RESEARCH ARTICLE

A qualitative approach in comparing six cities toward a resilient response plan: COVID-19 and inequalities

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Abstract

COVID-19 has dramatically affected financial markets, economies, and societies worldwide and exposed pre-existing inequalities in cities. This work aims to understand the inequalities in some cities worldwide, their reasons and circumstances, and impacts to drive lessons for future prevention, intervention, and post-catastrophe/ hazard plans such as COVID-19 that would raise resilience and decrease damages. Six major cities were included in the analysis and contrasted based on specific assessment criteria. The study included the impact of the pandemic on the economy and the government's responses global crisis. Additionally, newfound measures and technologies developed to control the hazard, including the community's response and cooperation to solving the issue were explored. The outcomes of this work shed a light on problems to be addressed in the future towards enhances the resilience of cities pre- and post- global crisis. Through the comparisons made in this paper, conclusions regarding the cities' successful combat against COVID-19 were drawn. According to the comparative analysis, it became apparent that poverty, culture, and governance are primary factors that control the success of states under emergency. Moreover, it is understood that technology is a significant factor in combating pandemics and health emergencies as large as COVID-19, especially for tracking and monitoring.

Keywords COVID-19, Resilient cities, Spatial inequality, Temporal inequality, Infrastructure, Governance practice, Technologies, Lockdown

Introduction

The emergence of the COVID-19 pandemic, even if not the highest in death tolls throughout history, resulted in the largest distributional consequences in the history of pandemics (Cabral and Xu 2021). Consequently, many researchers have studied the environmental and socio-economic impacts, management, and governance of the crisis caused by the pandemic (Sharifi and Khavarian-Garmsir 2020), These studies established that the old socio-economic inequalities, such as healthcare, unemployment, and housing, already existing in major cities became more exposed as a result of the pandemic (Sharifi and Khavarian-Garmsir 2020).

Inequality exists in various forms, such as, between rural and urban areas, majority and minority of a community (Visagie and Turok 2021), or in vulnerable areas with poor living conditions with limited accessibility to basic infrastructure (de Groot and Lemanski 2020). The factors leading up to such inequalities can be reduced to poverty, culture, and, more importantly, governance. Therefore, the inclusion of these factors ahead of time is determinantal to the success of prevention, rehabilitation, or control measures plans, implemented in the time of national or international crisis.

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The fundamental understanding of culture is paramount for proper assessment and communication of the global response to COVID-19, taking into consideration factors such as individualism vs. collectivism, cultural identity, diversity of nationalities, and cultural background (Airhihenbuwa et al. 2020). Furthermore, a cultural framework for community engagement is essential to ensure a global communication response to COVID -19 and a collaboration with the government (Cruz et al. 2020).

The role of technology cannot be ignored in tracking, monitoring, and supporting COVID-19 control measures. The Information and Communication Technologies and Big Data analysis assisted in the resilience of cities throughout the duration of the pandemic (Linkov et al. 2021). However, the use of technology may highlight the inequalities caused by COVID-19 (Madianou 2020), citizens within the poverty limits or poor urban areas are incapable of easily accessing technology. Another measure that can slow down the spread of COVID-19 but also accentuates the inequalities is the lockdown that limits the mobility of vulnerable areas and people (Gozzi et al. 2021). Hence, governments should prioritize the systematic elimination of inequalities to ensure proper and fair future pandemics prevention or mitigation plans accessible to all citizens across different social classes (Sharifi and Khavarian-Garmsir 2020).

Notwithstanding, inequalities detrimental to the success or failure of pandemic preventive measures and resilience of cities are not limited to minorities, poverty rate, culture, or urban vs. rural areas. They also encompass gained experience in combatting previous hazard/catastrophe or governance. Therefore, it can be said that a city with a low poverty rate does not automatically mean more resilient toward the COVID-19 crisis. Likewise, a city with less experience combatting such pandemics is not necessarily less resilient.

In this contribution, we aim to demonstrate the effect of some cases of inequalities between different cities in combatting the spread of the pandemic. The examined inequalities span across different factors such as, (1) spatial and temporal factors in diagnosis, treatment, and rehabilitation of COVID-19, (2) inequalities of the use of digital infrastructure for monitoring, tracking, and supporting the COVID-19 control measures, as well as (3) inequalities in governance practices on COVID-19 health risks, prevention, and intervention. In this regard, six cities were selected and studied to understand their inequalities based on the aforementioned criteria. Finally, a qualitative approach was followed to make a comparison in order to identify the success of each city's prevention plans or responses to the COVID-19 crisis.

Methodology
City selection
Towards assessing the effect of inequalities on the success rate for a given country in mitigating a global crisis, a cause-and-effect relationship was established though collecting secondary data. Using previous research, journals, newspapers, and government records; the necessary data was collected to assess the success rates of the cities being studied.

Six major cities were selected, including Abu Dhabi (UAE), Amman (Jordan), Sao Paulo (Brazil), New York state (United States), Bengaluru (India), and Shanghai (China). Additionally, for the sake of establishing a fair comparison, each two cities were paired and compared based on a specific shared criterion that influenced their response to the pandemic, as such:

Abu Dhabi and Amman were compared due to their similar geographical locations in the Gulf region, along with being affected by the pandemic at a later time than other major cities.

Sao Paulo and New York state were compared due to their similar population densities.

Bengaluru and Shanghai were compared owing to their effective implementation of various technologies throughout the pandemic.

The cities mentioned above were compared based on three criteria: (1) the impact of governance practice, (2) the spatial and temporal inequality, and (3) the impact of digital infrastructure on monitoring and tracking COVID-19. The impact of governance practice denotes the government's response and actions in halting the progression of the pandemic in their respective cities. On the other hand, spatial and temporal inequalities are focused on the lack of recourses, supplies, and infrastructure in cities leading to difficulties in mitigating the COVID-19 crisis. Conversely, the impact of digital infrastructure on monitoring and tracking encompasses the diverse range of technologies used in the efforts against the novel coronavirus.

To assure the reliability and objectivity of the data collected, several methods were applied. First, the data gathered from a variety of sources was normalized to insure it does not contain any inconsistencies and was uniform. To review the scientific literature, a thorough understanding of bias and how it affects study results was vital. For instance, the sources used focused on both the positives and negatives of the city being analyzed, with an objective point of view. Sources that failed to adequately point out the reasoning behind criticizing the city or the government were eliminated.

Through the comparisons made in this paper, conclusions regarding the cities' successful combat against COVID-19 were drawn. These conclusions establish

different tools and initiatives that are vital to learn from and recognize governance weaknesses to ensure preparedness for future pandemics or equivalent unforeseen events.

Case studies

Case of Abu Dhabi, UAE
Abu Dhabi was one of the lucky cities to be hit by the virus later than most countries, giving it a sufficient span of time to learn and prepare efficient methods to deal with the possible outbreak. Abu Dhabi is the capital of UAE, with a population of 1,511,768 (World City Populations 2021, 2021); and occupying 972 km^2 of UAE. Even with a large population, Abu Dhabi citizens showed an excellent response to the outbreak, due to the government's constant awareness and prevention campaigns. Similar to the case of Shanghai, the local GDP per capita grew by 2.4% as of 2021, resulting in a GDP of US $ 98,000 (Abbas 2021).

Case of Amman, Jordan
Amman is one of the cities that faced problems handling the COVID-19 pandemic. As of 2021, the city has a total population of 2,182,151 (Amman Population 2021 Demographics, Maps, Graphs, 2021), with an area of 1680 km^2, making it the largest city in Jordan. Due to the pandemic, the GDP of Jordan in 2020 decreased by 3.76% reaching 43.70 billion US Dollars (Trading Economics 2020). Moreover, the GDP per capita in 2019 was 4,426$US, decreasing to 4,259$ US in 2020 due to the government's late response to the pandemic (Jordan GDP per Capita, 1980–2020—Knoema, 2021).

Case of New York State, USA
New York state is ranked as the fourth most populated state in the United States, with a total population of 19,299,981 as of 2021, and a total area of 783.8 km^2 (U.S. States by Size in Square Miles 2020).

As such, the population density of the city is 38,242 people per square kilometre, making it the densest city in the United States (New York Population 2021 Demographics, Maps, Graphs, 2021). By the year 2020, the total gross domestic product (GDP)of the United States decreased by 2.3% reaching US $ 20.93 trillion $ (Gross Domestic Product, 4th Quarter and Year 2020 (Advance Estimate) | U.S. Bureau of Economic Analysis (BEA), 2021). This was a larger drop for the state of New York due to COVID-19 and the governments' restrictions, declining by 36% in the second quarter of 2020 (New York's Economy and Finances in the COVID-19 Era 2020).

In USA, The GDP per capita in 2019 was recorded to be US $ 65,254, with a change of 3.49% from the preceding year, however, in 2020 the GDP per capita decreased to US $ 63,416, changing by − 2.82% (United States of America GDP per Capita, 1980–2020—Knoema.Com, 2021).

Case of Sao Paulo, Brazil
The city of Sao Paulo is the largest among all cities in Brazil. As of 2021, Sao Paulo has a total population of 22,237,472 and an area of 1,521 km^2, with a density of 7,216.3 people per square kilometer (Sao Paulo Population 2021 Demographics, Maps, Graphs, 2021). Owing to its position as the foremost industrial center in Latin America, the Brazilian federal government has to initiate actions and programs that guarantee corporate income and business durability. The COVID-19 emergency assistance program has reached 66 million people, with payments of 50.7 billion US $, or close to 3.9% of GDP. In total, the federal government spent around 111 billion US$, nearly 8.6% of GDP. The central bank has also supported credit expansion in the financial system, which underpinned a rise of over 37%, equal to 1.7% of GDP. Overall, monetary and lending measures of around 12% of GDP were allocated to the COVID-19 response. As an outcome of these resources, more than 50% of the Brazilian population obtained support to counteract the fall in their income resulting from 10 million job losses in the first four months of the pandemic (ECLAC 2020).

Case of Bengaluru, India
As of 2021, Bengaluru is the capital and largest city in Karnataka state in India, with a total population of 12,764,935 (Bangalore Population 2021 Demographics, Maps, Graphs, 2021), and a total area of 709 km^2. It is also dubbed as the "IT capital of India", as it houses a multitude of Indian IT companies. Due to the pandemic, India's GDP growth rate was one of the slowest among emerging economies (currently $1.956 Trillion), with the number of poor people increasing by nearly 7.5 scores. According to the Pew Research Center, the pandemic pushed 32 million people into poverty in India last year, taking into consideration the majority of the 54 million people globally falling-out from the middle social class (Singh and Kumar 2021).

India's coronavirus cases and deaths have broken world records reporting 314,835 new cases on one day, surpassing the previous one-day high reported in the United States (297,430) in January 2021 (India—COVID-19 Overview—Johns Hopkins, 2021a). However, working with the assumption that the pandemic has worsened inequality in India, hence, the increase in poverty would have been far greater than predicted, along with the likelihood of shrinking the middle class (Das 2021).

Case of Shanghai, China

China was one of the first countries to be affected by COVID-19, positioning the country at the frontline of combating the pandemic as the virus emerged from the city of Wuhan. While the virus was still being investigated, Shanghai was one of the first cities to implement COVID-19 preventive measures.

Shanghai is the most populous city in China and the world, with a population of 26,317,104, in a total area of 6,340 km^2 (World City Populations 2021, 2021), along with being deemed as a central financial hub. As of 2020, the local GDP Per Capita is 24,046.23$US, which surprisingly has increased by 1.7% due to the government cutting taxes, which later proved helpful in keeping unemployment rates below 4.4%. Furthermore, the city encouraged digital enterprise development, allowing significant economy growth by 17.6%. This encouragement, in turn, gave the city a chance to recover from the losses occurring due to the pandemic (Global Times 2021).

Comparative analysis

Case study findings

To facilitate a fair comparison and identify common factors among the selected cities, this research examines significant inequalities in each city and their impact on their response to the crisis. In Table 1, we provide general information about these cities, including their population, area, GDP as of 2019–20, and the number of COVID-19 cases and deaths as of July 20, 2021, sourced from the World Health Organization (WHO).

Key percentages to consider are the proportion of COVID-19 cases relative to each city's population. Bengaluru and New York exhibit higher percentages at approximately 31.76% and 31.19%, respectively. In contrast, cities like Shanghai and Abu Dhabi have notably lower percentages of cases, at approximately 0.42% and 6.73%, respectively.

For the percentage of total deaths in relation to the population, Amman has a relatively high percentage of cases, approximately 79.67%, compared to its population. In contrast, other cities like New York show lower percentages of deaths relative to their populations, with New York at approximately 0.37%.

These percentages reveal the varying impact of COVID-19 in each city, highlighting the different degrees of effect on their populations.

The following figures represent the significant dates in the pandemic; first confirmed cases, case peak, first death, death peak, and lockdown implementation and lifting, to further understand the situation each city.

Figure 1. shows the first case and peak in each compared city; the figure indicates that cities like Abu Dhabi, Amman, and New York state took the longest to reach their daily case peak. However, New York is the highest number of cases out of the three. Moreover, Sao Paolo, since the start of the pandemic, reached its peak and amounted up to 20,483 cases in one day.

Figure 2. The following figure presents the first confirmed death and peak in each city that was chosen to compare. In addition, the death toll has also been included, where the highest death count of 1,082 was in Sao Paulo in late May, and the lowest was Shanghai having a peak of one death in a day.

Figure 3. represents the dates and the duration of the city-wide lockdown imposed as an emergency response to COVID-19. Amman, New York, Sao Paulo, and Bengaluru had a similar range in their implemented lockdown, where it generally lasted from 3 to 4 months. It can be noted that Abu Dhabi sustained the most extended lockdown of the compared cities. In contrast, Shanghai did not impose a lockdown but instead opted to enforce a 14-day quarantine period on anyone entering the city on 25th Jan 2020. Other cities later implemented this measure to reopen while maintaining infection rates.

Analysis of comparative study between Abu Dhabi and Amman

Provided in Table 2 are the major findings of the comparative analysis of Abu Dhabi and Amman cities based on the three criteria highlighted in "Case studies" section

Based on the governance impact criterion in Table 2, both capitals' governmental restrictions and rules were similar. They followed the policies listed by the World

Table 1 General information of selected cities and number of COVID-19 cases and deaths (Ritchie 2020)

City	Population	Area (km^2)	GDP of country 2019–20 (us $)	Total cases no. (as of sept 2022)	Total deaths no. (as of sept 2022)
Abu Dhabi	1,511,768	972.0	$2.49 trillion	1,020,000	2,342
Shanghai	27,795,702	6,340.0	$5.97 trillion	63,951	595
New York	19,299,981	783.8	$20.93 trillion	6,020,000	70,643
Bengaluru	12,764,935	709.0	$1.956 trillion	4,060,000	40,264
Sao Paulo	22,237,472	1,521.0	$473 billion	6,060,000	174,000
Amman	2,182,151	1,680	$43.70 billion	1,740,000	14,114

First Confirmed COVID-19 Case and Peak Dates*

Abu Dhabi
First Confirmed case 18th Mar 2020   26th Jan 2021   3,601

Amman
First Confirmed case 22nd Mar 2020   11th Feb 2022   18,872

New York
First Confirmed case 1st Mar 2020   11th Jan 2022   49,410

Sao Paulo
First Confirmed case 25th Feb 2020   19th Jun 2021   20,483

Shanghai
First Confirmed case 12th Jan 2020   18th Apr 2022   3,084

Bengaluru
First Confirmed case 20th Mar 2020   7th May 2021   48,781
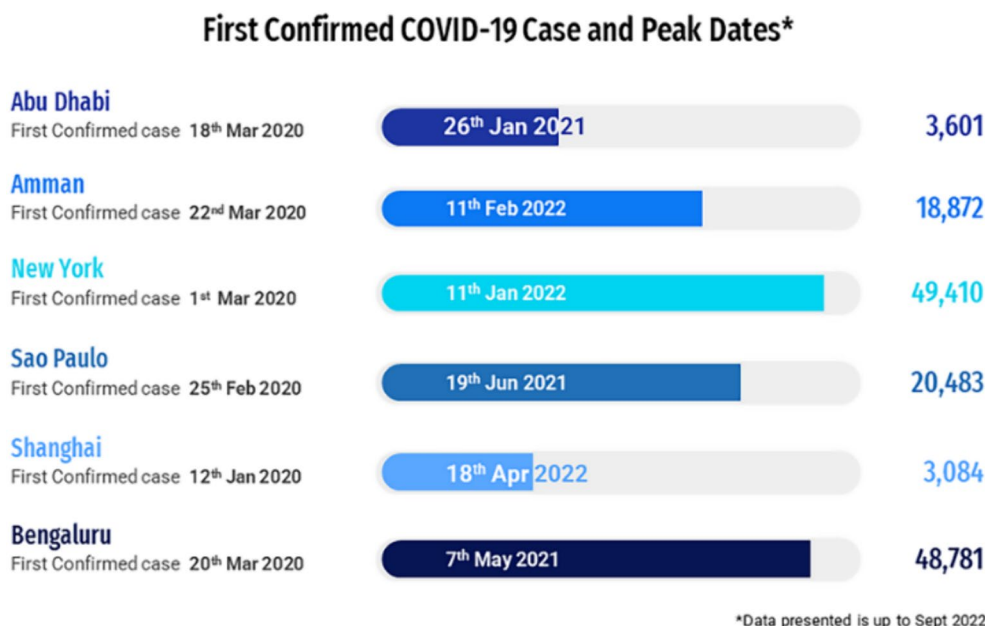
*Data presented is up to Sept 2022

Fig. 1 Abu Dhabi, Amman, New York state, Sao Paolo, Shanghai, and Bengaluru first confirmed cases of COVID-19 and peak timeline peak timeline (Ritchie 2020; Timeline: WHO's COVID-19 Response 2020)
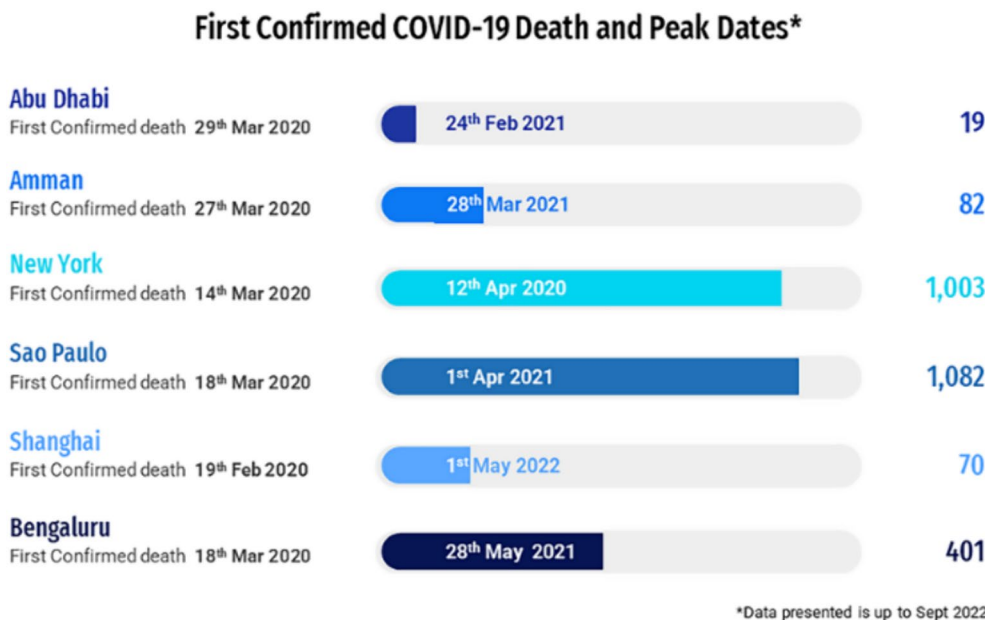
First Confirmed COVID-19 Death and Peak Dates*

Abu Dhabi
First Confirmed death 29th Mar 2020   24th Feb 2021   19

Amman
First Confirmed death 27th Mar 2020   28th Mar 2021   82

New York
First Confirmed death 14th Mar 2020   12th Apr 2020   1,003

Sao Paulo
First Confirmed death 18th Mar 2020   1st Apr 2021   1,082

Shanghai
First Confirmed death 19th Feb 2020   1st May 2022   70

Bengaluru
First Confirmed death 18th Mar 2020   28th May 2021   401

*Data presented is up to Sept 2022

Fig. 2 Abu Dhabi, Amman, New York state, Sao Paolo, Shanghai, and Bengaluru first confirmed death from COVID-19 and peak timeline (Ritchie 2020; Timeline: WHO's COVID-19 Response 2020)

Health Organization (WHO); however, with different implementation approaches. The major factor assisting Abu Dhabi throughout the pandemic timeline was its pre-existing emergency response system run by National Crisis and Emergency Management Authority (NCEMA). This enabled the city to be vigilant in detecting the virus, even issuing the first alert of the pandemic before it was announced as an international level public health emergency by WHO (al Hosany et al. 2021).

Emergency Lockdown in Response to COVID-19 Pandemic Timeline*

*The lockdown timeline presented is specific to the initial phase of the covid-19 emergency response plan for a full lockdown. Thus dates, where the cities imposed a partial lockdown, were not included.

Fig. 3 Emergency COVID-19 lockdown timeline for Abu Dhabi, Amman, New York state, Sao Paolo, Shanghai, and Bengaluru (Ritchie 2020; Timeline: WHO's COVID-19 Response 2020)

Abu Dhabi government practiced excellent risk communication with its public through a platform named "Weqaya" by NCEMA, catering to various groups in the community, while providing detailed awareness campaigns and updates on the status of the pandemic. Additionally, the city pushed the social distancing regulations standards set by WHO from 1 to 2 m, practiced the use of face masks before it was issued as a policy by WHO (al Hosany et al. 2021). Moreover, the city has closed public gathering spaces without entirely limiting the circulation in the capital except for the specific curfew hours of 8 pm–6 am. However, access from other cities in the UAE was entirely restricted. Additionally, the government of Abu Dhabi during the lockdown duration ensured mental health and safety for all its citizens by launching awareness campaigns, postponing fees, reducing bills, and providing aid to the elderly. They have also launched a National Disinfection Program to disinfect the city from the virus (al Hosany et al. 2021).

On the other hand, in the case of Amman, the governmental regulations restricted movement without any exceptions for an extended period, with the effects of prolonged confinement being damaging to mental health (Jordan: The Toughest Lockdown in the World | KfW Development Bank 2021).

Amman's forced lockdown permitted citizens movement only when shopping for necessities to neighbouring supermarkets (Jordan: The Toughest Lockdown in the World | KfW Development Bank 2021). In addition, bread and water were distributed to houses with buses and vehicles. Still, the service caused overcrowding in some neighbourhoods in the capital (BBC News 2020).

On the other hand, Abu Dhabi has created many field hospitals, transformed large spaces, formed screening centres, and dedicated hospitals for COVID-19 patients in various parts of the city (AlQutob et al. 2020). They have enough medical gear and equipment to supply different medical facilities to help accommodate patients (al Hosany et al. 2021). However, Amman had several field hospitals and hospitals that accept Coronavirus patients. Abu Dhabi was prepared to control the pandemic with its resources, citizens' cooperation, and preparedness plans (Abu Dhabi Government Incentives in Light of COVID-19 in Can Be Viewed Here. 2021). According to Table 2, Amman struggled with managing the disease due to the citizens' response and minimal resources. Abu Dhabi also launched a disinfection program to prevent the spread of the disease and ensure safety for all citizens and was careful to label it as a "Disinfection program" in lieu of lockdown to manage panic and provide a sense of security that extended for months till the outbreak subdued (Smart Solutions to Fight COVID-19-The Official Portal of the UAE Government 2020).

Similarly, Amman had a disinfection program for a short period to sanitize terminals, buses, stores, and streets (Constructionweekonline 2020). Moreover, both capitals used virtual learning during the outbreak through various platforms and applications. Additionally, they have both created applications that monitor and track COVID-19 cases. Nevertheless, Abu Dhabi had a

wider variety of applications that catered to many users like senior citizens and Abu Dhabi citizens abroad, as depicted in Table 2. Furthermore, Abu Dhabi extended its technology by utilizing drones and robots to disinfect and monitor people breaking social distancing laws or going outside curfew hours (Smart Solutions to Fight COVID-19-The Official Portal of the UAE Government 2020).

Based on Table 2, the delay in receiving the wave of the COVID-19 pandemic has played in favour of both cities. However, Abu Dhabi's strong economy and emergency plans enabled them to withstand the lockdown for a more extended period and carry out its response swiftly with the cooperation of the residents. On the contrary, Amman started strong yet did not have enough resources to carry out their lockdown since it risked the livelihood of the citizens; the circumstances forced them to return to their jobs. This comparison proves that a delay in the wave only helps learn how other cities respond to the emergency. However, it is almost impossible to sustain that response without enough resources.

Table 2 shows the comparison of the capitals Abu Dhabi and Amman. Both cities have similar geographic locations in which they are in the Gulf region.

Table 2 Comparative study between Abu Dhabi and Amman

Abu Dhabi	Amman
Impact of Governance practice	
• The first detected COVID-19 case in the UAE was in January 2020, but the government publicly announced the threat of COVID-19 in February 2020 (al Hosany et al. 2021) • Initially, a 28-day quarantine was required for people coming to the UAE, which was later reduced to 14 days (Policy Responses to COVID19, 2020) • The UAE launched the National Disinfection Program to sanitize all public facilities, streets, public transportation, and metro services to ensure the highest level of protection and prevention (Abu Dhabi Government Incentives in Light of COVID-19 2021) • National and international travel and transportation were banned, and visas issued to all foreigners were suspended as a precautionary measure (al Hosany et al. 2021) • The government declared the execution of penalties for all public health violators (al Hosany et al. 2021) • A stimulus plan of AED 156 billion (42.4 US$) was created to support and later reboot the national economy (Policy Responses to COVID19, 2020) • The validity of expired IDs, visas, and passports was extended to help citizens find stability in the city (al Hosany et al. 2021) • Electricity and water consumption bills were reduced by 20% for three months (Policy Responses to COVID19, 2020) • The "Secure Together" initiative provided medical aid, disinfection, and sanitation services to the elderly in their homes (Smart Solutions to Fight COVID-19 - The Official Portal of the UAE Government 2020)	• Jordan recorded its first COVID-19 case in March 2020, which was considered a delay compared to other countries (AlQutob et al. 2020) • More than 30 hotels were used for quarantining people coming from abroad (BBC News 2020) • The government implemented comprehensive and hourly curfews, along with the closure of non-essential facilities to limit the spread of the disease (Smart Solutions to Fight COVID-19-The Official Portal of the UAE Government 2020) • Violators of the curfew were imprisoned (Jordan: The Toughest Lockdown in the World | KfW Development Bank 2021) • Amman closed its borders with adjacent cities and suspended movement during the curfew (C. 2020) • There was a travel and transportation ban, both nationally and internationally (Alqutob et al. 2020) • The Government of Jordan launched two programs in the past two years to support households, workers, and businesses by delaying tax payments, providing partial payments of salaries, and offering special loans to small and medium companies (Overview 2020) • Municipalities delivered water and bread to citizens' homes using buses and vehicles (BBC News 2020)
Conclusion: Both cities took commendable steps in managing the pandemic despite the initial time advantage Abu Dhabi had. However, Abu Dhabi's stronger health sector and larger budget allowed it to control the pandemic for a longer duration compared to Amman	
Spatial and temporal inequality	
• Abu Dhabi launched the Al Meer Initiative to provide essential food supplies to 12,000 vulnerable families and foreign workers and distributed face masks and food parcels to laborers (Abu Dhabi Government Incentives in Light of COVID-19 2021) • A stem cell research center was established in Masdar City to research cures for the virus and new tracking methods (al Hosany et al. 2021) • Abu Dhabi Health Services (SEHA) set up field hospitals in the city, including Complex 3, a quarantine facility capable of accommodating 10,000 patients. This facility was erected in just nine days (al Hosany et al. 2021)	• Jordan initially faced a shortage of medical gear and supplies, requiring aid from multiple countries, including the UAE (UAE Sends Third Medical Aid Flight to Jordan in Fight against COVID-19, 2020) • Jordan had an excess of face masks, allowing them to export them to other countries in need (Jordan Set to Export Medical Equipment in Light of Global Shortage 2020) • The country significantly increased its face mask production, reaching 1.5 million masks daily by June 5, 2020 (Gov't Further Eases Lockdown as Most Sectors to Resume Operations Saturday 2020) • Jordan opened three field hospitals to expand bed capacities, accommodating a total of 1,000 beds, with 180 beds designated for intensive care (Al Arabiya English 2020) • The UAE assisted in the establishment of a field hospital in Aqaba, Jordan, with a capacity of 216 beds, including 56 intensive care beds (The National, 2021) • Jordan had several hospitals dedicated to treating COVID-19 patients, including Al-Isra'a Hospital, Istiklal Hospital, and Prince Hamzeh Hospital (Ministerie van Buitenlandse Zaken 2021)

Table 2 (continued)

Abu Dhabi	Amman

Conclusion: Abu Dhabi's robust, government-funded and private health sector provided resilience. In contrast, Amman faced shortages of beds and supplies due to the inability to sustain extended lockdowns, unlike Abu Dhabi

Impact of digital infrastructure on monitoring and tracking

Abu Dhabi	Amman
• UAE efficiently adapted remote learning in both private and government schools (Abu Dhabi Government Incentives in Light of COVID-19 2021) • Provided free PCR tests to various categories, including Emiratis, domestic workers, people of determination, pregnant women, residents over 50 years old, students, teachers, health workers, people with chronic illnesses, those with coronavirus symptoms, and all contacts of infected patients (al Hosany et al. 2021) • Launched the 'Weqaya' electronic platform to raise public health awareness about COVID-19 (al Hosany et al. 2021) • Deployed drones to monitor gatherings and issue warnings to the public to stay home and avoid gatherings (al Hosany et al. 2021) • Introduced disinfection robots to support the national sterilization program (Smart Solutions to Fight COVID-19 - The Official Portal of the UAE Government 2020) • Launched a COVID-19 awareness IVR prompts service for phone calls (Smart Solutions to Fight COVID-19 - The Official Portal of the UAE Government 2020) • Introduced an interactive health map that includes data for 13 drive-through COVID-19 testing centers, hospitals, healthcare centers, and clinics across the country (Smart Solutions to Fight COVID-19 - The Official Portal of the UAE Government 2020) • Launched the AL HOSN app for receiving and updating PCR testing results and vaccination validity (Smart Solutions to Fight COVID-19 - The Official Portal of the UAE Government 2020) • Introduced the TAWAJUDI mobile application to track citizens abroad and facilitate their safe return to the UAE, even during travel bans (Smart Solutions to Fight COVID-19 - The Official Portal of the UAE Government 2020)	• Jordan implemented comprehensive curfews, necessitating virtual learning for all educational facilities to assist, monitor, and test students (Putting Technology at the Forefront of Jordan's COVID-19 Fight 2020) • Jordan launched the "AMAN" mobile tracing application to inform citizens if they've been around a positive case and provide necessary procedures for close contacts (Jordan: New Executive Regulations on Preventive Measures to Combat COVID-19 Issued 2020) • A vaccine registration website was created to guide individuals on booking vaccination appointments (MoH COVID-19 VACCINE 2021) • The Ministry of Health established a dedicated website for COVID-19 news, updates, and analytical descriptions (Ministry of Health, the Official Website of the Jordanian Ministry of Health | Coronavirus Disease 2021) • Artificial intelligence was harnessed for vaccine and treatment development (Ministerie van Buitenlandse Zaken 2021) • Amman initiated a disinfection program to sanitize crowded terminals, buses, stores, and streets (Constructionweekonline 2020)

Conclusion: *Both cities employed successful and similar technological solutions to combat the virus, with Abu Dhabi having an edge due to its use of a broader range of technological approaches compared to Amman*

Additionally, Abu Dhabi and Amman received a delay in the wave of the coronavirus long after a significant number of cities got hit by it. The capitals dealt with the outbreak in different ways through governmental restrictions and the supply of medical gear. However, they had similar approaches by following the policies set by WHO and monitoring the spread through applications and websites.

Analysis of comparative study between Sao Paulo and New York State

Both Sao Paulo and New York faced terrible times due to the substantial rise of COVID-19 cases. Although each city struggled to mitigate the outbreak, they had a plan to control the spread by enforcing lockdowns. The government requested people to stay home, limiting the capacity at non-essential businesses and setting a national curfew. All these prevention measures are effective; however, they were not successful in these cases as demonstrated from the analysis shown in Table 3.

Both presidents represented a failed model for their citizens by spreading false information about the virus, demeaning the level of threat COVID-19 had on people's lives, and dismissing any safety precautions issued by the world's health organization (WHO).

As shown in Table 3, Sao Paulo had Bolsonaro shunning masks, advocating for fake healing methods, and favouring the economy over the safety of his people. The citizens of Sao Paulo were influenced by their leader, thus ignoring the safety rules enforced to minimize virus spread. In addition, New Yorkers also had to witness Former President Trump belittle the Coronavirus, which caused them to disregard precautions.

The adverse reactions of Former President Trump and Bolsonaro reduced their credibility in the publics' eyes due to not showing any concern for the safety of their people. Furthermore, both failed to demonstrate any understanding of the situation's risks and ramifications, resulting in a consistently high infection rate and shortage of medical resources.

Although New York and Sao Paulo had a similar outcome to COVID-19, there were special measures that New York state has implemented to control the transmission of the virus. New York has transformed

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Table 3 Comparative study between Sao Paulo and New York

Sao Paulo	New York
Impact of governance practice	
• Delayed government response and late preventive measures enforced by the federal government, with President Bolsonaro downplaying the severity of the virus (Watson 2020) • President's reaction influenced citizens to ignore restrictions and spread misinformation, such as opposing mask usage and lockdowns (Watson 2020) • Absence of a contingency plan, resulting in measures like travel bans and curfews upon lockdown implementation (COVID-19 - NYC Health 2020) • The Brazilian government's response included inactivity and wrongdoing, such as promoting chloroquine as a treatment without sufficient evidence of its efficacy ("Governor Cuomo updates New Yorkers on State's progress During Covid-19 pandemic. New New York State", 2021) • The lack of a unified national plan led to varied local responses in terms of shape, intensity, duration, and timing ("Governor Cuomo updates New Yorkers on State's progress During Covid-19 pandemic. New New York State", 2021)	• The government implemented restrictions for citizens to control the virus's spread, including avoiding crowds and public spaces, leaving home only for work, school, emergencies, or essential reasons, and staying home when feeling sick unless for testing (COVID-19 - NYC Health 2020) • President Trump initially downplayed the necessity of masks and proper precautions, suggesting the virus should be treated like the flu and later admitted not wanting to cause panic (Funke 2020) • As of May 10, 2021, many restrictions were adjusted, including the removal of capacity limitations for entertainment and dining facilities, the lifting of restrictions on residential gatherings, and increased capacity allowances for both outdoor and indoor crowd limits (Millman 2021) • Travelers arriving without symptoms were no longer required to quarantine in New York, which could potentially lead to an increase in cases (Novel Coronavirus (COVID-19), 2020)

Conclusion: Similarly, both cities struggled with controlling the spread of the disease. However, New York's government responded to the crisis better than Sao Paulo, primarily because of the difference in their economic situation and resources. New York was able to afford all the necessary precautions while Sao Paulo struggled

Sao Paulo	New York
Spatial and temporal inequality	
• Approximately 10 million people lost their jobs • Shortages of crucial intubation drugs, like neuromuscular blockers and sedatives, highlighted weaknesses in the overcrowded healthcare system, which operates under a profit-oriented model (Reuters et al. 2021) • There was a lack of comprehensive vaccine planning, and the rejection of 70 million Pfizer vaccines by the President (Ross & Hale 2021) • Vaccination began slowly due to limited dose availability, leading to a continuation of numerous deaths without immediate containment and a coordinated vaccination strategy (Castro et al. 2021) • Certain areas with social inequalities had a high number of COVID-19 cases due to factors such as limited access to piped water in homes, high population density per household, and economic instability. These conditions made it difficult to implement effective prevention strategies (Guedes et al. 2021)	• Disposable medical gear was reused due to supply shortages (Breazzano et al. 2020) • Health stakeholders and the EDC created a New York reserve plan to address equipment shortages, as the federal government's response was inadequate (Feuer et al. 2020) • There were delays of up to four weeks in PPE delivery, with prices increasing by 25% compared to pre-pandemic levels (David Robinson, The Journal News 2020) • Manufacturers increased production rates to meet the city's needs (Anderson 2021) • The Federal Emergency Management Agency and the Army Corps of Engineers added temporary facilities in New York, providing around 4,000 beds. Field hospitals were set up in The Bronx, Queens, Brooklyn, and Staten Island (Lardieri 2020) • University dorms and campuses, including those at the City University of New York's City College and Queens College, were used as temporary facilities for COVID-19 cases (Lardieri 2020) • Various facilities, such as the Brooklyn Nursing home, Marriott Brooklyn Bridge, "The Comfort" navy ship, Javits Convention Centre, and the Brooklyn Centre, were repurposed as field hospitals to accommodate COVID-19 cases (Lardieri 2020)

Conclusion: Both cities were at a significant disadvantage when it came to lack of medical resources and overflow of patients; however, New York managed to create more field hospitals and manufacture more supplies

Sao Paulo	New York
Impact of digital infrastructure on monitoring and tracking	
• Agência FAPESP developed a home diagnostic and monitoring system for remote monitoring of COVID-19 patients (Brazilian Startup Develops Technology for Monitoring of Patients with Suspected COVID-19, 2020) • The system includes a device placed on the index finger to track clinical symptoms • All patient data is connected to an application and a control panel monitored by a medical team (Brazilian Startup Develops Technology for Monitoring of Patients with Suspected COVID-19 2020)	• Watch brands like Fitbit and CarePredict collaborated with medical facilities to track positive cases and developed enhanced online shopping applications (5 COVID-Technology Advancements Show the Power of Innovation 2020) • A COVID-19 Technology SWAT team was formed to create technology-based solutions for virus control (TechCrunch Is Part of the Yahoo Family of Brands 2020) • The government established a website for people to propose suitable services to resolve their issues (Governor Cuomo Announces New Tool to Help New Yorkers Access Critical Benefits Amid COVID-19 Pandemic, 2020) • Schools operated both in-person and online, based on parental consent, with weekly testing requirements (Foresman 2021)

Conclusion: In the case of New York, their technological solutions were more oriented on monitoring, while Sao Paulo created solutions that helped in both monitoring and tracking patients and local changes in the pandemic

various public spaces into COVID-19 testing centres and field hospitals; this was an effort to treat more patients. Moreover, New York transformed dorms, nursing homes, ships, large public spaces, centres, and hotels for quarantine purposes and medical treatment of COVID-19 patients; this is undoubtedly a preventative measure that Sao Paulo could have implemented to manage the excessive numbers of patients. As the COVID-19 pandemic continues to grow, cities must adopt ways to have a plan of action to build resilience against any shortcomings.

Sao Paulo and New York lacked medical equipment at crucial times. In both cases, oxygen supplies were rationed, ICU beds were fully occupied, and both staff and equipment were lacking. Additionally, hospitals experienced overcrowding, due to the high number of cases. However, local manufacturers in New York contributed to resolving the issue through producing a sufficient number of medical equipment to cover the city's needs.

Ultimately, these two cases showed a failed example of governance where leaders were supposed to direct and help solve the problem. As such, unfortunately, both New York's and Sao Paulo's leaders were part of the problem, causing great panic and promoting negligence, contributing to the increased number of cases.

This table draws a comparison between two major cities around the world; Sao Paulo and New York. These two cities have a similar density. The table illustrates many ways in which the governments of each city had a drawback, whether it was a shortage in supplies, response, and digital infostructure and monitoring.

Analysis of comparative study between Shanghai and Bengaluru

Both cities were one of the few cities that were hit by the pandemic in its first stages, however, with different approaches towards containing its progression, as highlighted from the analysis included in Table 4. Shanghai was more proactive in solving the COVID-19 problem

Table 4 Comparative study between Shanghai and Bengaluru

Shanghai	*Bengaluru*
Impact of governance practice	
• The city's experience with SARS helped in early detection of the coronavirus (Policy Brief: COVID-19 in an Urban World 2020) • Ensured availability of face masks by preventing price hikes • Utilized a Public Health Emergency Mechanism with specialized on-site epidemiology teams to track and assess the virus (Lentin 2020) • Focused on close contacts of COVID-19 patients rather than mass nucleic acid testing (Shanghai's Recent COVID-19 Outbreak under Control: Mayor—Xinhua | English.News. Cn 2021) • Increased spending on epidemic prevention and control (Lentin 2020) • Expedited disbursement of unemployment insurance, extended support to migrant workers, provided tax relief, and waived social security contributions (Policy Responses to COVID-19, 2020) • Implemented strict containment measures, including extending the national Lunar New Year holiday and imposing a national-level lockdown with mobility restrictions (Policy Responses to COVID-19, 2020) • Enforced social distancing regulations with legal consequences for violations (Policy Responses to COVID-19, 2020) • Imposed a 14-day quarantine period for returning migrant workers (Lentin 2020) • Used testing and individualized health QR codes to track the virus and manage outbreaks (Lentin 2020)	• Indian authorities dismissed warnings of a second wave (Foresman 2021) • Facilities initially allocated to COVID-19 were repurposed for other use (Foresman 2021) • Public spaces and events continued despite citizens ignoring COVID safety protocols (Policy Brief: COVID-19 in an Urban World 2020) • India exported 193 million vaccine doses, while only 1.79% of the population was fully vaccinated as of April 30, 2021 (India—COVID-19 Overview—Johns Hopkins, 2021b) • The government administered 100 million vaccine doses to accelerate the vaccination pace • Requested help from NGOs (non-governmental organizations) (India—COVID-19 Overview—Johns Hopkins, 2021b) • NGOs played a crucial role in delivering basic necessities to the poor, providing medical and safety gear, raising awareness on social distancing, setting up health camps and isolation facilities, and offering rehabilitation to disadvantaged groups (India—COVID-19 Overview—Johns Hopkins, 2021b) • Voluntary sectors, including civil society, non-governmental, and community organizations, helped allocate resources to areas the Indian government couldn't reach (India—COVID-19 Overview—Johns Hopkins, 2021b)
Conclusion: The speed in which both cities dealt with the emergency enabled them to control the pandemic much more effectively and gave them time to develop their technologies further than deal with a lack of resources	
Spatial and temporal inequality	
• The city increased its capacity by opening field hospitals in high-density areas (Lentin 2020) • Migrant populations, primarily construction workers, were sent back to their villages to prevent infection spread in densely packed housing. Outstation college students were advised not to return after spring break to reduce population density in vulnerable areas (Lentin 2020) • The return of immigrant factory workers led to delays in medical supply production (Lentin 2020)	• The healthcare system faced overwhelming demand, resulting in low supplies and pharmacies struggling to provide medicines (Pandey 2021) • Hospitals had to turn away patients due to shortages of medical supplies, beds, and high-flow oxygen (Pandey 2021) • Social distancing was challenging, particularly for slum residents who needed to travel to communal taps (Du et al. 2020) • In non-emergency conditions, households in these areas had access to much less water than the World Health Organization's recommended 50 L per day (Du et al. 2020) • Hospital admissions increased due to the emergence of Delta Plus variant cases (Chatterjee 2021)

Table 4 (continued)

Shanghai	Bengaluru
Conclusion: While Shanghai's migrant population returned to their villages to enforce better social distancing rules and help decrease the concentration of people in a small space; Bengaluru's citizens stayed in the slums with no chance to abide by social distancing laws	
Impact of digital infrastructure on monitoring and tracking	
• China implemented various innovative strategies in response to COVID-19: • Developed a new nucleic acid testing method (How Emerging Technologies Helped Tackle COVID-19 in China 2020) • Enforced a mandatory health passport app for public and work facility entry (How Emerging Technologies Helped Tackle COVID-19 in China 2020) • Utilized research centers to develop and approve three COVID-19 vaccines, achieving a 60% vaccination rate by July 2021 (Policy Responses to COVID-19, 2020) • Employed BeiDou, the national GNSS constellation, for patient and area tracking (How Emerging Technologies Helped Tackle COVID-19 in China 2020) • Continuously monitored makeshift hospital construction using high-resolution earth observation satellites like GaoFen, Zhuhai-1 hyperspectral imaging satellite, and ESA's Sentinel-1 (How Emerging Technologies Helped Tackle COVID-19 in China 2020) • Equipped hospitals with robots for tasks like delivery, food preparation, sanitization, and scanning, based on BeiDou (How Emerging Technologies Helped Tackle COVID-19 in China 2020) • Combined TFSTAR's data processing with geocoding to visualize COVID-19's geographical reach and user proximity to active infections (How Emerging Technologies Helped Tackle COVID-19 in China 2020) • Created an epidemic situation awareness map displaying the geographical distribution of new cases, cumulative diagnoses, and recoveries through administrative divisions and community grid maps (How Emerging Technologies Helped Tackle COVID-19 in China 2020)	Indian Smart Cities played a crucial role in combating COVID-19 (Durga et al. 2020) • COVID War Rooms, dashboards, and smartphone applications, including the INDEX app, Sahaaya Sethuve app, and BBMP Contains app, provided technological solutions (Durga et al. 2020) • The War Rooms used GIS and GPS for mapping and tracking individuals (Durga et al. 2020) • Heat mapping technologies were used for containment plans (Durga et al. 2020) • Containment zones were monitored using the BBMP Contain app, drones, and CCTVs to control congestion and ensure sanitization (Durga et al. 2020) • Surveillance technologies tracked ambulances and disinfection services (Durga et al. 2020) • The dashboard offered real-time data and enabled micro-monitoring (Durga et al. 2020) • Information about food distribution drives was provided through the Hunger Helpline • A home delivery helpline ensured compliance with lockdown measures • Predictive modeling will be used in the future to understand virus spread and containment strategies (Durga et al. 2020)
Conclusion: Given the circumstances, Bengaluru's response to the pandemic and utilization of technology was impressive and very successful in mitigating the second wave. On the other hand, Shanghai had a more all-rounded approach by utilizing technology in several required fields, both medical and informational	

than Bengaluru. Since China had prior experience with the SARS pandemic, they implemented the most effective solution being the "suppression strategy," by hunting down the virus instead of resisting it to cut the transmission levels to zero. This strategy gave Shanghai a more explicit goal in creating technologies that helped track high transmission areas. Using satellites and GNSS constellations like the BeiDou and GAOFin, created maps showing the geographical location distribution of new confirmed cases, cumulative diagnoses, and recovered cases as shown in Table 4.

As mentioned in the spatial and temporal inequality, Shanghai and Bengaluru faced the issue of slums and closed dormitory-style housing, which made social distancing impossible. The In Urban world policy issued by the UN (Policy Brief: COVID-19 in an Urban World 2020) dictated that adequate housing is paramount to adhering to the coronavirus social distancing and hygiene guidelines; therefore, the lack of it is an inequality of itself leading to the high rates of COVID-19 cases in poor and rural areas. Nonetheless, Shanghai evicted some of those areas, which helped lessen the

congestion. Unfortunately, Bengaluru could not do the same and still suffered from the large outbreak in those areas; especially those where most residents were poor and could not afford to move to different areas. In addition, the disregard for the dangers of the pandemic resulted in a significant shortage in medical supplies, a pre-existing problem in Bengaluru, yet worsened with the second wave with the number of COVID-19 cases reaching 2 million as shown in Table 1. This issue was mitigated by countries sending relief of supplies and helping them build more field hospitals to increase their bed capacity and oxygen supplies.

Bengaluru, though it had to suffer from the two waves of the coronavirus pandemic, the city managed to successfully create tracking technologies to deal with the growing outbreak. They utilized GIS and GPS to map and track patients, while also using heat mapping to locate congested areas and draw up containment plans. In addition, both cities used surveillance technologies, with Bengaluru using the BBMP Contain app, drones, and closed-circuit televisions (CCTVs), while Shanghai utilizing robots and drones as well as satellites.

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Overall, Shanghai's approach to technology was much more rounded due to prior experience with pandemics. This enabled Shanghai to act early and focus on terminating the source of the problem, as opposed to the high level of negligence seen in the case of Bengaluru.

This table represents a comparison between two major Asian cities: Bengaluru and Shanghai. The cities' response to the COVID-19 pandemic was technology-centred; however, each utilized it to suit their demands. While Bengaluru centred on information technology and Shanghai was more versatile in its approach and took on both information technology and biotechnology, both cities provide excellent examples of the latest smart tools that can mitigate and control the intensity of coronavirus.

These cities demonstrate the vital role of technology in fighting against emergencies and pandemics to ensure the safety of their communities.

Conclusion for the analysis and comparison of the case

According to the comparative analysis, it became apparent that poverty, culture, and governance are primary factors that control the success of states under emergency. Moreover, it is understood that technology is a significant factor in combating pandemics and health emergencies as large as COVID-19, especially for tracking and monitoring. Each city had a different approach in utilizing the technology, thus proving its versatility and usefulness. Furthermore, it is noticeable that the cities that understood their inequalities and weak points were the most successful examples, like Abu Dhabi and Shanghai.

In the case of how the governance practice impacted the cities' response, inequalities were discovered, such as time, resources, and response speed. For example, cities like Amman implemented proper measures against the pandemic but failed to sustain it for long durations due to their economic standing and lack of resources. Moreover, the case of Sao Paulo, New York, and Bengaluru showed that unless the community cooperates, any implemented initiatives will fail.

In successful examples like Abu Dhabi and Shanghai, both had a different type of advantage. Abu Dhabi received the pandemic wave later than other cities, ensuring they had enough time to prepare for the outbreak and develop their technologies with their government-funded emergency response team. On the other hand, Shanghai already experienced the SARS outbreak in 2002, giving them enough knowledge and prior experience to control the spread and progression of such pandemics.

Despite the geographical location and circumstances (criteria) of the six case studies, the factors that were more influential in the creation of spatial and temporal inequality were primarily governance negligence and a lack of resources. In the case of Amman, it suffered from a shortage of beds, forcing them to rely on aids. COVID-19's impact has united with existing socio-economic vulnerabilities (Cities Policy Responses 2020). The crucial factor in the crisis was not the urban density but rather the urbanization quality and structural inequalities, hence disproportionately affecting unprotected populations and minorities like immigrants, POC, poor, the homeless, women, and the elderly(Cities Policy Responses 2020).New York and Sao Paulo were at a significant disadvantage when it came to the lack of medical resources and the overflow of patients; nevertheless, New York chose to manufacture more supplies and build field hospitals. On the other hand, Shanghai's government implemented an initiative to return immigrant workers to their villages. In addition, it urged international students to stay in their countries to lessen the density and solve the issue of overpopulation in the region. The same issue was faced in Bengaluru, since the city housed many settlement-like buildings; however, the government took no action to solve this overcrowding issue. Therefore, as a measure to solve those inequalities, post-pandemic urban design adapted must respect social distancing rules (Culture Shock: COVID-19 and the Cultural and Creative Sectors 2020).

Finally, the paper also focused on the impact of digital infrastructure on monitoring and tracking, displaying how cities utilized technology to fight the pandemic. For example, the standard utilization of technology in Amman, New York, and Sao Paulo was focused on monitoring and tracking patients and assessing the infection rates. However, Shanghai prioritized locating the sources of the infection rather than its spread, giving them the advantage in terminating the sources of infection in that region. Further, cities like Abu Dhabi, Bengaluru, and Shanghai provided a comprehensive approach using technology, as they used it in the medical aspect of the pandemic, which later helped them create solutions to combat the virus. Although, the variety in utilization gives varied results. Monitoring was needed to track and understand the level of damage being done to the city. In contrast, a comprehensive approach provided the cities with a better grip on the pandemic to understand it and resolve it.

Factors and recommendations

Through the analysis and comparison conducted in this work, we conclude that it is essential for governments to work together with local and international NGOs and accept and fairly distribute international aids for the common interest of the public. On the other hand, governments should refrain from using their national power and influence to provide or receive aid, as this can create

inequalities in responses to COVID-19 and hinder international collaboration. (Ryan 2020). Good governance that targets resilience should call for a multi-layer collaboration (Sharifi and Khavarian-Garmsir 2020).

It is clear that if the inequalities in cities persist, public health could be threatened since enforcing protective measures will become difficult (Sharifi and Khavarian-Garmsir 2020). Hence, identifying and stopping such inequalities is necessary, and each government should prioritize the city recovery plan from the pandemic (Florida et al. 2021). However, this cannot be done without policies that protect the most vulnerable areas (Du et al. 2020).

Finally, and for future research, we recommend exploring the social changes that COVID 19 may bring in both short and long terms in the structure and morphology of cities, suburbs, metropolitan, and regions at different geographical scales (Airhihenbuwa et al. 2020).

Limitations

Due to the immediacy of the topic the authors referred, while starting this research, to news and references on websites. Later references have been updated and peer-reviewed journals and reliable reports from United Nations and OECD have been considered and added. The data gathered in this paper are subjective to change due the ongoing pandemic and new results and reports that are produced and published daily. Therefore, everchanging numbers of cases and deaths are undeniably anticipated. Furthermore, this paper adopted certain criteria for the comparisons that were made between each two cities. However, there are additional measures that can be used for drawing conclusions.

References

Abbas W (2021) Abu Dhabi GDP's 2019 level to reach in 2023, says S&P. Khaleej Times. https://www.khaleejtimes.com/business/abu-dhabi-gdps-2019-level-to-reach-in-2023-says-sp

Abu Dhabi Government incentives in light of COVID-19 in can be viewed here (2021) Abu Dhabi Global Market (ADGM). https://www.adgm.com/abu-dhabi-government-incentives-in-light-of-covid-19

Airhihenbuwa C, Iwelunmor J, Munodawafa D, Ford C, Oni T, Agyemang C, Mota C, Ikuomola O, Simbayi L, Fallah M, Qian Z, Makinwa B, Niang C, Okosun I (2020) Culture matters in communicating the global response to COVID-19. Prevent Chronic Disease. https://doi.org/10.5888/pcd17.200245

Al Arabiya English (2020) Coronavirus: Jordan opens first COVID-19 field hospital. https://english.alarabiya.net/coronavirus/2020/12/08/Coronavirus-Coronavirus-Jordan-opens-first-COVID-19-field-hospital

Al Hosany F, Ganesan S, Al Memari S, Al Mazrouei S, Ahamed F, Koshy A, Zaher W (2021) Response to COVID-19 pandemic in the UAE: a public health perspective. J Global Health. https://doi.org/10.7189/jogh.11.03050

Alqutob R, AlNsour M, Tarawneh MR, Ajlouni M, Khader Y, Aqel I, Kharabsheh S, Obeidat N (2020) COVID-19 Crisis in Jordan: response, scenarios, strategies, and recommendations. JMIR Public Health Surveillan 6(3):e19332. https://doi.org/10.2196/19332

AlQutob R, Moonesar IA, Tarawneh MR, AlNsour M, Khader Y (2020) Public health strategies for the gradual lifting of the public sector lockdown in Jordan and the United Arab Emirates During the COVID-19 Crisis. JMIR Public Health Surveill 6(3):e20478. https://doi.org/10.2196/20478

Amman Population 2021 (Demographics, Maps, Graphs) (2021) World Population Review. https://worldpopulationreview.com/world-cities/amman-population

Anderson M (2021) NY hospitals now have large stockpiles of PPE. Beckers Hospital Review. https://www.beckershospitalreview.com/supply-chain/ny-hospitals-now-have-large-stockpiles-of-ppe.html

Bangalore Population 2021 (Demographics, Maps, Graphs) (2021) World population review. https://worldpopulationreview.com/world-cities/bangalore-population

BBC News (2020) Coronavirus: Jordan eases indefinite curfew and allows shops to open. https://www.bbc.com/news/world-middle-east-52020261

Brazilian startup develops technology for monitoring of patients with suspected COVID-19 (2020) EurekAlert! https://www.eurekalert.org/news-releases/757543

Breazzano MP, Shen J, Abdelhakim AH, Glass LRD, Horowitz JD, Xie SX, de Moraes CG, Chen-Plotkin A, Chen RW (2020) New York City COVID-19 resident physician exposure during exponential phase of pandemic. J Clin Investig 130(9):4726–4733. https://doi.org/10.1172/jci139587

C (2020) Jordan: Country to indefinitely extend curfew from March 23 to curb COVID-19 transmission /update 7. GardaWorld. https://www.garda.com/crisis24/news-alerts/325686/jordan-country-to-indefinitely-extend-curfew-from-march-23-to-curb-covid-19-transmission-update-7

Cabral L, Xu L (2021) Seller reputation and price gouging: evidence from the COVID -19 pandemic. Econ Inq 59(3):867–879. https://doi.org/10.1111/ecin.12993

Castro MC, Kim S, Barberia L, Ribeiro AF, Gurzenda S, Ribeiro KB, Abbott E, Blossom J, Rache B, Singer BH (2021) Spatiotemporal pattern of COVID-19 spread in Brazil. Science 372(6544):821–826. https://doi.org/10.1126/science.abh1558

Chatterjee S (2021) The news minute | Karnataka. The news minute. https://www.thenewsminute.com/article/bengaluru-covid-19-situation-continues-improve-two-weeks-unlock-152615

Cities policy responses (2020) OECD. https://www.oecd.org/coronavirus/policy-responses/cities-policy-responses-fd1053ff/

constructionweekonline.com (2020) Constructionweekonline. https://www.constructionweekonline.com/products-services/263810-covid-19-jordans-gam-carries-out-disinfection-programme-in-amman

COVID-19-NYC Health (2020) NYC Health. https://www1.nyc.gov/site/doh/covid/covid-19-main.page

COVID-technology advancements show the power of innovation (2020) World Economic Forum. https://www.weforum.org/agenda/2020/08/5-technology-advancements-during-covid-19-wearables-ai/

Cruz EER, Grin EJ, Sanabria-Pulido P, Cravacuore D, Orellana A (2020) The transaction costs of government responses to the COVID-19 emergency in latin America. Public Adm Rev 80(5):683–695. https://doi.org/10.1111/puar.13305

Culture shock: COVID-19 and the cultural and creative sectors (2020) OECD. https://www.oecd.org/coronavirus/policy-responses/culture-shock-covid-19-and-the-cultural-and-creative-sectors-08da9e0e/

Das K (2021). Covid-19: Poverty doubled in India in 2020. Will second wave make it worse? India Today. https://www.indiatoday.in/business/story/covid-19-poverty-doubled-in-india-in-2020-will-second-wave-make-it-worse-1793826-2021-04-22

de Groot J, Lemanski C (2020) COVID-19 responses: infrastructure inequality and privileged capacity to transform everyday life in South Africa. Environ Urban 33(1):255–272. https://doi.org/10.1177/0956247820970094

Du J, King R, Chanchani R (2020) Tackling inequality in cities is essential for fighting COVID-19. World Resources Institute. https://www.wri.org/insights/tackling-inequality-cities-essential-fighting-covid-19

Durga M, Kunal K, Arindam G, Anindya M (2020) Technology and data governance in cities indian smart cities at the forefront of the fight against COVID-19. http://www3.weforum.org/docs/WEF_Technology_and_Data_Governance_in_Smart_Cities_India_2020.pdf

ECLAC (2020) Preliminary overview of the economies of Latin America and the Caribbean. https://repositorio.cepal.org/bitstream/handle/11362/46504/64/PO2020_Brazil_en.pdf

Feuer W, Higgins-Dunn N, Kim J (2020) New York City builds coronavirus strategic medical reserve: "We can't depend on the federal government," mayor says. CNBC. https://www.cnbc.com/2020/04/21/new-york-city-builds-coronavirus-strategic-medical-reserve-we-cant-depend-on-the-federal-government-mayor-says.html

Florida R, Rodríguez-Pose A, Storper M (2021) Cities in a post-COVID world. Urban Stud. https://doi.org/10.1177/00420980211018072

Foresman B (2021) Amid coronavirus outbreak, tech keeps students connected—for good or ill. EdScoop. https://edscoop.com/amid-coronavirus-outbreak-technology-keeps-students-connected/

Funke DP (2020) Lie of the Year: The Downplay and Denial of the Coronavirus. Kaiser Health News. https://khn.org/news/article/lie-of-the-year-the-downplay-and-denial-of-the-coronavirus/

Global Times (2021) Shanghai set GDP growth target above 6% for 2021. https://www.globaltimes.cn/page/202101/1213704.shtml

Governor cuomo announces new tool to help New Yorkers access critical benefits amid COVID-19 Pandemic (2020) NY GOV. https://www.governor.ny.gov/news/governor-cuomo-announces-new-tool-help-new-yorkers-access-critical-benefits-amid-covid-19

Governor cuomo updates New Yorkers on state's progress during covid-19 pandemic. New York State (2021) https://www.governor.ny.gov/news/governor-cuomo-updates-new-yorkers-states-progress-during-covid-19-pandemic-201.

Gov't further eases lockdown as most sectors to resume operations Saturday (2020) Jordanian Ministry of Health. https://corona.moh.gov.jo/en/MediaCenter/1180

Gozzi N, Tizzoni M, Chinazzi M, Ferres L, Vespignani A, Perra N (2021) Estimating the effect of social inequalities on the mitigation of COVID-19 across communities in Santiago de Chile. Nat Commun. https://doi.org/10.1038/s41467-021-22601-6

Gross Domestic Product, 4th Quarter and Year 2020 (Advance Estimate) | U.S. Bureau of Economic Analysis (BEA). (2021). U.S. Bureau of Economic Analysis. https://www.bea.gov/news/2021/gross-domestic-product-4th-quarter-and-year-2020-advance-estimate

Guedes MBOG, de Assis SJC, Sanchis GJB, Araujo DN, Oliveira AGRDC, Lopes JM (2021) COVID-19 in Brazilian cities: Impact of social determinants, coverage, and quality of primary health care. PLoS ONE 16(9):e0257347. https://doi.org/10.1371/journal.pone.0257347

How emerging technologies helped tackle COVID-19 in China (2020) World Economic Forum. https://www.weforum.org/agenda/2020/04/how-next-generation-information-technologies-tackled-covid-19-in-china/

India–COVID-19 Overview–Johns Hopkins (2021a) Johns Hopkins Coronavirus Resource Center. https://coronavirus.jhu.edu/region/india

India-COVID-19 Overview-Johns Hopkins (2021b) Johns hopkins coronavirus resource center. https://coronavirus.jhu.edu/region/india

Jordan GDP per capita, 1980–2020 - knoema.com (2021) Knoema. https://knoema.com//atlas/Jordan/GDP-per-capita

Jordan set to export medical equipment in light of global shortage (2020) Jordan Times. http://jordantimes.com/news/local/jordan-set-export-medical-equipment-light-global-shortage

Jordan: new executive regulations on preventive measures to combat COVID-19 issued (2020) The library of congress. https://www.loc.gov/item/global-legal-monitor/2020-11-12/jordan-new-executive-regulations-on-preventive-measures-to-combat-covid-19-issued/

Jordan: the toughest lockdown in the world | KfW Development Bank (2021) KfW Development Bank. https://www.kfw-entwicklungsbank.de/International-financing/KfW-Development-Bank/About-us/The-Corona-situation-in-our-external-offices/Jordan/

Lardieri A (2020) Access Denied. US News. https://www.usnews.com/news/health-news/articles/2020-03-27/new-york-is-establishing-more-temporary-hospitals-to-handle-surge-of-coronavirus-patients

Lentin S (2020). Mumbai-Shanghai: two COVID-19 stories. Gateway House. https://www.gatewayhouse.in/mumbai-shanghai-covid-19/

Linkov I, Keenan JM, Trump BD (2021) COVID-19: Systemic Risk and Resilience (Risk, Systems and Decisions) (1st ed. 2021 ed.). Springer.

Madianou M (2020) A second-order disaster? Digital technologies during the COVID-19 pandemic. Soc Media Soc 6(3):205630512094816. https://doi.org/10.1177/2056305120948168

Millman J (2021) Cuomo: Most NY, NJ capacity restrictions to end starting may 19; social distancing (Mostly) Stays. NBC New York. https://www.nbcnewyork.com/news/coronavirus/nyc-bar-scene-roars-back-monday-kicking-off-key-reopening-week-big-nj-news-due/3032296/

Ministerie van Buitenlandse Zaken (2021) Not found. Netherlandsworldwide. Nl. https://www.netherlandsworldwide.nl/binaries/en-nederlandwereldwijd/documents/publications/2021/02/02/jordan---pcr-test-locations/Jordan_PCR_test_list_accredited%2Blabs%2Band%2BCOVID-19%2Bpublic%2Band%2Bprivate%2Bhospitals.pdf+&cd=2&hl=en&ct=clnk&gl=ae&client=firefox-b-d

Ministry of Health, the official website of the Jordanian Ministry of Health | Coronavirus disease (2021) Jordanian Ministry of Health. https://corona.moh.gov.jo/en

MoH COVID-19 VACCINE (2021) Jordanian Ministry of Health. https://vaccine.jo/cvms/ (MoH COVID-19 VACCINE, 2021)

New York's Economy and Finances in the COVID-19 Era (2020) Office of the New York State Comptroller. https://www.osc.state.ny.us/reports/covid-19-october-14-2020

New York Population 2021 (Demographics, Maps, Graphs) (2021) World population review. https://worldpopulationreview.com/states/new-york-population

Novel Coronavirus (COVID-19) (2020) Department of Health. https://coronavirus.health.ny.gov/home

Overview (2020) World Bank. https://www.worldbank.org/en/country/jordan/overview#2

Pandey BV (2021) Covid-19 in India: Patients struggle at home as hospitals choke. BBC news. https://www.bbc.com/news/world-asia-india-56882167

Policy Brief: COVID-19 in an Urban World (2020) UN Sustainable Development Group. https://unsdg.un.org/resources/policy-brief-covid-19-urban-world#:%7E:text=With%20an%20estimated%2090%20per,the%20spread%20of%20the%20virus

Putting technology at the forefront of Jordan's COVID-19 fight. (2020). Jordan Times. https://www.jordantimes.com/opinion/taofeike/putting-technology-forefront-jordans-covid-19-fight

Policy Responses to COVID19. (2020). IMF. https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19

Reuters Paraguassu L, SimÃµes E (2021). Healthcare collapse imminent, Brazil's Sao Paulo warns, as COVID-19 cases surge. Reuters. https://

www.reuters.com/world/americas/healthcare-collapse-imminent-brazi
ls-sao-paulo-warns-covid-19-cases-surge-2021-04-14/

Ritchie H (2020) Coronavirus (COVID-19) vaccinations-statistics and research. Our World in Data. https://ourworldindata.org/covid-vaccinations?country=OWID_WRL

Robinson D (2020) The Journal News. As COVID-19 surges, NY health care leaders concerned about repeat of PPE shortages. New York State Team. https://eu.lohud.com/story/news/coronavirus/2020/11/16/what-we-know-and-dont-know-ppe-supplies-ny-covid-surges/6277955002/

Ross G, Hale L (2021) Special Delivery: Latin Americaa™'s Medical Suppliers. Wilson Center. https://www.wilsoncenter.org/blog-post/special-delivery-latin-americas-medical-suppliers

Ryan MJ (2020) Covid-19: volume I: global pandemic, societal responses, ideological solutions. Routledge. (Ryan, 2020)

Sao Paulo Population 2021 (Demographics, Maps, Graphs) (2021) World population review. https://worldpopulationreview.com/world-cities/sao-paulo-population

Shanghai's recent COVID-19 outbreak under control: mayor–Xinhua | English. news.cn (2021) Xinhua. http://www.xinhuanet.com/english/2021-01/28/c_139704468.htm

Sharifi A, Khavarian-Garmsir AR (2020) The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. Sci Total Environ 749:142391. https://doi.org/10.1016/j.scitotenv.2020.142391

Singh KD, Kumar H (2021). Covid-19 Pushes India's middle class toward poverty. The New York Times. https://www.nytimes.com/2021/04/16/business/economy/india-covid19-middle-class.html

Smart solutions to fight COVID-19 - The Official Portal of the UAE Government (2020) The Official Portal of the UAE Government. https://u.ae/en/information-and-services/justice-safety-and-the-law/handling-the-covid-19-outbreak/smart-solutions-to-fight-covid-19

TechCrunch is part of the Yahoo family of brands (2020) Tech Crunch. https://techcrunch.com/2020/03/25/new-york-state-seeks-tech-talent-for-its-covid-19-technology-swat-team/

The National (2021) Coronavirus: UAE helps Jordan set up field hospital with more than 200 beds. https://www.thenationalnews.com/uae/government/coronavirus-uae-helps-jordan-set-up-field-hospital-with-more-than-200-beds-1.1152927

Timeline: WHO's COVID-19 response. (2020). World Health Organization. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline?gclid=CjwKCAjwzOqKBhAWEiwArQGwaJW_Cj-oQgFeRCNjmWpSybK5Hz4VWVTOdRS-EXwGYke9SbU4rQEV2hoCHdMQAvD_BwE#category-Response

Trading economics (2020) Jordan GDP | 2022 Data | 2023 Forecast | 1965–2021 Historical | Chart | News. https://tradingeconomics.com/jordan/gdp

UAE Sends Third Medical Aid Flight to Jordan in Fight against COVID-19 (2020) Mofaic. https://www.mofaic.gov.ae/en/mediahub/news/2020/11/6/06-11-2020-uae-aid

U.S. States by Size in Square Miles (2020) State Symbols Usa. https://statesymbolsusa.org/symbol-official-item/national-us/uncategorized/states-size

United States of America GDP per capita, 1980–2020–knoema.com. (2021). Knoema. https://knoema.com/atlas/United-States-of-America/GDP-per-capita

Visagie J, Turok I (2021) Rural–urban inequalities amplified by COVID-19: evidence from South Africa. Area Develop Policy 6(1):50–62. https://doi.org/10.1080/23792949.2020.1851143

Watson BK (2020) Coronavirus: How pandemic turned political in Brazil. BBC News. https://www.bbc.com/news/world-latin-america-53021248

World City Populations 2021 (2021) World City Populations. https://worldpopulationreview.com/world-cities

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