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Meta-synthesis of COVID-19 lessons: charting sustainable management of future pandemics

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ABSTRACT

Development of the COVID-19 vaccines has been creating a lot of hope for an ultimate return to normality, but returning to normality as we had before would mean we will continue to ignore life-ravaging lessons, as we did for severe acute respiratory syndrome, Ebola, and Middle East respiratory syndrome. This meta-synthesis of COVID-19 lessons charts sustainable pandemic management in terms of choosing strategies that are situated in their contextual specifications and beginning preparations for future application of such strategies from now. To guide selection of a situated strategy, the paper provides a comprehensive list of epidemiological determinants (e.g. communicativeness, poverty, supply chain, density, wind, remoteness); consolidates knowledge about strategies of elimination, suppression and mitigation; and proposes a quantified SWOT analysis of epidemiological determinants that produces coordinates for strategy identification in a Cartesian plane divided into twelve strategy quarters. To guide prior preparations for future application of pandemic management strategies, the paper consolidates lessons learned in implementation of situated strategies and proposes preparations at the national level for elimination, at the local/community level for suppression, and at the regional level for mitigation.

Highlights:

- Lessons of COVID-19 (coronavirus) chart sustainable management of future pandemics
- Epidemiological determinants and their mechanisms of impact are listed
- Knowledge about elimination, suppression and mitigation strategies is consolidated
- A quantified SWOT and Cartesian plane enable selecting context-specific strategies
- Preparations for future elimination, suppression and mitigation are listed

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COVID-19 (coronavirus) pandemic; epidemiological determinants; elimination; suppression; mitigation; SWOT analysis

1. Introduction

This paper is about sustainable pandemic management – a term coined by the author in a meta-synthesis of COVID-19 lessons to primarily characterize application of anti-

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contagion strategies that are situated in their contextual specifications. COVID-19 or coronavirus disease is a high risk contagious respiratory zoonosis originated in December 2019 in Wuhan, China. In March 2020, the World Health Organization (WHO) announced that the outbreak was officially a pandemic – i.e. an epidemic occurring worldwide (Williamson, 2020). The world is still grappling with multi-dimensional impacts of this crisis. The Microsoft co-founder Bill Gates believes that world should be back to normal by end of 2022 due to vaccines (Reuters, 2021), but warns that humanity is not prepared for a next pandemic that could be 10 times worse (Entrepreneur, 2021).

Despite recent lessons of severe acute respiratory syndrome, Ebola, and Middle East respiratory syndrome, COVID-19 created a pressing policy-making condition for epidemiologically unprepared governments (Anttiroiko, 2021; Weible et al., 2020). Some silo health analyses recommended applying strategies to contain the spread of COVID-19 without due consideration for inter-sectoral requirements and consequences of implementing that strategy (Naumann et al., 2020). There are observations about some unsituated strategies imposed to contain COVID-19 turning more destructive than the disease (Ghosh, 2020). There has been a wake-up call for context-specific pandemic management that considers interrelations between biological, economic and social health (Menoni & Schwarze, 2020; Nacoti et al., 2020; Wilkinson, 2020).

Trial-and-error and blindly replicating strategies that seem to be working in other places can lead to closure of windows of opportunity to contain the disease and save lives on the one hand, and social unrest and irreparable damage to poor households and gross domestic product (GDP), on the other hand (Coccia, 2021a; Egger, Jones, Justino, Manhique, & Santos, 2020). For instance, strategy of suppression – which in surge of community transmission requires full lockdown (hereafter lockdown) also known as stay-at-home order with exception of essential services (Ghosh, Gupta, & Misra, 2020) – has become a blueprint for COVID-19 response (Hodgins & Saad, 2020). Meanwhile, a recently completed survey in Bangladesh showed that after its initial days of lockdown, 72% of urban and 54% of rural households had lost their main source of earnings (Chowdhury et al., 2020).

There is growing understanding that a systematic analysis of potentials and limitations of a place in arresting outbreaks should underpin selection of a pandemic management strategy (Coccia, 2020a; Loayza, 2020). Application of this understanding for sustainable management of future pandemics requires a meta-synthesis of COVID-19 lessons that integrates knowledge about epidemiological determinants; consolidates knowledge about pandemic management strategies and their requirements; and conceptualizes a technique to situate selection of strategies in epidemiological determinants of their context. Undertaking this meta-synthesis is Objective I of the present study.

Meanwhile, evidence from COVID-19 indicates that sustainable pandemic management is not only situated in its context; it also improves that context (Combs & Pardo, 2021). Lessons that places have learned in application of their situated strategies should inform preparations for future application of those strategies. For example, a study by Naumann et al. (2020) about Germany's strategy to contain COVID-19 showed that public acceptance of associated mobility restrictions was initially high, but it declined with long-term implementation of these measures. Indeed, some Germans are now ignoring bans on gathering in parks and public venues (Thomasson, 2021).

Table 1. Research questions (Author).

Objective	Research question
I	What are epidemiological determinants?
	What are pandemic management strategies and their requirements?
	What technique can situate selection of a strategy in epidemiological determinants?
II	What prior preparations are needed for future application of each pandemic management strategy?

New Zealand, widely known as a success story of situated elimination of COVID-19, faces 1% drop in its GDP as over a year of border closure hits its vital tourism sector (Smyth, 2021). It is Objective II of this meta-synthesis to interpret and consolidate these lessons. Table 1 displays research questions that subsequent sections of the paper will explore to meet study objectives.

2. Study design

This study is a meta-synthesis. Meta-synthesis involves evaluating, interpreting and integrating the findings of multiple research studies with the aim of transforming individual findings into new conceptualizations (Cronin, Ryan, & Coughlan, 2008). Meta-syntheses offer an appropriate balance between an objective framework and the necessary contribution of the researcher's subjectivity in the construction of the final work. They propose a third level of comprehension and interpretation that brings original insights, improves global understanding on the subject and proposes immediate practical implications (Lachal, Revah-Levy, Orri, & Moro, 2017).

This meta-synthesis involved two phases of literature search, selection and interpretation. Phase 1 was undertaken between 2 April 2020 and 27 August 2020 when transition from first to second pandemic wave took place in many countries. This enabled reliable reflection on medium-term consequences of pandemic management strategies by studies that were included in this meta-synthesis. Exclusion criteria for scholarly sources consisted of repetition and contradiction. In respect of contradiction, for example, because most studies observed that population density contributes to transmission (Table 2), studies that contradicted this dominant observation were excluded from the meta-synthesis. Content analysis of 221 from 269 retrieved scholarly records was carried out in phase 1.

Phase 2 was undertaken between 16 March 2021 and 10 May 2021 when many countries had their third or even fourth pandemic waves. In this phase, 180 new scholarly records were retrieved from which 116 proceeded to full content analysis. In phase 2, grey literature was also used because by then it was possible for the researcher to rely on own conceptualizations for screening grey literature in terms of accuracy. However, it was attempted to limit grey contents – which primarily served an updating and complementary role – to those produced by reliable bodies like international organizations and credible news agencies.

3. Results and discussion

3.1. Epidemiological determinants

Before the outbreak was first reported in December 2019, the primary public health concerns were non-communicable diseases associated with unsustainable environments

Table 2. Epidemiological determinants (Author).

Sphere	Determinant	Mechanism(s) of impact	Example studies
Governance	**(I) Communicativeness**	Co-sense-making of anti-contagion strategies and unifying of associated actions	Dodds et al. (2020); Shaw, Kim, and Hua (2020); Van den Oord et al. (2020)
	(II) Smartness	Technological enhancement of disease surveillance	Ting, Carin, Dzau, and Wong (2020); Elavarasan and Pugazhendhi (2020); Das and Zhang (2020)
	(III) Robustness or professional bureaucracy (definition of emergency powers …)	Agile adaptation to epidemic crisis	Ansell, Sørensen, and Torfing (2020); Janssen and van der Voort (2020); Christensen and Lægreid (2020)
Society	**(I) Poverty**	Increasing exposure to infection; reducing ability to comply with shelter-in-place protocols; reducing the immune system's ability to combat infection	Patel et al. (2020); Ahmed, Ahmed, Pissarides, and Stiglitz (2020); Wright, Sonin, and Driscoll (2020)
	(II) Demography	Men and younger people are less compliant with mobility restrictions; aging population increases health impact of infection; larger household size elongates the lockdown period needed	Al-Hanawi et al. (2020); Brouard, Vasilopoulos, and Becher (2020); Sjödin et al. (2020); Alanezi et al. (2020)
	(III) Beliefs	Higher religiosity results in less adherence to public gathering restrictions	Brouard, Vasilopoulos, and Becher (2020) ; Al-Sabbagh et al. (2021); DeFranza, Lindow, Harrison, Mishra, and Mishra (2020)
	(IV) Culture	Caring culture increases voluntary adherence to anti-contagion protocols, and provides support for the vulnerable in lockdown	Drury, Carter, Ntontis, and Guven (2021); Barrios et al. (2021); Durante, Guiso, and Gulino (2021)
Economy	**(I) Sectoral structure**	Homogeneous economic structure increases vulnerability to mobility restrictions	Mofijur et al. (2020); Sharifi and Khavarian-Garmsir (2020); Ndung`u (2020)
	(I) Supply chain	Global supply chain increases vulnerability to mobility restrictions	De Souza Jabbour et al. (2020); Zhu, Chou, and Tsai (2020); Blay-Palmer et al. (2021)
	(III) Circularity	Circular economy (recycling, resource efficiency and product life extension) reduces vulnerability to mobility restrictions	Wuyts, Marin, Brusselaers, and Vrancken (2020); Ibn-Mohammed et al. (2021); Giudice, Caferra, and Morone (2020)
	(IV) Gross domestic product	Low GDP increases vulnerability to mobility restrictions	Egger et al. (2020); Hodgins and Saad (2020); Walker et al. (2020a)
Built environment	**(I) Density**	High population densities catalyze airborne transmission; dense urban environments may improve access to healthcare facilities and community support groups	Rocklöv and Sjödin (2020); Teller (2021); Wu (2021)
	(II) Sprawl	Zoonoses often emerge in peri-urban areas; sprawl reduces access to healthcare; epidemic clusters increase in long daily trips in sprawled areas	Connolly, Keil, and Ali (2021); Zhao, Li, and Liu (2020); Carteni, Di Francesco, and Martino (2020)

(*Continued*)

Table 2. Continued.

Sphere	Determinant	Mechanism(s) of impact	Example studies
	(III) Transportation	Public transportation increases the risk of airborne and object surface transmission	Luo et al. (2020); Hu et al. (2021); Yang et al. (2020)
	(IV) Sewage treatment	Poorly treated sewage may become a route for transmission	Bhowmick et al. (2020); Adelodun, Ajibade, Ibrahim, Bakare, and Choi (2020); Arslan, Xu, and El-Din (2020)
	(V) Air pollution	Airborne pathogens might be attached to particulate matter in heavy air pollution increasing infection and mortality rates in such contexts	Coccia (2021b); Lolli, Chen, Wang, and Vivone (2020); Travaglio et al. (2021)
	(VI) Healthcare sites	Large urban hospitals can become sources of infection	Paterlini (2020)
Nature	**(I) Wind** ** Inconsistent findings*	Low wind speeds may increase airborne transmission due to longer viral permanence in air	Coccia (2021c); Yuan et al. (2021); Guo et al. (2021)
	(II) Temperature	Transmission of most respiratory pathogens increases in lower temperature	Cai et al. (2007); Dowell and Ho (2004); Guo et al. (2021)
Geo-position	**(I) Remoteness**	Geographic remoteness delays and reduces infection import	Herr (2021); Hughes and Convey (2020); Issanov et al. (2020)
	(II) Connectedness	Island settings might delay and reduce infection import	Jefferies et al. (2020); Grydehøj et al. (2020); Boyd, Baker, and Wilson (2020)
Outreach	**(I) Overseas politics**	Politics of soft power can uplift anti-contagion goal	Shimizu, Tokuda, and Shibuya (2021)
	(II) Trans-boundaries	Cross-border communities complicate implementation of mobility restrictions	Peyrony (2021)

(Freestone & Wheeler, 2015). However, reminding of Lenin's words that 'There are decades where nothing happens; and there are weeks where decades happen', there has been a proliferation of scientific literature about epidemiological determinants and their mechanisms of impacting transmission, anti-transmission responses and associated outcomes. Meta-synthesis of this literature resulted in producing Table 2.

3.2. Pandemic management strategies and their requirements

Pandemic management strategies are classified into three main categories according to their anti-contagion target. *Elimination* seeks to achieve zero community transmission, *suppression* seeks to reduce community transmission to minimum and *mitigation* accepts moderate community transmission (Baker, Wilson, & Blakely, 2020a). Before elaborating on these strategies, Table 3 provides a glance at their surveillance measures and mobility restrictions.

3.2.1. Elimination

Elimination strategy seeks to reduce to zero incidence of infection in a given territory, usually a country or region, with active measures to prevent pathogen re-introduction

Table 3. Pandemic management strategies at a glance (Author).

Strategy	Surveillance		Mobility restrictions					
			Lockdown					
	Managed isolation & quarantine	Contact tracing of cases	Full (stay-at-home order)	Partial: closing of schools, public gatherings, high risk businesses	Home stay of the vulnerable	Social distancing (e.g. 1.5 meters)	Border closure (quarantine of essential arrivals)	
							Blanket	Selective (with high risk countries)
Elimination								
Suppression								
Mitigation								

Legend

Suspicion of community transmission

Minimum / slow community transmission

Surge of community transmission

Peak of community transmission

Until strategy is accomplished

Throughout pandemic

from other territories after elimination (Klepac, Funk, Hollingsworth, Metcalf, & Hampson, 2015). Measures to prevent re-introduction should continue until eradication of the contagion or pharmaceutical developments that remove its threat. Eradication means that a disease has become extinct at the global level, at least outside laboratories (Baker, Kvalsvig, Verrall, & Wellington, 2020b).

Elimination, which has been at the centre of WHO guidelines about the pandemic (Heymann & Shindo, 2020), is an ambitious strategy for highly transmissible diseases (Handel et al., 2020). Where there is evidence or suspicion (Menon, 2020) of community transmission – that is infection among persons without a known exposure by travel or close contact with a patient with confirmed infection (Zwald et al., 2020), elimination involves prolonged lockdown until zero detection of community transmission and a subsequent cautionary period for silent transmission (Baker et al., 2020a). If successful, elimination allows a return to normal life within national borders, but border closure and quarantine of essential arrivals remain in place throughout pandemic (Baker, Kvalsvig, Verrall, Telfar-Barnard, & Wilson, 2020c).

When the pandemic arrived later than many other territories on 26 February in New Zealand, the government initially applied the existing *New Zealand Influenza Pandemic Plan* (Ministry of Health, 2017) which was a mitigation strategy (Kvalsvig & Baker, 2021). With realization that the novel virus is more serious than influenza, the government followed advice from epidemiologists and swiftly shifted to an elimination strategy involving border closure, implementation of national lockdown and surveillance enhancements (Jefferies et al., 2020). New Zealand was fortunate with its low population density and slow community transmission meaning that the window of opportunity for elimination had not been closed by the original mitigation strategy. However, it still took seven weeks of shutting down for New Zealand to declare itself COVID-19-free in early June 2020 (Hollingsworth, 2020).

New Zealand's border has been closed to most travellers, but the country remains vulnerable to case imports post-elimination (Baker, Wilson, & Anglemyer, 2020d). In a first

instance, a week after declaring the country COVID-19 free, New Zealand Prime Minister announced that an 'unacceptable failure' resulted in two new cases of the virus. This failure was about two women arriving from London to visit a dying relative testing positive for COVID-19 after being allowed to leave a mandatory 14-day quarantine early on compassionate grounds and driving across the country. This deficit in integration of border management with public health led the Prime Minister to appoint the country's assistant chief of defence to oversee managed quarantine and isolation facilities (VOA, 2020). Management of these imported cases prevented community transmission. New Zealand enjoyed normal domestic life without community transmission for 102 days, but there was a subsequent community transmission in Auckland related to an unknown border failure. The government returned Auckland to lockdown. The rest of the country was moved to Alert Level 2, encouraging social distancing but allowing gatherings of up to 100 people and domestic travel (Normile, 2020).

New Zealand has since had rounds of city-wide lockdown between periods of domestic normality with zero community infection. This, along with prospect of a double-dip recession as the impact of its closed border on the vital tourism industry hits home (Smyth, 2021), have divided some scholarly, public and local political opinions about New Zealand's elimination strategy.

However, New Zealand's strategy, including its re-gaining of elimination by geographically targeted and shorter lockdowns, remains one of the most widely discussed Western cases in terms of successful government intervention (Anttiroiko, 2021; Baker et al., 2020a; Wilson, 2020). There were incidents of defying lockdown in Auckland in February 2021 (Hunt, 2021), but most New Zealanders still support elimination as evidenced by the government's strong re-election victory. There are concerns about job losses in the tourism sector, but construction activity remains at historically high levels with relatively long periods of domestic normality (Smyth, 2021). There are arguments about insufficient engagement with Māori communities, but the government responded to errors (Jamieson, 2020), for example, by ordering a review into handling of COVID-19 to *sharpen* elimination and improve its communication as the unique strategy that delivers best result for New Zealand (Hunt, 2021).

Independent SAGE, a group of scientists providing independent scientific advice on COVID-19, has called on the UK, which has a similar Global Health Security Index to New Zealand, to work towards elimination of COVID-19. At the sub-national level, Scotland and Northern Ireland pursue elimination urging England and Wales to join them in a four nation elimination strategy (Torjesen, 2020). However, some experts argue that even if these nations achieve elimination, the big challenge is maintaining the COVID-19 free status because of dependence on lorries for food from Europe and challenges of quarantining every truck driver (Science Media Centre, 2020). Greenland – an Arctic autonomous island jurisdiction of Denmark – eliminated the pandemic more or less in isolation. However, due to Greenland's economic reliance on Denmark and inconsistency of Greenland's elimination strategy with the Danish government's mitigation strategy, this success may be fragile (Grydehøj, Kelman, & Su, 2020).

Whereas some scholars argue that heavily restricting borders throughout pandemic and extending lockdowns designed to eliminate the virus will severely damage economies and translate to unemployment, with strong relations to other illnesses and suicide (Lee, Thornley, Morris, & Sundborn, 2020), others note that the socio-economic, healthcare

and public health advantages of elimination outweigh initial economic costs (Baker et al., 2020a; Lu et al., 2021; Shimizu, Tokuda, & Shibuya, 2021). Most are, however, unanimous about ramifications of non-situated elimination (Wilson, Barnard, Kvalsvig, & Baker, 2020).

Meanwhile, there are contexts like the Caribbean small island developing states in which their low capacity to respond to health emergencies, on the one hand, and their manageable number of physical entry points and later arrival of the virus in these remote territories led to adoption of elimination as 'Plan A' strategy (Hambleton, Jeyaseelan, & Murphy, 2020). After elimination could not continue due to social ramifications of lockdowns and heavy reliance on the tourism sector, there was a strategy shift to suppression. The nations of the Caribbean began to reopen from June, 2020, most demanding that visitors present a negative PCR test and complete a period of quarantine. Jamaica set up a so-called resilient corridor, outside of which tourists were not permitted, but January 2021 saw a surge in community transmission followed by lockdowns in some of the island states. It is yet to be seen if suppression will work in these contexts or there has to be another shift, this time to mitigation, for example, given highly transmissible new variants of the virus entering the Caribbean with tourists while communities react negatively to recurring mobility restrictions (Burki, 2021).

3.2.2. Suppression

Another pandemic management strategy increasingly advocated in scientific circles is suppression (Ferguson et al., 2020; Handel et al., 2020; Walker et al., 2020b). Suppression aims to substantially lower case numbers and keep community transmission at minimum until effective pharmaceutical interventions (Baker et al., 2020a). In suppression, stringent mobility restrictions are applied later and for a shorter period than in elimination (Table 3). In other words, lockdown and border closure are put in place when community transmission is surging and lifted when it returns to minimum (Walker et al., 2020b).

In the suppression strategy, the more successful the interventions are applied the less possibility of herd immunity. Therefore, despite its healthcare and public health advantages, suppression involves higher possibility of new epidemic waves after relaxing stringent interventions while the virus is still in the community (Kassem, 2020). For this reason, some mobility restrictions known as *partial* lockdown – e.g. closing of schools and public venues – continue throughout pandemic (Kayı & Sakarya, 2020) (Table 3).

However, a study by Gollwitzer, Platzer, Zwarg, and Göritz (2020) about public acceptance of mobility restrictions aimed at suppressing COVID-19 in Germany explored that length of restrictions was more impactful on negative community reactions than their intensity. In May 2020, Bohr et al. (2020) wrote an article in Spiegel International indicating challenges of suppression strategy in its prolonged limitation of socializing and recreation. Bohr et al. (2020) referred to a tweeted photograph from a popular Berlin park showing hundreds of people sitting close together under the sunny sky with little in the way of social distancing.

Naumann et al. (2020) explore particular dissatisfaction among Germans with closing public transportation. Meanwhile, some top-down decision-making in city planning confined the scope for creating safe spaces for walking and bicycling. For example, pop-up bikeways in Berlin were taken down after a legal dispute (Combs & Pardo, 2021). When partial closing of stores and the shutdown of hotels, restaurants, gyms

and cultural venues was followed by announcement of a five-day lockdown over Easter 2021 in response to surging infections, the plan caused widespread criticism leading to its cancellation and a public apology by German Chancellor who called the plan a 'mistake' on implementation grounds (Delfs & Rogers, 2021).

Meanwhile, in the early phase of the outbreak Germany missed to set up suppression. On 27 January, shortly after the outbreak in Wuhan, the infection was detected in Germany with an employee of the Bavarian automotive production factory Webasto infected by a Chinese visitor from Wuhan to the company (Acuto, 2020). Despite evidence of community transmission, there was a failure to ban carnival gatherings and close the border with high-risk areas. Universities, schools and kindergartens were only closed on March 16 when there were already more than 9000 confirmed cases in Germany (Jung, Krieger, Hufert, & Küpper, 2020). On 22 March, a total of nine rules of conduct were put in place for Germany to 'reduce public life as far as it is justifiable'. Despite the surging cases, these measures did not constitute a lockdown because people were still allowed to go to work. In this respect, some categorize Germany's strategy against COVID-19 as mitigation rather than suppression (Lu et al., 2021). However, although most states in Germany took similar anti-contagion measures in accordance to central directives, heavily impacted states such as Bavaria implemented more stringent policies (Desson, Lambertz, Peters, Falkenbach, & Kauer, 2020). For instance, when the Bavarian district of Wunsiedel at the German-Czech border became a disease hot spot with over 300 new infections per 100,000 people over 7 days, a lockdown was put in place for the district by State of Bavaria until the rate drops to below 35 that is a suppression target.

In strategy of suppression, with continuous disease circulation in the community that is intended to be kept at minimum, there have been moves towards comprehensive, techno-driven societal surveillance. However, this has been controversial in most developed nations. Tracking of mobile phones of infected persons without their consent for contact tracing was met with public criticism in Germany (Naumann et al., 2020) and has been avoided for the same reason in Canada (Hansen & Cyr, 2020). However, South Korean government maintained a public database of known patients including their travel routes (Dar, Lone, Zahoor, Khan, & Naaz, 2020) obtained through interviews, medical facility records, credit card transactions and closed-circuit television (Hansen & Cyr, 2020). This helped South Korea to rather exceptionally suppress the disease not only avoiding a lockdown but also operating most businesses as usual amid an outbreak in mid-February 2020 (Sonn & Lee, 2020).

In February 2020, in just a few days after the first case was reported in the northern region of Lombardy, Italy became the epicentre for the disease (Sjödin, Wilder-Smith, Osman, Farooq, & Rocklöv, 2020). High spread and health impact of the disease in Lombardy was associated with several factors, including industrial facilities with global connections, e.g. to China, population density, aging population and air pollution (Bontempi, 2021). Also, in contrast to some other regions with decentralized primary care, Lombardy was reliant on large, urban hospitals which backfired in the pandemic, funnelling sick people into the hospitals, which in turn became sources of infection (Paterlini, 2020).

On 22 February 2020, Italy imposed a lockdown in 'hotspot' regions (Sjödin et al., 2020). On 11 March 2020, a national lockdown was put in place which lasted until 4

May 2020 (Alanezi et al., 2020). Long duration of the lockdown was partly affected by multi-generational homes in Italy (Baniamin, Rahman, & Hasan, 2020). On the other hand, the caring Mediterranean culture was behind community volunteerism helping the elderly with their shopping and other errands in this period. Purchases for essential items did increase under lockdown, but with collaboration networks of municipalities, multifunctional farmers, local markets, etc., no stockout harmed the food security of Italians (Cavallo, Sacchi, & Carfora, 2020). Psychological implications of the lockdown were more significant. Some residents of apartment buildings and tower blocks responded to their stress of confinement by balcony signing in solidarity (Thorpe, 2020). After the lockdown controlled the transmission in all regions, a cautious lifting of some restrictions began (Lavezzo et al., 2020). For example, wholesale retail linked to manufacturing and construction reopened; parks were reopened, on condition local authorities ensured that people would not form groups there, and people were allowed to go for walks further away from their homes. Alert thresholds were monitored to enable timely intervention in localized situations to prevent a new wave of the disease (Follain & Rotondi, 2020). Italy has since adjusted its suppression measures with the extent of community transmission, but overall, it has almost been under continued restriction of socializing. Meanwhile, critics blame government for a less stringent stance on public transport seen as major culprit for infection surge in October 2020 (Amante, 2020).

3.2.3. Mitigation

The most common response to COVID-19 has been the usual pandemic planning based on a mitigation strategy. Mitigation allows more relaxed community living with the pathogen than is usual in suppression (Kassem, 2020). It involves a range of measures (Table 3) to slow the spread of the disease and flatten the epidemic curve (Saez, Tobias, Varga, & Barceló, 2020). In the mitigation strategy interventions have to be timely instituted (not too early) to give controlled chance for herd immunity to develop and to allow economic and social activities to further continue in fragile settings (Chowdhury et al., 2020; Kassem, 2020). Lockdown is imposed, but only near or at peak of epidemic when the number of intensive care unit cases reaches capacity, and is lifted usually after 2 weeks to 1 month when the respective peak is flattened – i.e. the number of intensive care unit cases drops to 50% of capacity (Menoni & Schwarze, 2020). Mitigation continues until effective pharmaceutical interventions or until a large pool of people have gradually acquired immunity to the virus (Kwok, Lai, Wei, Wong, & Tang, 2020).

India began its response to the pandemic with a suppression strategy that was not situated in the specific socio-economic contexts and characteristics of life and work for most people. Ghosh (2020, p. 519) describes consequences of this non-situated suppression as follows:

> The most destructive effects of COVID-19 in India have not been the result of the disease, but the nature of the government response. The most stringent lockdown in the world destroyed the economy and forced millions into poverty and hunger, but did not control virus transmission.

In India, the first case of COVID-19 was reported on 30 January 2020, followed by two similar cases on 2 and 3 February. All three had a travel history to Wuhan, China. A sharp

increase in numbers followed (Khanna, Cicinelli, Gilbert, Honavar, & Murthy, 2020). Early into the pandemic, on 25 March 2020 when the country had 320 cases the Indian government required all international travellers entering the country to self-quarantine for 14 days, cancelled all travel visas to other countries (Khanna et al., 2020) and imposed a national lockdown confining people to their homes (Ghosh, 2020). The lockdown was intended to last for 21 days but had to be extended three times until 31 May when despite 8782 daily infections the government of India eased the lockdown. This was the beginning of a shift to a mitigation strategy by the central government that had imposed, without coordination with state governments, a lockdown order which was too soon and too long for its context. In India, large population groups are below the poverty line and operate at the margin of subsistence, and around one-third of the urban population and at least quarter of villagers live in extremely congested conditions, in very small dwellings with five or more people confined to one room (Alanezi et al., 2020; Ghosh, 2020). As a result, not only COVID-19 infections and deaths continued to increase under the lockdown but also there were at least 600 unnecessary deaths resulting from the non-situated lockdown, including deaths of migrant workers attempting to reach their homes in difficult circumstances (Ghosh, 2020).

Negative implications of this suppression attempt overshadowed implementation of its substitute mitigation strategy. For example, whereas the nation has world's highest tally of daily infections, hundreds of thousands of Hindu devotees were allowed to gather in April 2021 by the Ganges River for special prayers provided they test negative for the virus and maintain 'social distancing' (Aljazeera, 2021a). This was followed by record cases and hospitals reporting severe shortages of beds and oxygen supplies in the light of which Indian government announced weekend lockdowns in the capital (Aljazeera, 2021b).

Brazil's first COVID-19 case was confirmed on 26 February 2020. The case was that of an elderly man living in São Paulo who had returned from a trip to Italy. The disease spread rapidly (Oliveira, Duarte, França, & Garcia, 2020). More than half of the cases were concentrated in the states of São Paulo and Rio de Janeiro with a high aerial network, which imported the disease, and population density facilitating the dissemination of the virus (Szylovec et al., 2021). At the time the disease was introduced into the country, the majority of cases were imported and there was an attempt to contain the disease by tracing and isolating cases and contacts. With the growth in the number of cases and the occurrence of community transmission, a mitigation strategy was introduced (Oliveira et al., 2020).

In March 2020, the Ministry of Health stated that Brazil's health system would collapse by the end of April. For instance, the shortage of hospital beds was worrying (Szylovec et al., 2021). Lockdowns were imposed in most states but they were maintained only until hospital beds, mechanical ventilators and healthcare teams were sufficient available (Aquino, Silveira, Pescarini, Aquino, & Souza-Filho, 2020). In political terms, it would have been challenging for the autonomous states to extend lockdowns beyond this length while the president was making public statements against restrictions on movements and business (Aquino et al., 2020). Furthermore, this strategy of mitigation was situated in Brazil's challenging social-economic context such as budget deficit, disparities and significant proportions densely living in *favela* – i.e. a slum located within or on the outskirts of the country's large cities, on daily wages (Khalifa et al., 2020; Oliveira et al., 2020). The nation's global food sector is also

inconsistent with stringent restrictions. For example, the period of closure of meat processing plants in Brazil due to COVID-19 led to animals being euthanized as the supply chain backed up, and cool storage capacity was also under increasing pressure (OECD, 2020).

By the end of June 2020, Brazil had the second highest number of infections in the world, but it has now been overtaken by India. In contrast to critiques about India's lockdown victims (Agoramoorthy & Hsu, 2021) 'in vain' (Ghosh, 2020), some argue that Brazil's consistent mitigation is defendable (Szylovec et al., 2021). However, populations more vulnerable to community circulation of the virus such as the elderly and favela dwellers did not receive particular attention in implementing the strategy of mitigation (Szylovec et al., 2021). Inadequacies of Brazil's central leadership, local resources and healthcare logistics were partly addressed by prior existence of regional partnerships such as the Santa Catarina Interfederative Consortium of municipalities which, for example, helps municipalities involved in COVID-19 treatment to place shared bids and find supplies to cover current needs (Ramírezde la Cruz, Grin, Sanabria-Pulido, Cravacuore, & Orellana, 2020).

3.3. Selecting a strategy that is situated in epidemiological determinants

Analysis of internal **s**trengths and **w**eaknesses, and external **o**pportunities and **t**hreats, known collectively as SWOT, is used to guide strategy selection in fields such as business management and public health (Dyson, 2004). SWOT analysis of the epidemiological determinants can assist in choosing a situated strategy of pandemic management. As their mechanisms of impact in Table 2 indicate, epidemiological determinants in territorial terms may be divided into internal and external determinants. Internal determinants consist of governance, society, economy, built environment and nature. External determinants comprise geo-position and outreach. SWOT analysis of these determinants can help selection of a strategy by providing a holistic view in a 2-by-2 table. However, as Table 4 indicates, this traditional SWOT analysis lacks a systematic methodology for concrete contribution to selecting a particular strategy (Leigh, 2010).

Table 4. A conventional framework for SWOT analysis of the epidemiological determinants (Author).

Internal: governance, society, economy, built environment, nature	**S**trengths	**W**eaknesses
	a.	a.
	b.	b.
	c.	c.
External: geoposition, outreach	**O**pportunities	**T**hreats
	a.	a.
	b.	b.
	c.	c.

Table 5. The TOWS strategies and their matching pandemic management strategies (Author).

	External	
Internal	**O**pportunities	**T**hreats
Strengths	**S-O** or **Maxi-Maxi:** Uses strengths to maximize opportunities »»»» **Elimination of pandemic**	**S-T** or **Maxi-Mini:** Uses strengths to minimize threats »»»» **Suppression of pandemic**
Weaknesses	**W-O** or **Mini-Maxi**: Takes advantage of opportunities to minimizes weaknesses »»»» **Elimination-mitigation of pandemic**	**W-T** or **Mini-Mini**: Copes with weaknesses and threats »»»» **Mitigation of pandemic**

Weihrich's (1982) work, *The TOWS Matrix – A Tool for Situational Analysis* addresses this gap by offering a structure for generating four strategies through pairings of S and W with O and T. Table 5 demonstrates that these strategies based on their aims match particular pandemic management strategies. For example, strategy of W-O or Mini-Maxi that involves taking advantage of opportunities to minimize weaknesses corresponds to elimination-mitigation. This means that a 'go-early, go-hard' anti-contagion response should seek to eliminate the *slowly* (opportunity) entering pandemic to which governance, society economy, etc. are overall *vulnerable* (weakness), but if elimination fails in a certain duration, a shift to mitigation is advised because of damages of long term stringent measures to such fragile settings, but in the S-O or Maxi-Maxi strategy, persistent elimination is advised as the pandemic management strategy.

Systematic selection from between these strategies can be undertaken through arithmetic operations on S, W, O and T that are quantified on an interval scale (e.g. $-3 \leq W, T < 0; 0 < S, O \leq 3$). These arithmetic operations that sum up S and W values, and O and T values produce coordinates that not only identify one of the four strategies but also provide a measure indicating strategy's embeddedness (see Table 6). For instance, in the example scale, coordinates of (0.7, 1.1) identify a Maxi-Maxi or elimination strategy that is less embedded in epidemiological determinants than it would be with coordinates of (1.89, 2.1).

In order to utilize this measure of strategy embeddedness for more precise strategy identification, a Cartesian plane with twelve strategy quarters is proposed in Figure 1. According to the Cartesian plane, if the pair of coordinates is (−1.9, 2.5), a suppression strategy would be highly embedded, but for coordinates of (−0.8, 2.5), a reserve strategy of elimination should also be considered (because the threat value is in the lower half), and for coordinates of (−0.8, 1), a reserve strategy of mitigation is advised (because the strength value is in the lower half).

Table 6. Calculating coordinates of a situated strategy of pandemic management (Author).

Epidemiological determinants			Strength analysis	Weakness analysis	Opportunity analysis	Threat analysis
Ter.	Sphere	Example	$0 < S \leq 3$	$-3 \leq W < 0$	$0 < O \leq 3$	$-3 \leq T < 0$
Internal	Governance	Communicativeness, smartness	$\overline{S}G$	$\overline{W}G$		
	Society	Poverty, demography	$\overline{S}S$	$\overline{W}S$		
	Economy	Supply chain, gross domestic product	$\overline{S}E$	$\overline{W}E$		
	Built environment	Density, air pollution	$\overline{S}BE$	$\overline{W}BE$		
	Nature	Wind, temperature	$\overline{S}N$	$\overline{W}N$		
	Mean of means		$\overline{\overline{S}}$	$\overline{\overline{W}}$		
External	GeoPosition	Remoteness, connectedness			$\overline{O}GP$	$\overline{T}GP$
	Outreach	Overseas politics, trans-boundaries			$\overline{O}O$	$\overline{T}O$
	Mean of means				$\overline{\overline{O}}$	$\overline{\overline{T}}$
Coordinates of strategy			$Y = \overline{\overline{S}} + \overline{\overline{W}}$		$X = \overline{\overline{O}} + \overline{\overline{T}}$	

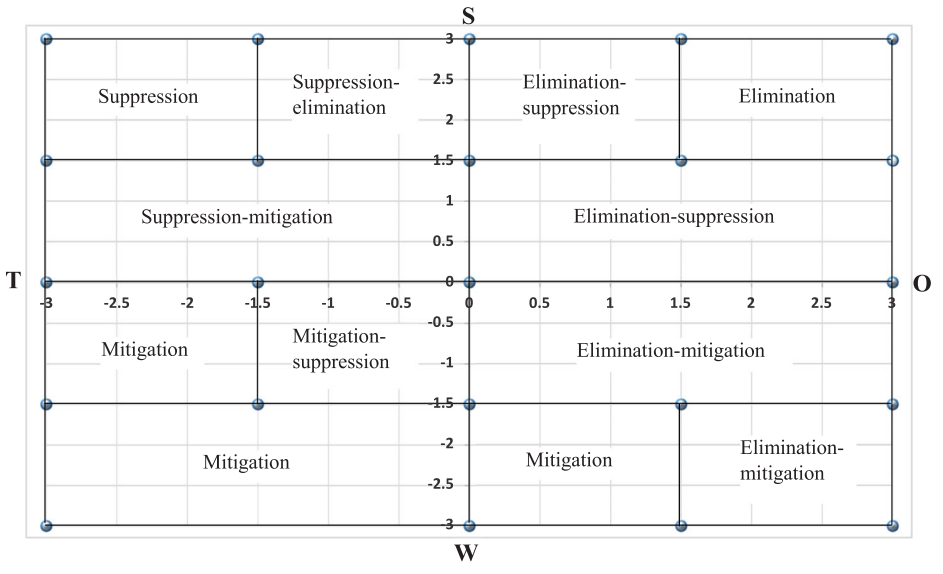

Figure 1. Cartesian plane for detailed selection of a pandemic management strategy (Author).

3.4. Preparing for future application of pandemic management strategies

Table 7 consolidates lessons learned from situated elimination, suppression and mitigation of COVID-19 that should constitute prior preparations for future application of these strategies. Although pandemic management strategies need consistent action across different scales, each strategy involves a scalar focus in navigating towards its particular goal. This scalar focus is national for elimination, local for suppression and regional for mitigation. Table 7 explains this scalar focus and explores main preparations for each strategy at its core scale.

Table 7. Prior preparations for future application of pandemic management strategies (Author).

Strategy	Scalar focus	Preparations
Elimination	**National** To achieve zero community transmission in the nation by multi-sectoral (e.g. border policy, economy configuration …) and multi-level policy integration	(I) A dedicated national agency is needed to put elimination preparedness at the center of all-of-government activities (Kvalsvig & Baker, 2021; Summers et al., 2020). (II) Multidisciplinary science input and establishment of inclusive communication channels should underpin the agency's work (Baker, Kvalsvig, & Wilson, 2021; Jamieson, 2020).
Suppression	**Local** To maintain minimum community transmission by continued restriction of socializing and by persistent contact tracing	(I) Cities should prepare for suppression by small-sized, diffused green spaces (Honey-Rosés et al., 2020) and healthcare services (Paterlini, 2020), as well as maze-like urban parks (Davies, 2020) to minimize risks and lower the burden of social distancing in dense environments (Teller, 2021); by enabling 'tactical' urbanism or user adaptations in housing and community spaces

(*Continued*)

Table 7. Continued.

Strategy	Scalar focus	Preparations
		(Graziano, 2021); by building self-contained (e.g. 15-minute) urban districts (Hanzl, 2020); by shifting sustainable mobility from public transportation to cycling and walking (Capolongo et al., 2020); and by assigning more bottom-up powers to tailor such changes to local development plans (Combs & Pardo, 2021). (II) Preparing for suppression requires organizing and technologically equipping community networks for decentralized, human-driven disease surveillance including voluntary sharing of health data and location histories (Intawong, Olson, & Chariyalertsak, 2021; Kummitha, 2020).
Mitigation	**Regional** To reduce public health and healthcare impacts of significant virus circulation by partnership work	(I) Preparing for mitigation requires creating regional partnerships of local governments, private and health sectors (Baxter & Casady, 2020a; Ramírezde la Cruz et al., 2020) that, for example: • pursue reasonable control of population density (Zhang and Yuan, 2021); • support inter-local healthcare organizing; • facilitate setting up virtual clinics so that that patients continue to receive clinical care while reducing physical crowding into hospitals with epidemic admission (Ting et al., 2020); • explore binding agreements between suppliers and consumers of medical equipment/goods (Baxter & Casady, 2020b); and • facilitate unsolicited proposals by private organizations like temporary allocation of tourism apartments as emergency housing for families in vulnerable situations and homeless (WHO, 2020) or like repurposing of hotels adjacent to hospitals to serve as auxiliary units in a crisis (Baxter & Casady, 2020b). (II) Regional slum programs are needed that coordinate actions and pool resources to upgrade water/sanitation, enhance space standards and create tailored health centers (Chigbu & Onyebueke, 2021). (III) Preparing for mitigation requires joint venture regional warehouses to stockpile medical equipments (Baxter & Casady, 2020b; Livingston, Desai, & Berkwits, 2020).

3.5. Discussion

This meta-synthesis of COVID-19 lessons explored four questions to chart sustainable management of future pandemics:

(a) What are epidemiological determinants? Findings of a multitude of individual studies exploring epidemiological determinants were interpreted and assigned to seven spheres. A comprehensive list of determinants and their mechanisms of impact was

provided. To the best of authors' knowledge, this list is encompassing at the time of writing, but it should be updated as new epidemic dynamics will unfold in the future.

(b) What are pandemic management strategies and their requirements? Knowledge about strategies of elimination, suppression and mitigation was consolidated in respect of their goals, measures and requirements for successful implementation with various international illustrations. Other strategy variants are in principle Plan A – Plan B combinations of these three basic strategies. This study excluded herd immunity because it is not an anti-contagion strategy.

(c) What technique can situate selection of a pandemic management strategy in epidemiological determinants? A quantified SWOT analysis of epidemiological determinants producing coordinates for strategy identification in a Cartesian plane divided into twelve strategy quarters was proposed.

(d) What prior preparations are needed for future application of each pandemic management strategy? Lessons learned from situated elimination, suppression and mitigation of COVID-19 constituted conceptualizations of prior preparations needed for future application of these strategies. These preparations for elimination should focus on national institutions and procedures, for suppression should focus on local land uses and communities and for mitigation need to focus on regional partnerships and logistics.

4. Conclusions

More than a year into the COVID-19 pandemic and with prospects of more emerging zoonoses, we need to stay ahead of similar crises in the future, and build back better from this crisis. Sustainable pandemic management was coined in a meta-synthesis of COVID-19 lessons to chart this in conceptual and technical terms. To stay ahead of future pandemics and avoid life ravaging mistakes made in selection of COVID-19 strategies, it is imperative that inter-disciplinary study projects for situated selection of strategies to tackle future pandemics begin from now. To build back better from the COVID-19 crisis, it is essential that prior preparations for future application of pandemic management strategies are put at the centre of all-of-government activities.

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