Title: Decision-making under epistemic, strategic and institutional uncertainty during COVID-19: findings from a six-country empirical study.

Authors

Sumegha Asthana[a], Sanjana Mukherjee[b], Alexandra L. Phelan[c d], Ibrahim B Gobir[e f], J. J. Woo[g], Clare Wenham[h], Mohammad Mushtuq Husain[i], Tahmina Shirin[j], Nevashan Govender[k], Mohannad Al Nsour[l], Winifred Ukponu[e] Adachioma C Ihueze[m], Roujia Lin[a], Sumit Asthana[n], Renee Vongai Mutare[a], Claire J. Standley[a o]

[a]Center for Global Health Science and Security, Georgetown University, Washington, DC, USA

[b]O'Neill Institute for National and Global Health Law, Georgetown University, Washington, DC, USA

[c]Department of Environmental Health and Engineering, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Maryland, USA

[d]Center for Health Security, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Maryland, USA

[e]Georgetown Global Health LTD/GTE Nigeria, Abuja, Nigeria

[f]Center for Global Health Practice and Impact, Georgetown University Medical Centre, Washington, DC, USA

[g]Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore

[h]London School of Economics and Political Science, London, UK

[i]Independent consultant, Dhaka, Bangladesh

[j]Institute of Epidemiology, Disease Control and Research, Dhaka, Bangladesh

[k]National Institute for Communicable Diseases, Johannesburg, South Africa

[l]Eastern Mediterranean Public Health Network, Amman, Jordan

[m]Independent Consultant, Ontario, Canada.

[n]Independent consultant, District of Columbia, USA

[o]Heidelberg Institute of Global Health, University of Heidelberg, Heidelberg, Germany

ABSTRACT

Background: Uncertainty is defined as limited knowledge or lack of predictability about past, present, or future events. The COVID-19 pandemic management was significantly impacted by uncertainty as the gaps between existing information and the necessary knowledge hindered decision-making. Current uncertainty literature primarily focuses on natural disasters, leaving a gap in understanding decision-making under uncertainty in times of public health emergencies. Analysing strategies for making decisions under uncertainty during the pandemic is crucial for future pandemic preparedness.

Methods: Using a comparative research design, we study the strategies governments used to make decisions under uncertainty during the COVID-19 pandemic. We collected data through desk reviews, stakeholder interviews, and focus group discussions with stakeholders from government, academia, and civil society from six purposefully selected countries: Nigeria, Singapore, South Africa, Bangladesh, Jordan, and the United Kingdom.

Results: Regardless of political, geographic, and economic context, all six countries adopted common strategies to make decisions under three types of uncertainties. Decision-making under epistemic uncertainty involved seeking expert advice and collecting evidence from other countries and international organisations. Decision-making under strategic uncertainty involved coordination, collaboration, and communication. Decision-making under institutional uncertainty involved using or adapting pre-existing experiences, structures, and relationships and establishing new institutions and processes.

Conclusions: We contribute to the theory and practice of public health crisis decision-making by presenting a unified national-level applied decision-making framework for events involving

uncertainty. We provide practical guidance for approaches to enhance decision-making in future health crises that could also be used for other emergencies.

What is already known on this topic

•   Health-related decision-making frameworks mainly concern clinical decision-making or individual-level decision-making except for a few overarching COVID-19 government-level frameworks.

•   The existing literature identifies various types of uncertainty and their impact on decision-making. However, most of this literature is in the form of viewpoints and perspectives highlighting the need for guidance informed by empirical evidence of strategies implemented during crisis situations.

What this study adds

•   This study presents a novel unified national-level applied 'decision-making under uncertainty' framework, enhancing existing knowledge of crisis decision-making. This framework is based on the empirical evidence of strategies implemented for making decisions under epistemic, strategic, and institutional uncertainty during COVID-19 in six countries with diverse political, geographic, and economic contexts.

How this study might affect research, practice or policy

•   This study offers a significant contribution to knowledge and practice of decision-making during a health crisis that can be applied to other public emergency and disaster situations. This

evidence gives an opportunity to strengthen governance processes during events involving uncertainty and overall pandemic preparedness efforts at the national level.

INTRODUCTION

Uncertainty is defined as limited knowledge or lack of predictability about past, present, or future events.[1] Uncertainty greatly affected the management of the COVID-19 pandemic, leading to delays in prevention and response efforts and excess morbidity and mortality. The lack of required knowledge impeded decision-making.[2] In addition to the uncertainty about virus's temporal and spatial trends, there was also ambiguity about how effective governments' policies and decisions were in curbing transmission.[3] However, efforts were made to mitigate uncertainty during the pandemic.[4,5]

In recent years, there has been a growing body of work on decision-making under uncertainty, focusing on the decision-making process. Previous disaster management literature suggests various decision-making methods such as policy architecture, and vulnerability analysis,[6] a three-stage approach of decision framing, stress test, and risk estimation,[7] analysis of similar cases[8] and involvement of political power and adjusting monitoring systems.[9] More recently, health-related studies advanced knowledge on decision-making frameworks both in the clinical and public health domains. Individual-level frameworks address issues such as vaccine acceptance[10] and fertility intentions,[11] while clinical decision-making frameworks recommend analysing similar cases to make decisions.[12] Government-level decision-making frameworks suggest stages of cognition, communication, coordination, and control[2] and consider policymaker's characteristics and preferences.[13]

Decision-making under uncertainty frameworks also proposed dividing uncertainty into categories based on its nature, like epistemic, ontological, and ambiguity and objects, such as substantive, strategic, and institutional, to help governments analyze uncertain issues in decision-making.[14] Others also allude to varied types of uncertainty, their causes and their impact on decision-making. For example, epistemic uncertainty deals with lack of knowledge[15] and is caused by unreliable data, missing probabilistic methods[16] and measurement methods,[16,17] or inaccurate assumptions and experts' disagreement[17]. Strategic uncertainty, on the other hand, concerns the deliberate behaviour of actors in interactive decision situations.[18] It pertains to the strategic decisions made by individuals engaged in governance processes.[14] Institutional uncertainty relates to institutional functions and processes that result in ambiguous roles and unclear expected actions.[19] Uncertain institutions are not fully developed, [20] and mitigating this uncertainty limits deviant behavior and provides clearer predictions .[21] While existing literature points to the existence of varied types of uncertainty and their impact on decision-making,[12-30] a unified national-level framework, informed by empirical evidence is needed for future pandemic preparedness and response. To address this gap, we conducted a study in six countries to examine the strategies adopted by governments at the national level for making decisions during the COVID-19 pandemic. This research aims to establish a novel framework that not only consolidates these strategies but also provides a robust empirical foundation for improving decision-making in the face of uncertainty in future health crises.

METHODS

Study design

We followed a comparative research design[22] through individual case studies[23] to examine the strategies adopted by the government at the national level for making decisions under uncertainty during the COVID-19 pandemic. Comparative research design enables us to investigate and understand the variations in the experience of the same social processes in different settings and allows us to understand the behaviours of nations.[22] On the other hand, case studies are empirical inquiry that examine a phenomenon in its real-life context, providing a detailed overview of the phenomenon.[23] The countries were purposively selected to reflect different geographical regions, country-income classifications, governance structures and political regimes. Based on this selection criterion, we invited stakeholders from nine countries, out of which six countries: Nigeria, Singapore, South Africa, Jordan, Bangladesh, and the United Kingdom (UK), agreed to participate in the study.

Data collection

Sources of data and methods of data collection

A combination of literature review, desk reviews of documents, remote and in-person interviews with key informants (KII) and Focus Group Discussions (FGDs) were used to collect data for the study. Documents and literature review provided country context, examined measures implemented during the COVID-19 pandemic, and identified potential key informants. Main sources of documents included 1) academic journal publications, 2) websites and published reports from the country's federal and state governments, 3) websites and reports from local and international organizations, non-governmental organizations, and civil society organizations and 4) local and international news media reports. KIIs and FGDs constituted the primary sources of data for this study. Participants for KIIs and FGDs were purposively sampled to represent a

wide range of organization affiliations, experiences, and views of the COVID-19 pandemic response in the six selected countries. Participants were selected till a saturation in responses was reached. In total, 63 stakeholders agreed to participate in a KII or FGD. A full list of participant types, primary data collection method, and data collection timeline for each country is provided in Table 1. Verbal informed consent was obtained from all participants at the start of the interview or FGD. A semi-structured interview guide and FGD schedule were used for KIIs and FGDs. KIIs and FGDs were conducted in English and recorded for transcription; Otter.ai software (Mountain View, California) was used for transcribing interviews. Each interview took approximately 30–60 minutes, while the FGDs took approximately 120 minutes. To maintain participant anonymity, all responses were de-identified unless participants provided permission for their names and affiliations to be used. To maintain participant confidentiality, all respondents were kept anonymous and given a unique identifier using the country code and a numerical value.

Ethics approval

Georgetown University's Institutional Review Board approved the study (STUDY00005099). Additional research ethics training was completed by researchers under requirements set by the West African Bioethics Training Program. A detailed author reflexivity statement, that examines equitable international research partnerships, is provided in the Supplementary Appendix (Author Reflexivity Statement).

Insert Table 1 List of types of participants and geographic distribution of participants included for key informant interviews and focus group discussions (FGDs)

Country	Participant Recruitment and Data Collection Timeline	Method of Primary Data Collection	Types of Participants	Number of Participants

			Federal Government Officials	7
Nigeria	01-06-2022–30-09-2022	Key Informant Interviews	State Government Officials	5
			Civil Society Organization Representatives	5
			Academic Experts	3
			Development Partner Representatives	1
		Focus Group Discussion	Civil Society Organization Representatives	4
Singapore	01-06-2022–30-09-2022	Key Informant Interviews	Government Officials	8
			Civil Society Organization Representatives	1
			Academic Experts	3
		Focus Group Discussion	Academic Experts	3
South Africa	01-01-2023 -31-03-2023	Key Informant Interviews	Government Officials	4
			Academic Experts	3
United Kingdom	01-09-2022- 30-06-2023	Key Informant Interviews	Government Officials	2
			Academic Experts	4
Bangladesh	01-06-2023- 30-09-2023	Key Informant Interviews	Government Officials	2
			Academic Experts	3
Jordan	01-07-2023-30-09-2023	Focus Group Discussion	Civil Society Organization Representatives	4
		Key Informant Interviews	Academic Experts	1
Total				63

Patient and public involvement

As this was not a patient-focused study, it was not appropriate to involve patients in the design, execution or dissemination of the study.

Data analysis

 KII and FGD transcripts were checked for reliability and completeness. Three independent researchers then analyzed the transcripts, coding data into themes, sub-themes, and codes related to the strategies adopted by the government at the national level for decision-making under uncertainty during the COVID-19 pandemic. Country strategy tables were prepared using the

findings from the literature review, desk reviews of documents, and findings from KIIs and FGDs. The study's primary analytical method drew inspiration from grounded theory[42] and employed an iterative process comprising multiple rounds of coding. The process began with descriptive or open coding, followed by focused and axial coding. The first round of open coding involved breaking down the data as codes describing the content and process for making decisions, such as the creation of task forces, allocation of resources and responsibilities, consultations with subject matter experts, and following the news from international organisations and other countries. The second round of axial coding combined and reassembled these codes under the sub-themes of strategies for decision-making during the pandemic, such as evidence generation, collaboration, coordination, and use of existing capabilities and institutions. During the third and final round of analysis, these sub-themes were reorganised under three broad themes of strategies for making decisions under epistemic, strategic, and institutional uncertainty, resulting in our framework (Figure 1).

Insert Figure 1 Framework for Decision-making Under Epistemic, Strategic and Institutional Uncertainty

RESULTS

Strategies for Making Decisions Under Epistemic Uncertainty

Epistemic uncertainty represents gaps in knowledge and is not well determined by historical observations, resulting from missing, scarce or imperfectly recorded historical data, often leading to incomplete or inaccurate probability estimates.[24] During the COVID-19 pandemic,

governments faced challenges in dealing with the issue of widespread lack of knowledge about the pandemic.[25] This epistemic uncertainty resulted from a lack of knowledge of the virus's mechanism of action, pathogenicity, immune response, duration of disease and immunization, etc.[26] It stems from unreliable data, missing probabilistic and measurement methods, inaccurate assumptions and disagreements between experts.[24,17]

In our study, respondents shared two broad strategies for making decisions under epistemic uncertainty. The first is obtaining evidence from different sources, including local data, data from other countries, and data from international health organisations. The second is consulting and including subject matter and policy experts in the decision-making process (see Table 2).

Obtaining evidence from local data, other countries, and international health organizations.

All six countries collected and shared disease surveillance data, such as infection and reproduction rates, pharmaceutical resource distribution, and people's beliefs and adherence to government policies. Triangulating this data with information from other countries and international organizations helped make decisions under uncertainty.

> I can speak to the masks… It got to a point where we were now looking to see what other countries have been doing and trying to learn from the way they even rolled it out so that we wouldn't rule it out and make the same mistakes, knowing that we would likely face a lot of pushbacks from citizens across the country on this. And I think that was an example of where the government looked to academia, the think tanks, you know, different groups of people to advise. It wasn't the government saying, we know what to do…(Nigeria_18)

In addition, local data was also compared with global information to confirm the data's reliability and alignment. Guidance and data generated from other countries were adopted as a reference for making decisions. Regular meetings with experts in other countries and monitoring publications from other countries constituted the main sources of collecting the information, while all countries paid specific attention to the information from China to evaluate the local situation.

> We were watching them [other countries] closely, and they escalated the readiness response framework that made us concerned that if they were getting additional information. So, that led us to convene our monitoring group within the Ministry of Health to collate and run through the data we had. And we then made a formal recommendation to convene the Homefront Crisis Group on the basis of information (Singapore_11).

Data from international organizations, especially the World Health Organization (WHO), was used in decision-making. National guidelines in all countries were developed using information from WHO as a reference, especially in the context of frequently changing decisions in other countries.

> At the beginning of the crisis, it was very difficult to make any decisions… I think for all the countries, they [other countries] take decisions, and after a few days or few weeks, they change the decision to another decision according to available data (Jordan_2).

Involving experts in the decision-making process

Technical subject matter experts and policy experts are involved in advising decision-makers about evolving data and policy actions in all countries. Each country formed a COVID-19-specific task force consisting of multi-sectoral experts. These taskforces were, in most countries,

divided into further sub-committees or working groups through which multiple experts were invited to continuously and repeatedly review the data, provide inputs on evidence on specific topics, and deliver that evidence to decision-makers.

> The advisories are often revised and re-looked at by a second advisor on the same subject and a third advisor on the same subject because things did move along as the pandemic moved along (South Africa_7).

In addition, Civil Society Organisations (CSOs) were involved in communicating government policies with the public and providing information on people's awareness and perception of the policies. On the other hand, academia was involved in most countries to provide policy-relevant information.

> The School of Public Health, I would say, was one of the main partners that we had in pulling some of this evidence and synthesizing it ... to tell us…what we are seeing and what was changing, so it was very useful…to tell what are the demands on our health care system (Singapore_21).

Countries involved local experts to provide clinical and public health information, provide feedback, and validate the government's decisions. The UK set up an open call for experts in different fields, including experts from natural science and social science. However, respondents expressed ambiguity about their involvement in decision-making. There were also concerns about the delayed involvement of social science experts while making decisions.

> And so, the big gap was that they [the government] didn't have the broader social considerations as part of the initial task force. So that came in later, they had an ethnicity

taskforce. And they [the government] then got anthropologists involved (United

Kingdom_29).

Insert Table 2 Strategies for making decisions under epistemic uncertainty

Strategies for making decisions under epistemic uncertainty

	Local Data Generated Within Country	Guidance and data generated from other countries and international health organizations	Involvement of Advisory Personnel and Experts to Advise Decision Makers About Evolving Data
Bangladesh	The Institute of Epidemiology Disease Control and Research (IEDCR) under Ministry of Health and Family welfare (MoHFW) initiated suspected case investigation and established laboratory capacity for detection of SARS-CoV2. Later active case search and contact tracing activities were scaled up and more than hundred laboratories were equipped for molecular detection of SARS CoV2 across the country. IEDCR and the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) initiated the genome sequencing of the first sixty-seven cases locally, and subsequently, the BMGF supported (National SARS-CoV-2 genomic surveillance in Bangladesh and later on National Respiratory Pathogens genomic surveillance in Bangladesh through a consortium). Wellcome Trust supported the Nationwide genomic sequencing capacity.	Government made decisions based on the WHO guidance and information from other countries.	National Technical Advisory Committee and sub-Committees involving subject matter experts for COVID-19 containment activities were formed under direct supervision of the Prime Minister Office (PMO).
	Management Information System (MIS) of the Directorate General of Health Services (DGHS) and a2i developed real time National COVID-19 dashboard for laboratory testing, hospital information and vaccination status for policy decision. DGHS continued issuing Press releases every day informing the update of COVID-19 cases & deaths and vaccination status in the country.	The government aligned decisions related to case definition and treatment protocols based on guidance from the Director General of the World Health Organization.	Subject matter experts were involved in various working groups and committees for development of guidelines/SOPs in country context for public health measures, treatment, diagnosis, and vaccines etc.
	MIS of DGHS/Information and communication Technology (ICT) Division led the digitization of vaccination activities such as enrollment and issuing of vaccination card, compiled all the data related to vaccination (aligned with National Identity - NID)	UNICEF and WHO worked together with the Ministry of Health to develop a strategic plan for making COVID-19 vaccines available and implementing smooth vaccine distribution.	Subject matter experts, Drug Administration, DGHS, IEDCR were involved in analysing the data for the policymakers.
South Africa	The Incident Management Team (IMT) was constituted to gather information from America and Europe to create draft advisories for the Ministerial Advisory Committee (MAC). The MAC would then formulate a formal draft advisory for the Ministry of Health.	Decisions on interventions such as mask-wearing, social distancing, screening and testing, and vaccination were based on guidance from international organizations like WHO and adapted to the South African context.	Experienced technical experts such as virologists, bioinformaticians, public health specialists and epidemiologists were involved in advisory groups such as MAC.
	Difficulty in obtaining actual data from the ground in the initial wave of the pandemic was reported because the outbreak had evolved very rapidly, and	A small working group, MAC for vaccination, was formed to collate COVID-19 information from Americans and Europeans, including	The WHO experts were involved via working groups to quickly access information on health emergency situations.

	the information systems had limited capacity.	organisations like WHO, the United States Food and Drug Administration (FDA), CDC, the Advisory Committee on Immunization Practices (ACIP), and similar UK bodies.	
	The Multi-sectoral Outbreak Response Team (MNORT) and the memorandum of agreement between the National Department of Health and the NICD were leveraged to establish and operationalize an Emergency Operations Centre (EOC).	International data, such as from the US, Europe, and Southeast Asia, was incorporated and triangulated with local South African data to make decisions.	The government's existing working relationships and collaborations with foreign experts from US CDC and WHO for planning and coordination aided in handling the crisis.
Jordan	Jordan University of Science and Technology (JUST) generated local scientific evidence using a primary synthesis machine at Princess Haya Biotechnology Center.	The government relied on WHO and CDC for information about the virus and preparedness and response policies.	Experts from the Jordanian National Committee for Epidemics initiated almost all decisions taken by the government.
	Online information collection platforms connected directly to hospitals at JUST and Jordan University were established to collect local COVID-19 surveillance data.	The government waited for the information on the virus to come from other countries, especially from the UK and European countries.	The Field Epidemiology Training Program (FETP) and Rapid Response Team (RRT) experts from all over the region were involved in different COVID-19 management sites such as points of entry like airports.
	At the beginning, JUST Hospital was the only hospital dealing with COVID-19 cases; university focal points were part of the National Committee for Epidemics.	Academia accessed publications from Science, Nature, and New England Journal of Medicine to learn about virus behaviour, mutations, and new variants and shared them with decision-making bodies.	Experts from the National Epidemiology Task Force were involved in assessing the epidemiologic situation in the country and producing a monthly bulletin on COVID-19.
Nigeria	Local epidemiological data was collected through the existing Surveillance, Outbreak Response Management and Analysis System (SORMAS).	Decisions for mask-wearing, international travel restrictions and evacuating Nigerians from abroad were based on information from WHO and US CDC	Experts who worked during Ebola, HIV and other infectious disease outbreaks were invited to support COVID-19 management.
	Decisions for the need for social and physical distancing based on locally generated epidemiological data regarding the asymptomatic spread of disease.	Treatment guidelines, including the use of additional drugs at the isolation centres, were changed based on evidence of the effectiveness of dexamethasone from the UK.	Experts in outbreak management, from modelling to public health interventionists, linked with a technical group from the UK, US, and Nigeria were involved to form a small advisory group to the Presidential Taskforce (PTF).
	Local data, such as the at-risk age group and pre-existing health conditions, was validated with global data identified through local case series.	The case definition of COVID-19 to include community transmission was updated based on information from China and Italy.	Experts from NCDC EOC and representatives of different sectors were involved to obtain diverse perspectives on COVID-19 management and response.
UK	The Coronavirus (COVID-19) dashboard provided statistics about vaccinations, cases, deaths, healthcare, and testing to local and national decision-makers.	The government observed decisions about lockdowns in Italy, Sweden, and other countries. However, the UK decisions were reported to have mainly resulted from the modelling data estimates.	The government made open calls for local experts in their respective areas of work to create a roster of experts. However, the level of their integration into policy decisions is unknown.
	The National Health System (NHS) proved effective in working as a unified health system and collecting routine health data from all hospitals across the UK. However, problems were reported with linking public health data with health metrics.	Professionals from various transnational organisations, like the WHO, were consulted to manage the pandemic. However, decisions reportedly accounted for industrial and trade relationships and were based on the national modelling data and perspectives of behavioural scientists within the Cabinet Office.	Decisions regarding COVID-19 management in the SAGE meetings were reportedly not transparent. This led to the establishment of a parallel independent group of experts to disseminate COVID-19-related information.
	The International Severe Acute Respiratory and Emerging Infection Consortium (ISARIC) assembled the world's largest international collection of accessible data on individuals hospitalised with COVID-19 and was helpful in collating clinical data across the UK.	The International Best Practice Advisory Group (IBPAG) helped collect clinical data from other countries to inform policymaking.	The government maintained interactions with professional bodies within the UK, such as with the Royal Colleges of different medical and clinical professions. However, the level of their integration into policy decisions is unknown.

Singapore	Decisions were frequently revised and updated by creating a feedback loop with doctors and clinicians on the ground sharing their learnings.	The government convened the HCEG based on information from Hong Kong regarding their escalated response and border control measures in the initial wave of the pandemic.	Experts and working groups, including a risk communication and community engagement working group, were involved in scanning the literature for evidence supporting or refuting COVID-19 measures and decisions.
	The government adapted to ensure an adequate supply chain in a pandemic setting, as per real-time local data regarding PPE shortages amidst export restrictions.	Early decisions about using mRNA vaccines were based on scientific publications about therapeutics from Israel, China, and Chile.	Long-standing collaborators from the School of Public Health at the National University of Singapore were involved in helping with literature reviews, finding evidence and giving a systematic assessment of existing knowledge about the virus.
	The case definition was updated to include asymptomatic cases based on identified risk factors from ICU patients.	The government was observing China very closely during the initial wave of the pandemic. However, the information from China was sparse. This moved the government to look for information from other countries closer to China.	Clinical experts were involved in synthesizing clinical findings quickly and sharing the new therapeutics and clinical protocols for managing COVID-19 patients.

Strategies for Making Decisions Under Strategic Uncertainty

Strategic uncertainty is defined as ambiguity concerning the deliberate behaviour of players in decision situations.[18] It pertains to the uncertainty surrounding the strategic decisions made by individuals engaged in governance processes.[14] Instituting a timely and trustworthy communication plan and using participative strategies reduce strategic uncertainty control in dynamic situations.[27] During the COVID-19 pandemic, government decision-making was dependent on the behaviours and responses of various actors. The governments made decisions under strategic uncertainty by coordinating with its internal actors, including officials in other ministries and sub-national and community levels, collaborating with external actors such as the private sector, civil society and academia, and most importantly, (risk) communicating with the public (see Table 3).

Coordination among government officials

Coordination refers to the joint action of organizing or putting together in order to achieve the same goal(s).[28] The nature and extent of intergovernmental coordination, whether vertical or horizontal, differed among countries with respect to the implemented measures.[29] Governments

made efforts to coordinate between decision-makers, health officials, and advisory bodies to regulate actors' behaviour and establish strategic consistency within different levels of government. This was achieved by setting up various (ad-hoc) committees, working groups and COVID-19-specific task forces that held regular meetings and involved actors at different levels of governance in the decision-making process.

> …Everybody within MAC [Ministerial Advisory Committee], the clinical people would come in... the modellers would come in…even the ones that were looking at immunology… humoral responses, and we'll be able to craft a presentation for the Minister [of Health]. Then there will be a meeting called by the President, with all the cabinet ministers…and we would make those presentations to say, it's different from what we saw last week, this is what we're seeing. [and ask] Are you, therefore, allowing us to announce this? And so, the announcement will be made together with the Minister of Health...(South Africa_16).

Multi-sectoral Collaboration

On the other hand, collaboration refers to a broader act of two or more persons or organisations working together toward an agreed-upon goal(s).[28] Governments called on experts to contribute to the decision-making process and leveraged diverse stakeholders, such as private sectors, civil society, think tanks, academia, and development partners, to provide assistance with policy implementation, emergency medical supplies, information about the virus, people's awareness and response to government policies, and resource mobilisation.

> So, all the parties, including our Director General of Health Services, Ministry of Health and Family Welfare, other relevant ministries, city corporations, development partners

(UNICEF, WHO) worked together and developed strategic plan for availability of vaccines and vaccines deployment (Bangladesh_12).

Leadership at the highest level played a significant role in establishing and sustaining national and international collaborative partnerships. This leadership varied from the highest positions held by different elected or non-elected public representatives in each country.

It's very difficult to bring all entities of the country under one leadership, including the army, civil society, community and governments, but there are different ministries etc. So, we have one of the strongest factors for us; it was, we have one leadership [the king] that we all respect (Jordan_1).

Public communication

Similarly, effective communication by government health officials to the public about the health emergency status and policies played a significant role in making decisions under strategic uncertainty during the pandemic. Governments in all countries attempted to communicate with the public about the virus, its magnitude, spread and control as well as government policies and justifications at different phases of the pandemic. They used various mediums, including traditional broadcast media through public addresses and chat shows, as well as digital social media using tools like public polls. However, social media, including Twitter and Facebook, were reportedly the most critical channels for public communication.

We recognized in the midst of this crisis that the public also needed an anchor around which they needed to understand how we perceive the threat…that misalignment between what the public perceives and what we were messaging internally… could lead to problems in public confidence and community incidents would start to rise...And so

we've chosen now instead to communicate in a more granular fashion and let [public] know what is important to them (Singapore_11).

Risk communication to the public by relevant government agencies played a significant role in building people's trust in the government and controlling the spread of misinformation pertaining to the nature of the virus, transmission mode, etc, during the pandemic, which further helped the government predict and manage the behaviour of people and make relevant decisions. Nigeria's Centre for Disease Control (NCDC) used public polls to counter false information and address rumours. However, some countries have reported a lack of expertise in countering misinformation on social media.

What has always been appalling in South Africa, in terms of cons, is the health department's Twitter, Facebook, and other sites. They are run by people who have no idea how to manage social media communications, and I think that was one of the great failings in comms [communication] because they allowed misinformation to gain a foothold without a good counterpoint (South Africa_20).

Countries approached communication with the public in different ways. South Africa focused on projecting an image of control, Singapore prioritized transparency and acknowledged uncertainty, and the UK reportedly lacked transparency, resulting in a loss of public trust.

I think you need transparency… and more of a public conversation about the decisions that are being made. And what are the basis for those decisions or the assumptions for those decisions? And I really think that concept of uncertainty needs to come across that we don't know. And so, we are making our best judgment based on these things, but we might be wrong (United Kingdom_ 29).

Insert table 3 Strategies for making decisions under strategic uncertainty

Strategies for making decisions under strategic uncertainty

	Coordinating with its internal actors	Collaborating with external actors	Communicating with public
Bangladesh	Prime Minister Office (PMO) Cabinet Division played a significant role in enabling inter-ministerial coordination.	Government involved NGOs (e.g.icddrb, BRAC) and community volunteers (e.g., grassroots clubs, Medical Associations, students groups) in delivering products and services, especially community mobilization for COVID-19 containment activities and manufacturing consumables like sanitizers and their distribution to the community.	Government created hotline services for the public to obtain accurate and up-to-date information, directives, advices, management etc regarding the pandemic.
	Virtual platforms helped in coordination with different stakeholders, working group meetings. Moreover, feedback of vaccine deployment activities, COVID-19 containment activities at field level were also conducted by virtual platform.	DPs like WHO, UNICEF, USAID and BMGF supported making decisions by providing technical assistance. Health cluster is a collective of UN agencies, Development partners, INGOs NGOs working in Bangladesh. They regularly held meeting to support government.	Government did live media briefings every day to deliver current situation in the country and health education messages for emergency risk communication.
	Government structures, including the Expanded Programme on Immunization (EPI), communicable disease control, IEDCR, and Directorate General of Drug Administration (DGDA) worked in coordination for COVID-19 surveillance, vaccination, and response to adverse effect of following vaccination (if any).	The government benefited from external structures like the COVAX facility to deliver the COVID-19 vaccines to the community.	Regular press release on vaccination status Digital vaccination platform Vaccine campaigning through electronic and print media and community engagement.
South Africa	National COVID-19 Command Council at the cabinet level was reported to be secretive and in a militarized command-and-control manner.	The government collaborated with academic experts such as virologists, infectious disease and infection, prevention and control specialists to work on specific areas about the virus such as to provide input on aerosol transmission of the virus.	The MAC advisories and presentations were published to provide the public with information.
	Meetings called by the president coordinated between the Minister of Health, members of MAC, clinicians, modellers at the South African Centre for Epidemiological Modelling and Analysis (SACEMA), and immunologists.	The government collaborated with other countries through bilateral conferences, such as with China and Russia in the early phase of the local outbreak and through the initiation of public vaccination.	The credibility of the experts was undermined by the media and public due to constant changes in messaging about measures and data.
	Coordinating structures, such as the EOC and IMT, developed during the listeria outbreak, were used during the COVID-19 pandemic.	The government collaborated with the private sector to expand COVID-19 testing from public institutions to private laboratories across the country.	Government health officials communicated frequently about disease metrics to the public and set up a toll-free call line, COVID-19 Hotline (+27800 029 999), to answer questions from the public.
Jordan	National Center for Security steered coordination between all ministries.	Conflicts between the National Center for Security and Health Committees were handled through consultations.	The public reported difficulty in understanding the government's communication because of the difficult terminology used by the government.
	Coordination and governance mechanisms enabled smooth communication and data sharing between national epidemic committees and other ministries.	Frequent communication about lockdown or abandoned travel between the Ministry of Health and the Jordanian National Committee for Epidemics, which includes many academicians, resulted in collaboration between academia and the government.	The government communicated with the public via TV talk shows like Nabd Al Balad/Roya TV and Sawt Al Mamlaka/Al Mamlaka TV.
	Ministry of Health was given an upper hand over other ministers like the Ministry of Economy and the Investment Ministry, which helped	The government involved civil society organizations and nonprofit organisations like EMPHNET, Jordan Medical Association for implementing decisions.	Press releases were used religious leaders were involved to share the decisions made by the Jordanian National

	minimise conflicts and enabled smooth coordination.		Committee for Epidemics with the public.
Nigeria	The government stakeholders coordinated through a "decision-making group" that convened every day during Public Health Emergency Operations Center meetings.	The private sector-led Coalition Against Covid-19 (CACOVID-19) led by Aliko Dangote Foundation(ADF), Late Herbert Wigwe of Access Bank, Zenith Bank, Guaranty Trust Bank, Central Bank of Nigeria (CBN) and others mobilised private sector leadership and resources to support health facilities.	NCDC's frequent updates on its website, through media, TV, radio, and the COVID-19 microsite developed and deployed by the Georgetown University team helped the public gain information about the pandemic and response efforts.
	The pandemic response among different ministries was coordinated through PTF meetings every day in the beginning, twice a week after a few weeks, and then once a week.	The United Nations (UN) partners formed a UN basket and put all money and resources from the UN family into that basket, which collectively supported the Presidential Task Force.	NCDC leveraged an existing biosurveillance platform called Tatafoo for mining social media to catch COVID related rumors. NCDC regularly polled the public to determine risk communication strategies and collect people's perceptions about the policies.
	State-level coordination occurred through Nigeria's Governors' forum and meetings of the National Economic Council with Governors.	The government collaborated with experts from other countries, such as the UK, and external partners, such as WHO, UNICEF, AFENET (Africa Field Epidemiology Network), GU (Georgetown University), US CDC, USAID, Africa CDC, and others, to respond to the pandemic.	Community and religious leaders were engaged, especially during the initial waves of the pandemic, to spread awareness in the public about the disease and arrest community transmission of the virus.
UK	The government coordinated with modellers within the Joint Committee on Vaccination and Immunisation (JVCI), a long-standing body for implementing immunization.	The government collaborated with the private sector to ramp up the diagnostic and vaccine capacity for COVID-19.	Confusing communication between the government and the public was reported during the lockdown.
	The government coordinated with the Scientific Advisory Group for Emergencies (SAGE), which provides independent scientific advice to support decision-making in the Cabinet Office Briefing Room (COBR) in the event of a national emergency.	The government used internal structures and mechanisms like the New and Emerging Respiratory Virus Threats Advisory Group (NERVTAG), SAGE, and IBPAG to collaborate with academics.	There was initially a lack of trust in the government in the context of Brexit happening in January 2020 and a polarised political spectrum, but when the government moved to daily press briefings, it was seen as a trusted source of information.
	A lack of communication was reported between the central government and the local government.	The government reportedly paid more attention to financial institutions like the World Trade Organisation (WTO) and the World Bank than to the public health international organisations.	Epidemiological principles were communicated to the people through media briefings, parliamentary scrutiny committees, publication of SAGE minutes, open access to medical journals, and publicly available summaries of the latest evidence.
Singapore	The government coordinated with different ministries through HCEG and MTF, which helped in sharing information about evolving data on topics such as mode of transmission, epidemiology of the virus, and treatment measures.	The government collaborated with academic experts from NUS's Saw Swee Hock School of Public Health to provide input on measures and decisions, conduct literature reviews, and assess information on viruses.	The government acknowledged the uncertainty associated with the emergency with the public and remained transparent about what was known and unknown about the situation.
	HCEG and MTF coordinated through regular daily and weekly meetings, which helped in the up-to-date sharing of information.	The government collaborated with other countries through bilateral conferences for data sharing and cross-exchange of information, such as China, Indonesia, Australia, and the Association of South East Asian Nations (ASEAN).	A lack of cohesive messaging about public health messaging was reported, especially around mask-wearing, with the need to emphasize decisions made on current data.
	Continuous communication and coordination with clinical personnel within the MOH as well as in the various public hospitals to review data helped in updating treatment guidelines from time to time.	Ministry of Health collaborated with academia, research institutions in Singapore, hospitals and the NCID to collate data and evidence.	Singapore's leadership, including the Prime Minister and MTF, updated the public about the health crisis by using the Disease Outbreak Response System Condition

Strategies for Making Decisions Under Institutional Uncertainty

The term 'institutions' is used in dual definitions, referring to both organizations and norms/rules/ideas/processes within a system.[30] Institutional context refers to the systems and processes used by the countries to structure authority, attention, information flows, and relationships in addressing policy problems.[31] It includes government effectiveness, freedom to maneuver, social trust, health ministry structure, and ruling party stability.[32] and are concerned with the formal power structure, legal system, and regulations.[41] During an emergency, the country's initial policymaking is path-dependent on its institutional context[33] and policies and procedures can undergo institutional rearrangement, changing the face of public health governance.[33] During the pandemic, institutional factors like administrative, implementation, and coercive capacity determined the government's capability to manage institutional uncertainty.[34]

In our study, respondents referred to two main strategies for making decisions under institutional uncertainty. The first was using or adapting pre-existing institutions, capabilities, and relationships, and the second was through establishing new institutions and policy mechanisms (see Table 4).

Using pre-existing institutions, capabilities, and relationships

All six countries used their existing institutions, capabilities and relationships to navigate and manoeuvre the institutional and organizational norms and processes to make decisions.

We leveraged the existing health structures that we do have. We have focal persons that are called ward focal persons... we have the existing polio structures...and also routine immunisation structures, and our community engagement structures. These governance structures are clearly defined (Nigeria_34).

Past experience with handling different epidemics proved to be particularly useful in managing COVID-19-related institutional uncertainty. Respondents referred to the UK's experience with the Foot and Mouth Disease (FMD) outbreak, Nigeria's experience with the Ebola outbreak and Singapore's experience with SARS to have developed experience and institutions to improve the capacity to make decisions in uncertain and urgent situations like pandemics.

I think, like the rest of the world, we had an inkling that something was happening in Wuhan in China. So, we started to plan, and it actually segues essentially from what was originally the SARS 'playbook'... that was developed essentially for SARS, that serves as a template. So, we do have a structure in place that brings together different industries within Singapore to look at potential resources and resourcing that might be required should we have to deal with something like what emerged subsequently from the end of 2019 until 2020 (Singapore_8).

Preexisting relationships across sectors, expertise and geographic regions proved to be particularly useful to promptly establish collaboration, draw lessons and transfer policy solutions to handle the uncertainties.

I think the biggest lesson that I learned in COVID is that the preexisting relationships enabled discussions, and there were already trust platforms in place. And I could call my colleague in Nigeria and… England and say…could you share your expertise and

experience? What do we need to look out for?... For some of my colleagues who didn't have those preexisting relationships, it took a lot longer for the formulation of those relationships with the norming, the storming, the performing, you know, the cycle of engagement and relationship building (South Africa_25).

Establishing new institutions and policy mechanisms

Countries found that the existing regulatory frameworks related to drug and vaccine authorization were not sufficient to implement the urgent decisions made during the pandemic. So, they created expedited access routes to ensure timely access to life-saving treatments during the pandemic.

> So, when the pandemic started, and we looked at our regulatory frameworks and filing groups, we, of course, realised that they won't do in a pandemic... that's where we started with what we called provisional authorization by our medical analysis group. And something for some conditional authorization. So, we sat down and looked at the fact that we needed to create a different route- an expedited route. This is where we then decided to develop the Pandemic Special Access Route (PSAR) that allows for interim authorization and early access to critical novel vaccines (Singapore_6).

Similarly, countries found that the existing legal frameworks needed refinement to assign more legal powers to public health agencies and experts to make urgent public health decisions during the pandemic.

> We realized that a little bit of refinement [of the law] was needed because the law, when it was developed, we didn't face this kind of pandemic. So, when we practiced, we felt that in some aspect, some kind of amendment might be required (Bangladesh_16).

Navigating the existing 'emergency laws and regulations' during the pandemic was also challenging as these regulations were not part of the health laws. Though in many countries, disaster and emergency legislation were all-encompassing, public health practitioners were found to be less conversant with the laws during the preparedness phase of a health emergency.

> So, we had to make sure we had the statutory framework. Now the laws we were operating under were not part of the health laws. There are laws and emergency regulations which all fall under our local government. So, if there's an earthquake or a volcano, or something massive happens, and the pandemic is obviously a massive something, but it happens to be a health [issue], it is different from if there is a huge forest fire... So those laws were not our laws, and we had to understand and make sure that we contributed to the regulations (South Africa_10).

Insert table 4 Strategies for making decisions under institutional uncertainty

Strategies for making decisions under institutional uncertainty

	Using pre-existing institutions, capabilities, and relationships	Strengthening or modifying existing institutions and policies	Establishing new institutions and policy mechanisms.
Bangladesh	Pre-existing facility at government level (IEDCR) and at non-government setup (icddr,b and The institute for developing Science and Health initiatives, ideSHi) started molecular detection of SARS-CoV2. The government also mobilized experts and resources by using preexisting relationships with development partners like WHO, UNICEF, CDC, USAID.	The Infectious Diseases (Prevention, Control and Eradication) Act 2018 was promulgated to manage and respond to localized outbreaks within the country. It was not adequate for responding to pandemic. So, the gap was addressed and mitigated by issuing government orders time to time (depending on the situation) by the Cabinet Division.	During the community transmission phase, Bangladesh increased the capacity of more than 100 laboratories for molecular detection of SARS-CoV-2 at the national and sub-national level. Molecular laboratories facilities of animal health and Universities were also utilized. Government established the National Technical Advisory Committee and sub-committees for COVID-19 to curb the spread of COVID-19 and improve the quality of services at hospitals.
	Government used the surveillance system instituted for influenza to generate data on COVID-19.	Government repurposed the existing influenza surveillance systems at health facilities for COVID-19 surveillance. Hospitals were repurposed for COVID-19 dedicated hospitals. In addition to routine vaccination, EPI was assigned for COVID-19 vaccination.	Bangladesh Preparedness and Response plan for COVID-19 and National Deployment and Vaccination plan for COVI-19 Vaccines in Bangladesh was developed.
	Government used IEDCR as the reference laboratory for COVID-19 testing during the community transmission phase. Similarly, Maternal Neonatal and Adolescent Child Health (MNACH) program of DGHS (EPI), DGDA, IEDCR and UNICEF conducted COVID-19 vaccination.	Government developed clinical guidelines and establish working groups and committees for COVID-19 management based on the Influenza pandemic preparedness plan 2009 .	Government established a national genome sequencing infrastructure for genome sequencing through a consortium of IEDCR, icddrb, ideSHi, and Child Health Research Foundation (CHRF).
South Africa	Existing capacities, such as a national COVID-19 incident management team, scientific networks, sequencing capacity, and sentinel surveillance systems, were leveraged to understand the disease's epidemiology.	Existing digital information systems such websites, dashboards, social media platforms were adapted and a Whatsapp chatbot (+27600 12 3456) was introduced for spreading COVID-19 vaccine information. Additionally the notifiable medications conditions surveillance system was augmented to act as the secure, national digital linelist (https://nmclist.nicd.ac.za/)	An advisory body (MAC) to the MOH for COVID-19 was set up to provide advice based on emerging data.
	Pre-existing collaborations with the National Health Laboratory Service, the National Institute for Communicable Diseases (NICD), US CDC, Africa CDC, WHO, Clinton Health Access Initiative (CHAI), private sector healthcare, academic institutions, and non-governmental organisations created during managing large outbreaks such as listeriosis, avian influenza, and cholera were used in decision-making.	Existing diagnostic and genomic surveillance capacities were adapted to sequence COVID-19 virus samples.	Research working groups and teams within the NICD were established to collate data and scan the literature and emerging evidence.
	Scientific expertise and previous knowledge of health officials in working on diseases like influenza were used in decision-making.	Existing legislative provisions in the Disaster Management Act of 2002 and the Public Finance Management Act of 1999 were adapted for budget and financial flexibility to respond to the pandemic.	Clinicians' forums was established to disseminate findings from the COVID-19 cases treated by clinicians in South Africa.
Jordan	Existing institutions like the Jordanian National Committee for Epidemic and the National Center for Security and Crisis Management were used to cope with the pandemic.	The existing National Committee for Epidemics was indirectly getting community feedback; Al Tebi company communicated with infected and vaccinated patients for feedback.	The government established the National Center for Security and Crisis Management (with law enforcement scientists) to manage the pandemic (relating to vaccines distributions, etc.).
	Existing relationships with academics at the Jordan University of Science and Technology were used to gather information about the virus and pandemic preparedness policies.	The existing National Security Center steered the pandemic response by giving oversight to all involved ministries.	The government established field hospitals in the north and south regions.

	....	Existing health infrastructure like hospitals, ICU units, and diagnostic facilities was used and converted into COVID-19 facilities to handle the pandemic.	Online Information systems were established, including Hakeem (a national system for patients in general); Sondos: COVID-19 Data collection system tracking positive and negative tested samples; and Kanz: on admission and deaths of COVID-19
Nigeria	The government based the COVID-19 treatment on previous knowledge of viral diseases and supportive treatment, the NCDC infectious disease outbreak response plan, and the incident coordination activation plan.	The existence of Public Health Emergency Operations Centers (PHEOCs) prior to the pandemic helped establish coordination mechanisms and networks between subnational and national levels during the pandemic.	NCDC EOC Research Pillar was established for collating information on epidemiology and surveillance.
	Standards of treatment and infection, prevention, and control (IPC) guidelines relied on exposure history and incubation period from Ebola Virus Disease and Lassa Fever.	The existing Lassa fever treatment centres were strengthened, and the PEPFAR and Global Fund Program laboratory infrastructure was optimised for rapid diagnosis using Gene Xpert Machines.	The National COVID Research Committee (NCRC) was established to collect and assess local in-country COVID-19 surveillance data.
	In the face of limited information, decisions were based on expertise and prior knowledge of officials - microbiology, virology, IPC and existing networks and partnerships with developmental partners and CSOs.	The government worked with the University of Abuja Teaching Hospital, to convert and repurpose the just constructed accident and emergency ward, to a COVID-19 isolation center. The National Reference Lab Gaduwa Abuja and National Public Health Lab Lagos were rapidly optimized based on their capacities in Viral Hemorrhagic Fever diagnosis to test for COVID.	A partnership pillar within the COVID-19 EOC, was established to coordinate partners and help avoid duplication of efforts and resources to address critical priority areas during the pandemic.
UK	The government used the preexisting relationships between the modellers established during previous pandemics, like Foot and Mouth Disease and Ebola.	In the early waves of the pandemic, Public Health England was replaced with various other structures, and public health was restructured into the UK Health Security Agency (UKHSA), removing health promotion entirely.	The National Institute for Health Protection (NIHP), including the Joint Biosecurity Centre (JBC), was established to meet the challenge of COVID-19. Later known as the UKHSA.
	Pre-existing NHS digital health systems were used to identify and access the COVID-19 data.	Existing operations and personnel, within NERVTAG and JVCI were consulted to improve access to COVID-19 vaccines.	The NHS Test and Trace service was established to control the spread of COVID-19 by testing people, tracing their close contacts, and asking them to self-isolate.
	The government's prior relationships with communities were used to distribute COVID-19 vaccines.	The existing permanent structure of SAGE was modified to constitute COVID-19 subcommittees like the Scientific Pandemic Influenza Group on Modelling (SPI-M) and Scientific Pandemic Influenza Group on Behavioural Science (SPI-B) to manage the pandemic.	The COVID-19 Genomics UK (COG-UK) Consortium was set up to provide information on virus sequencing.
Singapore	Previous experience with SARS in 2003 was used to develop clinical management strategies for COVID-19.	Regulatory processes for vaccine approval were adapted by using parallel processing as vaccine clinical trial data was available and not waiting for full dossier evaluation.	The National Center for Infectious Diseases was established in response to lessons learned from the previous SARS outbreak and has protocols and processes in place to respond to health crises.
	The government's pre-existing collaborations with people from different ministries and offices aided in handling the crisis such as the Inter-Agency Taskforce on Trafficking in Persons or the Inter-Ministerial Committee on Climate Change.	Existing HCEG used during the Ziba outbreak was used to mobilize decision-making structures and constitute MTF for COVID-19 management.	A working committee, including a 14-member Expert Committee on COVID-19 Vaccination that involved academia in both research institutions and hospitals, was formed to consult with the medical literature, create evidence and present the evidence to the MOH.
	Existing MOH pandemic readiness and response plan like Health Pandemic Readiness and Response Plan for Influenza and other Acute Respiratory Diseases (2014) aided in identifying	Existing Public Health Intelligence groups that work with other countries' MOHs were used to collaborate and gather COVID-19 data.	A digital mobile phone application, TraceTogether, was created for surveillance and to communicate with people and

relevant ministries to be involved and establish
clear roles and authorities for stakeholders.
provide them with information
regarding case clusters.

DISCUSSION

To our knowledge, this is the first multi-country study to empirically study the strategies
adopted by national-level governments for making decisions under different conditions of
uncertainty during the COVID-19 pandemic. We found that regardless of political, geographic,
and economic context, all six countries faced three common types of uncertainties and adopted
common strategies to make decisions in these situations.

Our results suggest that the countries found decision-making under epistemic uncertainty to be
most challenging, especially in the initial waves of the pandemic. Epistemic uncertainty has been
an issue of study by various scholars, emphasizing its components of randomness, subjective
judgment, and measurement error[35]; its objects like the level and sources of uncertainty [36]as well
as its potential implications resulting in mistakes in building models.[37] We found that both the
"known unknowns and unknown unknowns[38,39] represent epistemic uncertainty during the
pandemic. Similar to natural disasters, health emergencies also demand preparedness for
unknown unknowns or surprises and caution in relying on observational data and models, as they
may not always be comprehensive and accurate.[24]

The undetermined uncertainties[40] marked by the lack of or ambiguous knowledge about the
clinical, public health, and policy aspects of the virus created public mistrust in the government
and resulted in low public adherence to government decisions and policies. However, depending
on the technical capacities for generating and gathering information as well as the existing

relationships with other countries and international organisations and experts, countries managed to equip themselves with the best available knowledge to make decisions.

Our findings on decision-making under epistemic uncertainty confirm the earlier studies emphasizing the [skepticism around][41-42] and role of science and evidence in pandemic management[43-44] Like other existing evidence, our respondents alluded to the World Health Organization's (WHO) role in providing technical and policy guidance.[45-46] WHO was cited as a reliable organization in our study when it came to gathering the latest clinical and non-pharmaceutical guidelines. Likewise, most countries were observing China's decisions to control the pandemic.

The role of experts and diverse stakeholders in decision-making during the pandemic has been discussed by various scholars[47-48] and our results confirm the arguments made by Haeder and Gollust[61] highlighting the dominance of experts from fields of public health, medicine, and economics in the initial phase of the pandemic and only subsequently sociologists and political scientists, received more attention from policymakers as the pandemic progressed. In addition, we found that in most countries, civil society organizations were working independently of the government. These organizations were often either absent or overlooked until the governments invited them after issues of public mistrust and low adherence to government policies surfaced.[49-51]

The second main challenge was to make decisions in the context of the unpredictable behaviour of actors involved in the decision-making. Our results align with the existing research on the role of people's cooperation and trust in experts and government to make key decisions Cairney[52,53] as well as the role of social media in enhancing people's trust and compliance with decisions.[54,55] Similarly, we find that collaboration among external actors, hospital Systems[56] and interagency

coordination at all levels of government[57,58] are crucial for policy incoherence and avoiding conflicting messaging to the public.

We support the importance of emergency regulatory procedures and their influence on the overall quality of pandemic responses[59] as well as the insufficiency of current drug and vaccine regulations for urgent pandemic decision-making.[60,61] We find that all countries reported challenges in navigating the existing 'emergency laws and regulations' during the pandemic, as these were not health laws. Additionally, in most cases, public health experts were not well conversant about the scope of health-related issues under public emergency and disaster management laws. At the same time, countries like Singapore modified the existing regulatory structures and created expedited access routes or other temporary measures to ensure timely access to life-saving treatments during the pandemic. Private sector participation facilitated the production and distribution of medical countermeasures, especially vaccines However, more research is needed to study the power dynamics between the public and private sectors in ensuring fair and equitable access and distribution of these resources.[62,63]

Our study significantly enriches the existing literature on decision-making during events involving uncertainty, particularly by expanding the previous insights from literature on natural disasters and other public emergencies to health crises[6-13]. We introduce an applied framework that categorizes uncertainty into three distinct types of emergency situations. Our novel unified framework integrates learnings from individual stakeholder management, organizational and institutional processes and norms, and national level decision-making, capturing the complexity and dynamic prevalent during uncertain emergency situations. At the individual level, we advance the established models[10,11] to encompass a broader spectrum of decisions relating to the implementation of non-pharmaceutical interventions. At the organization and national level, we

integrate key components of existing disaster management and health decision-making models[7,8,64] and contribute to government-level decision-making framework by discussing stakeholder behavior including coordination, collaboration, and communication.

This study addresses several gaps in the literature on decision-making under conditions of uncertainty, particularly in public health and pandemic management, which distinguish it from previous decision-making models. First, there is limited empirical evidence demonstrating how various decision-making strategies are applied in health crises such as COVID-19. Second, existing literature lacks comprehensive frameworks for categorizing and analyzing different types of uncertainty, like epistemic, strategic, and institutional, within health contexts.[14-21] Our framework introduces innovative features as it provides a comprehensive applied categorization of uncertainty —epistemic, strategic, and institutional—spanning individual stakeholder management, organizational processes, and norms. Third, most health related studies concentrate on individual-level decision-making.[10-12] Even government or national-level decision studies typically examine the positions of policymakers[13] rather than considering the government as a whole. To address this gap, our overarching framework combines individual, clinical, and government-level perspectives, enhancing collaboration among sectors and fostering a comprehensive understanding of how uncertainty impacts decisions at various levels. Our approach emphasizes iterative and collaborative decision-making processes involving continuous engagement, communication and coordination[9] with diverse stakeholders. Fourth, existing frameworks are limited in their scope to demonstrate effectiveness across diverse contexts and pandemic phases. Our framework is uniquely designed for adaptability at different stages, enhancing relevance and equipping stakeholders to respond effectively to evolving challenges. The approach is flexible and responsive, allowing it to adapt to temporal disease trends, changing

knowledge, shifting relationships among stakeholders, the preferences and characteristics of policymakers, and revisions in decision-making across time and geographies. This flexibility is especially effective during rapidly evolving public health crises, unlike existing static models that rely on fixed parameters and assumptions. Finally, it is important to note that our study was not an evaluation study but a descriptive process analysis. Though we acknowledge the merit of evaluation-based methods studying the moral, political, and economic basis of the decision, we deliberately choose a judgment-free, neutral approach to study the decisions. This approach aligns with our objective to understand the process and development of decision-making under uncertainty framework for future health emergencies and facilitated our selection of countries based on diversity in geographic, economic, political and governance contexts. Similarly, we acknowledge the value of including country case studies in presenting this analysis. Nevertheless, our unified framework necessitated a comparative approach across countries, leading us to present detailed country-specific strategies in a tabular format.

We also recognize that the decisions and decision-making strategies varied over different waves of the pandemic, and a temporal analysis could offer deeper insights given the varying levels of uncertainty and evolving knowledge. However, a temporal analysis was beyond the scope of our study, which collected data from six countries that experienced different pandemic waves at different times. Consequently, we examined COVID-19 decision-making as one event rather than as the pandemic evolved. Nonetheless, our proposed framework can be adapted for a comprehensive temporal analysis, and we suggest this would be a fruitful future area of study.

We also acknowledge the limitations of interview and discussion-based research methods, especially their potentially narrow scope through providing insights from individual and small group perspectives[65] with the probable exclusion of vulnerable populations, civil society and the

citizens themselves. Even so, interviews and discussions with key stakeholders offer useful insights to understanding complex processes like decision-making through the sharing of lived experiences.

We would like to highlight the challenges and unforeseen situations we encountered while conducting the study. Initially, we experienced delays in obtaining confirmation of participation. A few of the countries we had initially identified for study, selected for their diversity of contexts, declined to participate. Data collection was further delayed due to ongoing events, such as the political inquiry into the COVID-19 response in the UK. During this time, we had to pause data collection, as government officials were reluctant to participate in the study.

There are three important areas that could be further explored in pandemic decision-making and governance research. First, there is a need to examine the power dynamics among different members of the decision-making task forces and the impact of group power dynamics on decision-making. Secondly, research is needed to understand the application and integration of technological solutions, such as decision support systems, data analytics, artificial intelligence, and modelling techniques, into decision-making systems while also considering their ethical and practical consequences. Finally, more empirical enquiries are needed to investigate the strategies to improve resilience and adaptability at all levels of decision-making, ranging from personal, organizational, and national levels.

facilitated the implementation of this project in South Africa. Preliminary results of this work were presented at the Global Health Security (GHS) conference in 2024.

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