations and cross-sector preparedness activities and support epidemiological response capacity. Cross-sector partnerships should be in an "always-on" state to allow for rapid response when the next crisis hits. This also involves information sharing systems, which consolidate data from different partners.

2 **Double down on global early-warning systems**

This includes surveillance systems – both national and regional mechanisms – that collect information on epidemic-prone diseases and implement statistical methods to evaluate the potential epidemiological trajectory. Taking the systems implemented in South Korea following the SARS and MERS crises of 2012 and 2015, respectively, as an example, these early-warning systems should immediately trigger prompt international public health interventions when appropriate.

3 **Create and follow through on integrated epidemic-prevention agenda**

Instead of a reactive approach to outbreaks, an internationally aligned and proactive approach to deepening our understanding and tackling the root causes of outbreaks could help prevent them altogether. These include increasing our understanding of the global virome to discover unknown zoonotic viral threats and limiting antimicrobial resistance. Other measures include understanding and reducing the risk of zoonotic disease in shared human–wildlife environments through a One Health approach, increasing environmental protection, and decreasing deforestation and monocultures in agriculture. A further point of action would be to close the global immunization gap, which is an objective of Gavi, the public–private partnership that has vaccinated over 760 million children since 2000.

4 **Invest in targeted research and development to improve diagnostics, therapeutics and vaccines**

R&D of diagnostics, therapeutics, next-generation antibiotics, and vaccines against known threats must be accelerated. Lessons from the COVID-19 pandemic show that investment in vaccines and broad-spectrum antivirals that can tackle a range of different viruses (potentially including viruses that their yet to emerge) is critical for managing the next viral outbreak. Furthermore, platforms for R&D focused on emerging infectious diseases should be established to increase global capacities for identification and early warning.

Containment and countermeasures

5 **Implement national containment and escalation plans**

These plans should be tied to the early-warning systems described above and include clear decision cadences that predefine the actions needed to contain virus spread given the evidence at hand. Actions may include quarantine regulations, local lockdowns, and testing regimes. One example at a national level is Rwanda's pandemic management effort, which includes the implementation of random testing and community contact tracing.

6 **Leverage digital contact tracing and monitoring app**

Implementing a digital patient management system can help governments and healthcare authorities share accurate information, promote patient safety, and prevent misidentification. Furthermore, contact tracing apps for effective transmission monitoring can help to relieve governments and healthcare authorities. While initially costly, such systems Virus containment spread of viruses and decrease fatalities, as has been demonstrated in Taiwan and South Korea. In addition to the technical infrastructure, such systems need to be institutionalized through buy-in for users, partnerships with other stakeholders (e.g., restaurants), and an agile legal framework (e.g., data protection guidelines and a framework for potential mandatory use).

7 **Establish emergency stockpile and associated "supplies and logistics" emergency system**

Containment will be most successful if countries already have much of what they need when the moment arises. This includes a national safety stock of key supplies, such as masks, tests, disinfectant, freezers, packaging, and dry ice. As the COVID-19 pandemic has demonstrated, the cost of maintaining a safety stockpile is very minimal compared to the cost of having to set up a last-minute emergency system. Based on experience with stocks of flu vaccines and ancillary supplies, the optimal per capita levels and maximum cost-effectiveness can be determined – meaning that countries will not need to stock more than is necessary. Moreover, stock cycling systems should be designed in such a way as ensure that the materials are put to use in the healthcare system before they expire, to keep waste at a minimum. To support the rapid rollout of these measures, countries might consider frame contracts with preferred logistics providers, which can ensure timely and flawless distribution whenever needed. Selection should be based on providers' access to global shipping networks at scale, the size of their local footprints, process excellence, data-driven insights, resilience, and demonstrated crisis response. Furthermore, adequate and reliable stockpiles need to be accompanied by frame contracts with preferred suppliers. Based on an initial long-list of potential supplies, countries should predetermine and contract a diverse set of preferred suppliers for key emergency products (e.g., masks, tests, disinfectant, freezers, packaging, dry ice), balancing risks related to location, transportation breakdown, or production shortages. By contracting these suppliers early on, governments can audit their quality and performance before an emergency and rely on them when needed.

Medication rollout capacity

8 Maintain "ever-warm" manufacturing capacity

Even between crises, public entities and NGOs should support the development and maintenance of manufacturing capacity for diagnostics, vaccines, and therapeutics on a global scale. Supporting such "ever-warm" capacity will enable a quick ramp-up to large-quantity production in case of an emergency, and diversify risks. Furthermore, such manufacturing capacity can support commercial production during noncrisis times. For example, both viral vector and mRNA platforms have found applications in more routine medical procedures such as gene therapy and personalized cancer treatment.

9 Define blueprint research, production and procurement plan for diagnostics, therapeutics, and vaccines

To support the development and production of diagnostics, therapeutics, and vaccines in case of a large-scale viral outbreak at an international level, there is a need for better coordination and collaboration of medical, scientific, and regulatory experts. The current World Health Organization R&D blueprint, with its disease-specific R&D road maps, target product profiles, and generic protocols, may serve as a basis. In addition to exploring how to support this framework, national governments should also work on processes and framework agreements and terms for early and reliable diagnostics, therapeutics, and vaccine purchase orders.

10 Maintain and expand rollout capabilities, for diagnostics, therapeutics, and vaccines

Based on the lessons learned from COVID-19, infrastructure (e.g., tools, plans, and partnerships) should be built to support in-country distribution of diagnostics, therapeutics, and vaccines as needed. Maintaining such rollout capacities means defining which products can be sourced nationally and which ones need to be imported, and instituting expedited processes (e.g., removal of import barriers) for the latter. Working together with preferred logistics suppliers in their country, governments should set up transportation protocols for commodity-specific requirements (e.g., temperature and shelf life) and identify transportation routes based on the existing transportation infrastructure, location of stockpiles, warehouses and delivery points, and the seasonality of the commodities to be transported.

In many critical ways, COVID-19 caught the world off guard. Knowledge gaps were quickly filled, but even when countries knew what they would need to protect their populations, getting their hands on those assets proved difficult. The good news is that through a concerted global effort and collaboration across sectors and borders, early barriers in medical supply chains were removed. By the time critical vaccines came to market, supply chains had been restored, and finely tuned end-to-end logistics processes ensured the safe and timely delivery of an unprecedented volume of vaccines and ancillary supplies around the world, with record-setting speed.

With the lessons learned and the partnerships and capabilities built over the last 12 months, countries now have a wealth of tools and insights at their disposal. Another global health event may be inevitable, but we don't have to trip over the same hurdles that held us back in 2020. With the right systems in place, the global community will be in a position to start on much better footing and meet the next challenge in a way that minimizes the impact on human lives and the global economy.

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