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بسم الله الرحمن الرحیم

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Lessons Learnt from COVID-19 Pandemic

Strategic lessons for vaccine innovation, manufacturing, public health preparedness and equitable access

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INNOVATION
platform readiness

RESILIENCE
industrial capacity

EQUITY
trusted access

October 2026 | Evidence-led, forward-looking



A fast timeline — and an unfinished preparedness agenda

The emergency phase has passed, but key governance and access questions are still being worked through.

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Current status matters: the WHO Pandemic Agreement was adopted in 2025; its Pathogen Access and Benefit-Sharing (PABS) annex remained under negotiation in September 2026.

Sources: WHO (2025, 2026); European Commission (EU Vaccines Strategy); supplied reports (2023).

The next pandemic is shaped before it begins

The central question for vaccine leaders: which capabilities must be ready before the next threat emerges?

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Sources: GAO (2021); Feddema et al., Vaccine (2023); WHO / CEPI materials listed in references.

Five lessons for leaders

The strongest response links discovery, manufacturing, quality, delivery and trust into one operating model.

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From emergency success to **enduring capability**

Sources: supplied WHO / CoVDP reports (2023); GAO (2021); Feddema et al. (2023).

Speed came from parallel work — not from removing evidence

The COVID-19 response compressed elapsed time by overlapping activities and funding risk earlier.

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The trade-off was moved forward: financial and manufacturing risk increased early, while scientific and regulatory evidence still had to mature

Sources: U.S. GAO GAO-21-319 (2021); EMA COVID-19 evaluation guidance; CEPI (2025).

A compressed timeline still needs hard quality gates

A fast path is credible only when each hand-off has clear evidence, ownership and decision criteria.

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Governance principle

Streamline process and preparation — never substitute speed for data integrity, manufacturing control or pharmacovigilance.

Sources: EMA COVID-19 guidance; WHO vaccine regulation and quality control; GAO (2021).

A diversified platform portfolio is a strategic hedge

Different platforms create options; platform choice must match pathogen, speed, quality, supply and deployment needs.

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mRNA

Rapid sequence redesign; depends on specialized inputs and delivery systems.

RNA sequence + lipid delivery



Viral vector

Uses a delivery vector; manufacturing and immunological considerations differ by construct.

Vector production + potency controls



Protein subunit

Uses a defined antigen; formulation and adjuvant performance are important.

Antigen expression + purification



Inactivated

Established technology base in many settings; requires reliable antigen production and inactivation control.

Bulk antigen + inactivation validation

Resilience principle: diversify options, but maintain quality systems and real production readiness on each platform.

Sources: GAO (2021); WHO mRNA Technology Transfer Programme; WHO vaccine quality framework.

Manufacturing readiness is an end-to-end chain

A bottleneck at any interface can slow the release of usable doses.

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Every stagie depends on a strong foundation

CAPACITY
Facilities, equipment, people

INPUTS
Critical materials & consumables

KNOW-HOW
Technology-transfer talent

COORDINATION
Priority allocation and interfaces

Sources: Feddema et al. (2023); GAO (2021); WHO vaccine regulation and quality control.

The bottlenecks were systemic — not just scientific

A 2023 study combined a scoping review with roughly 80 interviews and roundtable discussions.

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~80
interviews & roundtables
Study method; not sample survey

1. **Facility capacity** — Limited facilities, equipment or ability to scale out
2. **Critical inputs** — Raw materials and consumables in constrained supply
3. **Tech-transfer talent** — Too few experienced people to transfer and troubleshoot processes
4. **Coordination** — Misaligned stakeholders and regulatory/operational interfaces
5. **Trade restrictions** — Protectionist measures can disrupt cross-border flows

Implication: map dependencies and coordinate scarce resources before the emergency, not during it.

Source: Feddema JJ et al. Vaccine. 2023;41(30):4359–4368. doi:10.1016/j.vaccine.2023.05.027.

Regulatory readiness is part of manufacturing readiness

Prepared pathways can save time — provided they preserve evidence, traceability and accountability.

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01



EARLY DIALOGUE

Agree evidence plan, endpoints, CMC dossier and inspection needs.

02



ROLLING REVIEW

Submit mature data packages as they become available.

03



EMERGENCY / CONDITIONAL PATHWAY

Authorize only when available evidence supports benefit–risk.

04



LOT RELEASE & MONITORING

Maintain manufacturing controls and track product performance.

A faster review is not a lower standard. | Prepared data • clear ownership • robust follow-up

Sources: EMA COVID-19 evaluation guidance; WHO regulation and quality control of vaccines; WHO EUL documentation.

Safety monitoring is a continuous loop

Authorization marks the start of population-scale use — not the end of evidence generation.

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A report after vaccination is a signal to investigate — not proof of causation.

Use case review, population-level data, and epidemiological assessment to evaluate potential signals.

Sources: WHO vaccine quality framework; WHO / CoVDP reports supplied; EMA COVID-19 guidance.

Supply resilience requires visibility before a shortage

COVID-19 exposed vulnerabilities in critical inputs, transport, packaging and global allocation.

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Critical inputs

Raw materials, reagents, consumables

Manufacturing

Facilities, people, tech transfer

Packaging

Vials, stoppers, syringes, labels

Release

Testing, documentation, lot release

Distribution

Cold chain, allocation, transport

- **Map dependencies**
- **Dual-source critical inputs**
- **Contract surge capacity**
- **Coordinate allocation**

Preparedness includes the boring parts: supply mapping, maintenance, contracts and quality documentation.

Sources: GAO (2021); Feddema et al. (2023); supplied WHO / CoVDP report (2023).

A finished dose still has to survive the delivery system

Product-specific storage rules, unpredictable shipments and short shelf lives complicate last-mile logistics.

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1. **Plan stock** — Match product, site and eligible population
2. **Protect temperature** — Monitor cold-chain conditions
3. **Rotate stock** — Use expiry-aware allocation
4. **Track use & waste** — Reconcile doses, returns and disposal

Operational objective: the right product, in the right place, at the right time — with minimal avoidable wastage.

Source: supplied report, The COVID-19 Vaccination Response (2023), Chapter 4; Stocktake report (2023).

Equity is an operating requirement, not a communications slogan

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Delivery models must be designed for older adults, people with comorbidities and underserved communities.



01 Fixed sites
Known locations and reliable staffing

02 Mobile outreach
Reach remote and low-mobility groups

03 Community partners
Trusted messengers and local planning

04 Integrated services
Combine vaccination with routine care

Equity is built into delivery design — from the fixed site to the last mile.

Sources: supplied WHO / CoVDP country-experiences report (2023); Stocktake report (2023).

Trust needs the same operational discipline as supply

Misinformation, changing guidance and low confidence can reduce the public-health value of available doses.

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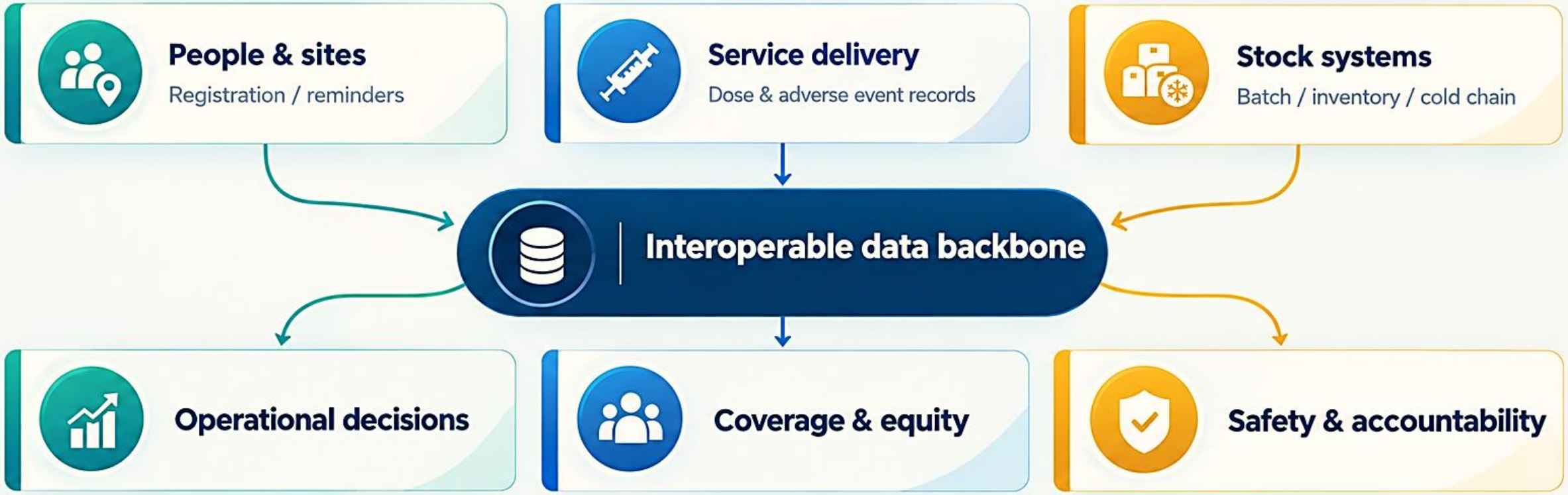
Communication should explain benefits, risks, uncertainty and what is changing — without overstating certainty.

Sources: supplied WHO / CoVDP country-experiences report (2023), Chapter 5; Stocktake report (2023).

Digital systems create value when they connect, not when they duplicate

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Registration, stock management, service delivery and monitoring should share reliable data and workable fallbacks.



Case examples in the reports: India's Co-WIN linked registrations and monitoring; Rwanda adapted DHIS2 for real-time tracking.

Sources: supplied WHO / CoVDP report (2023), Chapter 6; Stocktake report (2023).

Human resources are surge capacity — not an afterthought

Mass vaccination requires different roles, training, supervision and staff well-being protections.

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Communication & community

Risk comms, engagement, demand



Vaccine handling

Stock, storage, transport, cold chain



Vaccination teams

Registration, screening, administration, safety



Data & monitoring

Reporting, analysis, dashboards, follow-up



Supervision & support

Training updates, troubleshooting, staff well-being

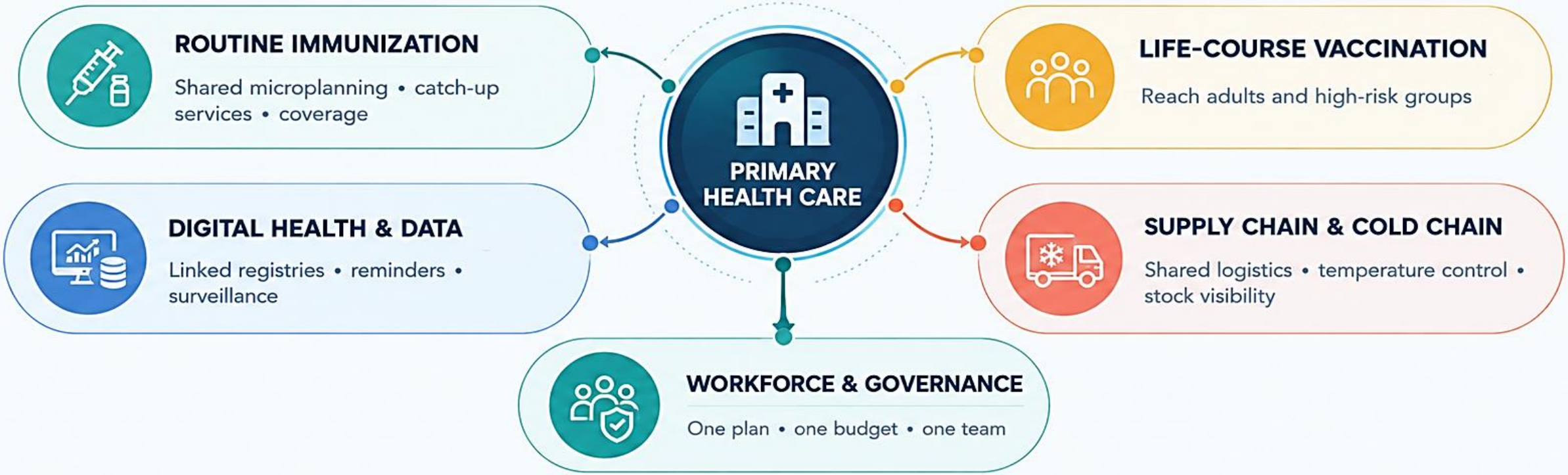
Capacity planning must avoid hollowing out routine services while the emergency programme scales up.

Source: supplied WHO / CoVDP country-experiences report (2023), Chapter 2; Stocktake report (2023).

Emergency structures should leave stronger routine systems behind

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COVID-19 investments can strengthen primary health care and adult / life-course immunization if integration is planned.



DESIGN FOR SUSTAINABILITY

1. Map shared assets
2. Fund recurrent costs
3. Track equity and routine coverage

Turn emergency capacity into durable, equitable primary care.

Source: Stocktake on COVID-19 Vaccination and Integration (2023); supplied WHO / CoVDP report (2023).

United States: accelerate by sharing risk early

Operation Warp Speed paired public investment, a diversified candidate portfolio and manufacturing during trials.

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UNITED STATES

Operation Warp Speed

Public–private effort to accelerate candidate development, manufacturing and delivery.

What it did ?

Portfolio diversity
Supported multiple vaccine candidates using different platform technologies.

Parallel timelines
Combined or overlapped selected study activities where justified.

At-risk manufacturing
Started scale manufacturing during ongoing clinical development.

Supply intervention
Prioritized critical supplies and worked on capacity bottlenecks.

Lesson: early public financing can reduce time-to-scale — but it does not remove supply constraints.

Source: U.S. GAO, GAO-21-319 (11 Feb 2021). https://www.gao.gov/products/gao-21-319

Europe: coordinate demand and reserve surge capacity

The EU used pooled procurement and expanded production — then established an “ever-warm” capacity network.

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€2.7B

up-front support via Emergency Support Instrument

2020 vaccine strategy

20M → 300M

doses/month production capacity and output



early to second half of 2021

325M

doses/year reserved capacity



EU FAB across mRNA, vector and protein platforms

EU FAB

A standing network of contracted manufacturers with facilities, staff and supply chains maintained for rapid activation.

PRE-AGREED CAPACITY

Strategic shift: move from emergency expansion alone toward maintained, activatable capacity.

Sources: European Commission, EU Vaccines Strategy; HERA / European Commission EU FAB.

Asia: manufacturing strength must connect to readiness

Asia is not a single model — but regional capability, regulation and collaboration are increasingly linked.

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> “Manufacturing scale alone does not guarantee timely access.”



INDIA

Large-scale vaccine manufacturing; digital systems such as Co-WIN supported mass rollout.



CHINA

WHO-listed inactivated and vector vaccines show the importance of manufacturing quality and transparent data.



INDONESIA

Bio Farma was selected as a recipient of WHO mRNA technology transfer, linking existing manufacturing with new platforms.



REGIONAL NETWORKS

Regulatory reliance, trial capacity and cross-border coordination support faster deployment.

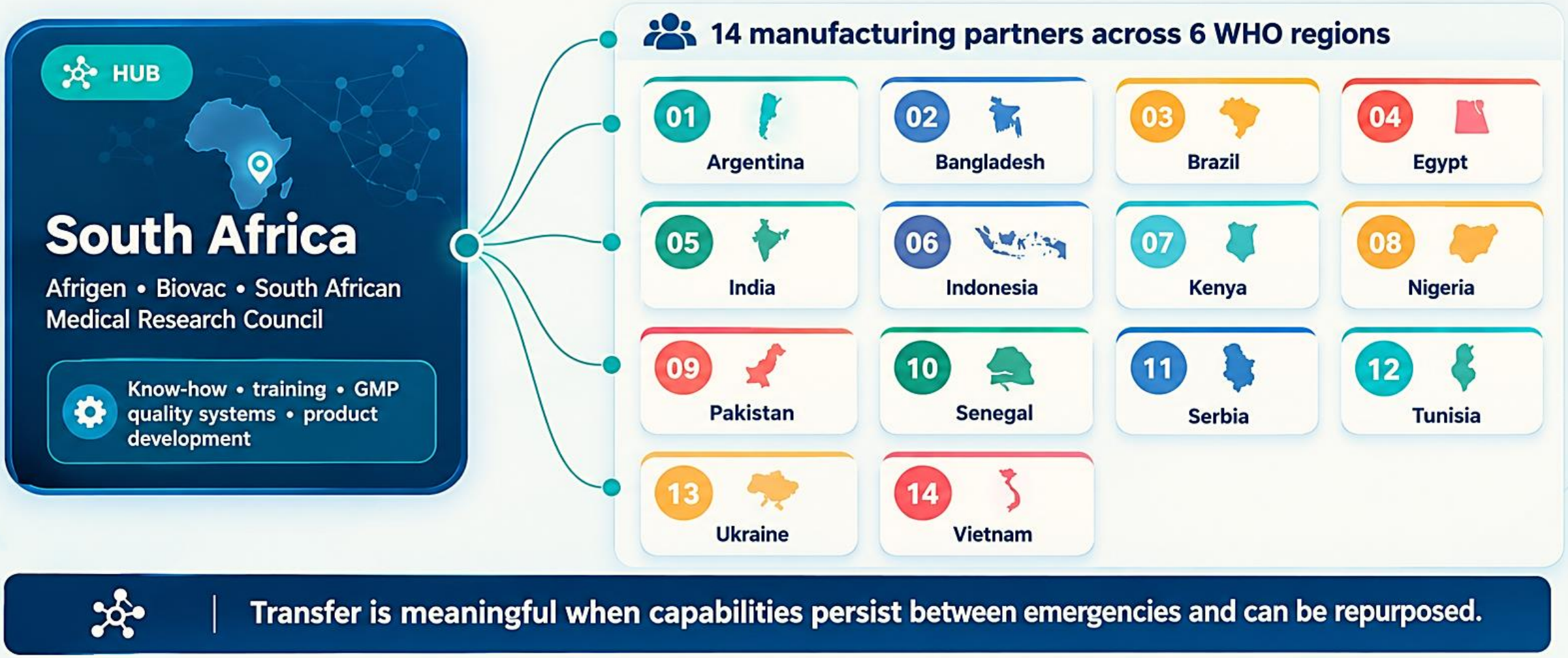
Lesson: manufacturing volume is only one part of regional health security; regulation, technology access and clinical networks matter too.

Source: WHO South-East Asia, CEPI Asia-Pacific Workshop speech (10 Mar 2026); WHO manufacturing workshop (2022).

Technology transfer is a network — not a single hand-off

WHO’s mRNA programme illustrates a hub-and-partner model intended to build sustainable regional capacity.

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Source: WHO mRNA Technology Transfer Programme; status as of 1 May 2025.

“Local production” is not one capability

A country or manufacturer can perform one or several links in the value chain; the dependency profile differs.

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01



Fill–finish & packaging

Useful surge capacity, but depends on imported bulk product or technology.

02



Drug substance / antigen

Requires process capability, facilities, controls and reliable inputs.

03



Analytical & quality systems

Methods, reference materials, validation, lot release and stability.

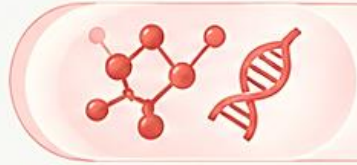
04



Process development & transfer

People, technical know-how, comparability and scale-up expertise.

05



Platform R&D & critical inputs

Sustained innovation, materials access and ability to adapt to new threats.

A strategic capability map should identify what is owned, what is outsourced, what can be activated, and what needs a partner.

Sources: WHO regional manufacturing workshop (2022); WHO mRNA Technology Transfer Programme; Feddema et al. (2023).

COVAX showed the value — and the limits — of pooled access

Global collaboration enabled access at scale, but early supply inequities persisted.

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FINANCE

Donor / public funding



PORTFOLIO

Investment in candidates



PROCUREMENT

Pooled purchasing / allocation



DELIVERY

Country readiness & last mile

What worked — A shared platform for financing, development and access.

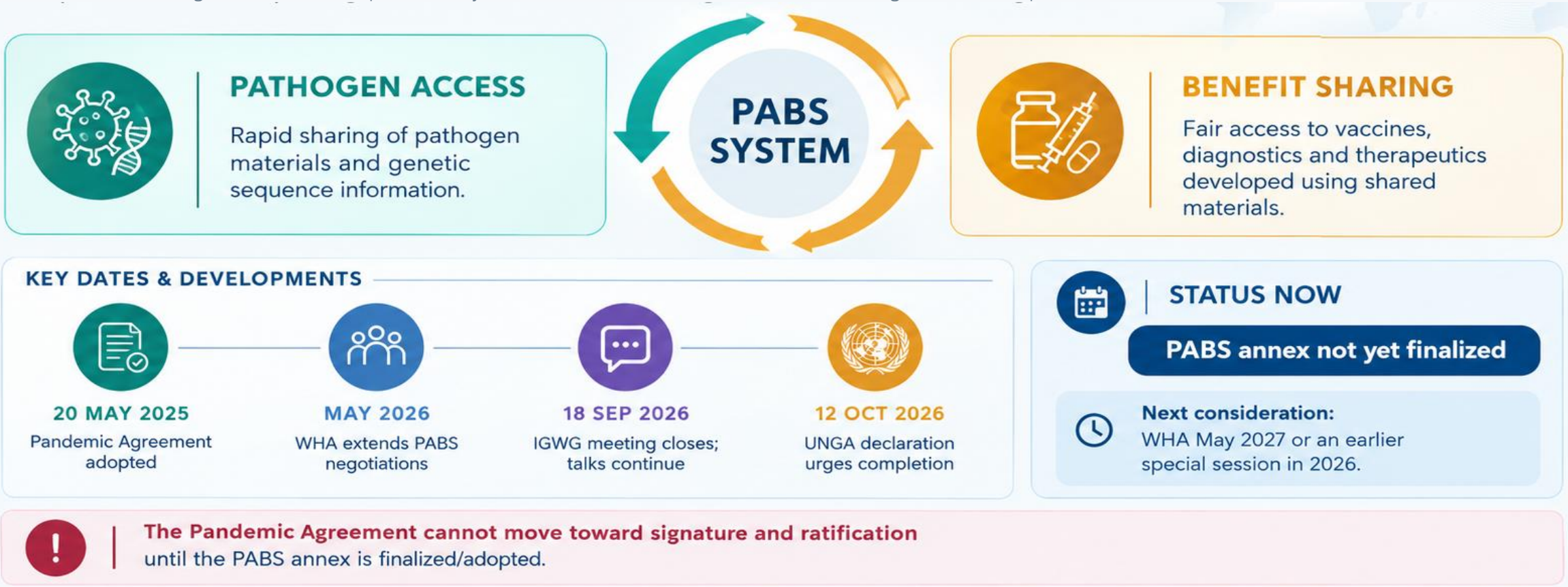
What remained hard — Early supply, export limits, delivery capacity and uneven coverage.

Sources: WHO COVAX overview; EU Vaccines Strategy; supplied WHO / CoVDP reports (2023).

Global rules are evolving, access and benefit-sharing remain central

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The WHO Pandemic Agreement was adopted in May 2025; the PABS annex remained under negotiation in September 2026.



Sources: WHO (20 May 2025; 18 Sep 2026).

The 100 Days Mission shifts the focus to pre-pandemic preparation

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The aspiration is to develop a safe and effective vaccine within 100 days of identifying a pandemic threat.



From identifying a pandemic threat to a safe and effective vaccine — an ambition that depends on years of readiness.

Manufacturing process
Ready-to-transfer process and control strategy

Formulation
Stability, presentation and delivery knowledge

Analytics
Potency, identity, purity and comparability methods

Supply chain
Critical inputs and reserved suppliers

Facilities
Maintained, staffed, tested capacity

Sources: WHO (20 May 2025; 18 Sep 2026).

Measure readiness with operational indicators, not a slide deck score

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The following is a proposed management dashboard, not an official WHO score or validated index.

PRODUCT

Sequence → candidate time

Median days from sequence receipt to a development-ready vaccine candidate.

TRACK
DAYS TO CANDIDATE



CAPACITY

Reserved / activatable dose capacity

Doses per month that can be mobilized within a defined activation window.

TRACK
DOSES / MONTH

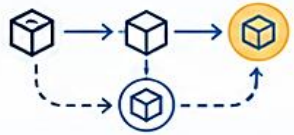


SUPPLY

Time to replace a critical input

Days to qualify and receive an approved alternate for a critical material.

TRACK
DAYS TO SUBSTITUTE



QUALITY

Batch-release lead time

Days from end of manufacture to documented quality release.

TRACK
DAYS TO RELEASE



PEOPLE

Qualified surge workforce

Trained staff. available within a defined notice period; report qualified FTEs.

TRACK
AVAILABLE FTES



ACCESS

Release → priority-group delivery

Days from product release to arrival at priority sites, reported by region.

TRACK
DAYS TO DELIVERY



For every KPI, assign an owner • baseline • target • data source • escalation threshold • exercise cadence.

Framework synthesized from GAO (2021), Feddema et al. (2023), WHO / CoVDP reports and CEPI readiness work.

A practical roadmap: secure the basics, connect the system, rehearse the response

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A three-horizon plan to turn COVID-19 lessons into institutional capability.

0–12 MONTHS

MAP & CLOSE GAPS

- Map product / platform capabilities
- Identify single-source inputs and bottlenecks
- Name owners for quality, safety and response
- Run a baseline readiness review

1–3 YEARS

BUILD & CONNECT

- Reserve contract manufacturing capacity
- Establish tech-transfer and analytics packages
- Integrate digital, stock and safety data
- Align emergency regulatory interfaces

3–5 YEARS

SUSTAIN & STRESS-TEST

- Maintain warm capacity and qualified staff
- Exercise multi-supplier disruption scenarios
- Review access and deployment partners
- Update readiness metrics annually

Build what must exist before the emergency; exercise what must work during it.

Framework synthesized from GAO (2021), Feddema et al. (2023), WHO / CoVDP reports and CEPI readiness work.

Six decisions for a vaccine-producing organization

Leadership can convert lessons into a capability portfolio with clear ownership and measurable readiness.

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01 

Choose priority platforms

Define which technologies must be maintained and why.

02 

Fund “warm” capacity

Pay to keep people, facilities, analytics and maintenance ready.

03 

De-risk critical inputs

Map dependency tiers; qualify substitutes and multiple suppliers.

04 

Pre-align quality & regulation

Build dossier, validation and safety plans before the emergency.

05 

Connect to delivery partners

Link producer, regulator, procurement, logistics and care networks.

06 

Test readiness annually

Use metrics, simulations and after-action reviews to close gaps.



A leadership decision is complete only when a person, budget, metric and exercise are assigned.

Source: Stocktake on COVID-19 Vaccination and Integration (2023); supplied WHO / CoVDP report (2023).

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Prepare the system, not just the product.

01 Build before the crisis.

02 Connect R&D to scale-up.

03 Protect quality and public trust.

04 Link supply to equitable delivery.

05 Keep capabilities warm and tested.

Lessons Learned from the COVID-19 Pandemic

Thank you



Selected sources | science, manufacturing and regulation

Use these primary and peer-reviewed sources to verify the principal claims and graphics.

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1 **GAO (2021)** — Operation Warp Speed: development status and manufacturing challenges. GAO-21-319.
https://www.gao.gov/products/gao-21-319

2 **European Commission** — EU Vaccines Strategy; production scale-up, Advance Purchase Agreements and EU FAB.
https://commission.europa.eu/strategy-and-policy/coronavirus-response/public-health/eu-vaccines-strategy_en

3 **European Commission / HERA** — EU FAB: reserved vaccine manufacturing capacity across mRNA, vector and protein platforms.
https://health.ec.europa.eu/health-emergency-preparedness-and-response-hera/preparedness/addressing-market-challenges_en

4 **EMA** — COVID-19 guidance on evaluation and marketing authorisation; rolling review procedures.
https://www.ema.europa.eu/en/human-regulatory-overview/public-health-threats/coronavirus-disease-covid-19-public-health-emergency-international-concern-2020-23/guidance-medicine-developers-other-stakeholders-covid-19/covid-19-guidance-evaluation-marketing-authorisation

5 **Feddema et al. (2023)** — Upscaling vaccine manufacturing capacity – key bottlenecks and lessons learned. Vaccine. 41(30):4359–4368.
https://doi.org/10.1016/j.vaccine.2023.05.027

6 **WHO** — Regulation and quality control of vaccines.
https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/vaccine-standardization/regulation-and-quality-control-of-vaccines

Full URLs are provided for verification; historical metrics are dated on the relevant slides.

Selected sources | regional experience and future preparedness

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The regional and governance sources below expand beyond the two reports supplied for this presentation.

7 **WHO (2025)**

mRNA Technology Transfer Programme; partner network status as of 1 May 2025.

https://www.who.int/initiatives/mrna-technology-transfer-(mrna-tt)-programme

8 **WHO South-East Asia (2026)**

CEPI Asia-Pacific workshop: regional collaboration, regulatory reliance and 100 Days Mission.

https://www.who.int/southeastasia/news/speeches/detail/importance-of-regional-collaboration-and-reliance-mechanisms-for-vaccine-development--manufacturing--and-rapid-deployment-cepi-asia-pacific-workshop

9 **CEPI**

Networks: Executing the 100 Days Mission.

https://cepi.net/securing-the-future/networks

10 **Ghanei et al. (2023)**

Exploring the experience of developing COVID-19 vaccines in Iran. Clin Exp Vaccine Res. 12(1):1–12.

https://doi.org/10.7774/cevr.2023.12.1.1

11 **WHO (2025; 2026)**

Pandemic Agreement adopted 20 May 2025; PABS annex status updated 18 September 2026.

https://www.who.int/news/item/18-09-2026-member-states-advance-negotiations-on-pathogen-access-and-benefit-sharing-ahead-of-un-general-assembly-meeting-on-pandemics