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Urbanization and preparedness for outbreaks with high-impact respiratory pathogens



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Urbanization and urban planning

Urbanization is a complex process that results in more and larger urban areas with an increased population. The associated socioeconomic changes (e.g. shifts in dominant occupations, lifestyles and behaviours) alter the demographic and social structures of both urban and rural areas, for example when younger people move to cities. There is no universally accepted definition of an urban area; countries often use size and density of population or economic or administrative indicators to define an urban area [1]. In 2018, 55% of the population lived in urban areas. This is projected to rise to 68% by 2050 (Figure 1), with Africa and Asia accounting for almost 90% of the projected growth [2]. The number of megacities (urban areas with over 10 million inhabitants) is projected to increase from the current 33 to 43 by 2030, most of them located in Asia and Africa [2] (See Appendix III for a list of current and projected megacities).

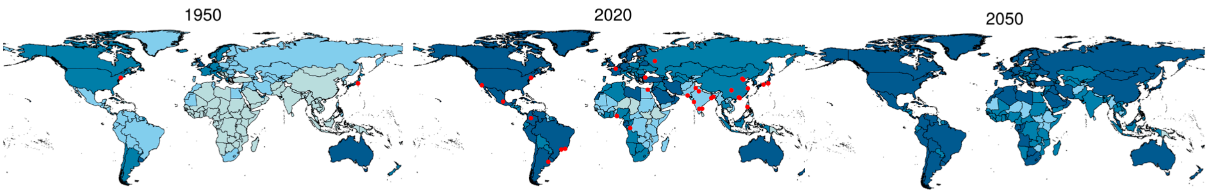

Figure 1
Changes and future projections of the proportion of people living in urban areas per country. Megacities (urban areas with over 10 million inhabitants) are shown as red dots (no projections of megacities were available for 2050) [1] *Norwegian Institute of Public Health*

In addition to positive aspects, such as better access to health care, urbanization can have negative impacts on health. These may be due to various factors, such as air pollution, strain on existing infrastructure (e.g. transport, housing, healthcare) following a rapid increase in population density, and social problems including socioeconomic inequalities, substance abuse, prostitution and crime [3, 4]. The population in urban areas is heterogeneous, both within and between cities, with various forms of inequality, including in health and healthcare access. In developing countries, informal settlements remain a large and growing feature of the urban landscape as the expansion of the urban population is exceeding the speed of planned city development, increasing the risk of disease [5, 6]. International networks promote sustainable and healthy urban development and enable collaboration between urban areas [4, 7, 8]. However, few of the networks are addressing emerging infectious diseases explicitly or making it a core priority of their work. For example, the World Health Organization (WHO) European Healthy Cities programme included healthy urban planning, with 12 specific objectives, but none of these specifically address epidemic risks for respiratory pathogens [9]. Similarly, the Partnership for Healthy Cities, backed by WHO-Bloomberg Philanthropies, has an explicit non-communicable disease focus. Efforts specifically targeted to urban epidemic control have been, until the recent coronavirus disease (COVID-19) outbreak, largely limited. The current crisis emphasizes how urban areas have characteristics that increase the risk of outbreaks of emerging respiratory pathogens, such as crowding and inequality.

Los Angeles, USA. Photo: Robert Paetz

Emerging respiratory pathogens

Emerging infections have shaped the course of human history. In particular, respiratory pathogens pose a threat due to their mode of transmission and non-specific symptoms, as shown in the influenza A(H1N1) and COVID-19 pandemics [10]. When outbreaks spread across and between large urban areas, the implementation of infection control measures is challenging, highlighting the importance of urban epidemic preparedness. For example, the 2014-2015 Ebola outbreak in West Africa showed the importance of population mobility and spread to urban areas with informal settlements [11, 12]. Similarly, the pneumonic plague outbreak in Madagascar in 2017 spread to urban areas, where health care workers were not used to diagnosing the plague, leading to delayed diagnoses and continued transmission as well as rapid spread due to population density and susceptibility [13, 14]. New subtypes of influenza viruses will continue to cause pandemics [15-17]. During the 2009 influenza A(H1N1) pandemic, challenges with preparedness were identified, including the sharing of influenza virus samples and data, access to vaccines and lack of good surveillance systems. As a result, WHO established the Pandemic Influenza Preparedness (PIP) Framework to improve pandemic influenza preparedness and response, specifically to facilitate the sharing of information on influenza viruses and ensure a degree of equity in vaccine access [18]. The current COVID-19 pandemic shows the importance of urban areas in the spread within and between cities, as well as the disproportionate burden on health care facilities, as seen in Wuhan, Madrid, New York, and Teheran. The Oslo case study shows the importance and challenges of urban areas in outbreaks (Appendix I).

Economic impact of epidemics

The economic impact of epidemics can be extremely high (Figure 2). However, little research is done on the economic impact of epidemics on cities and the majority of economic impact estimates are global or national.

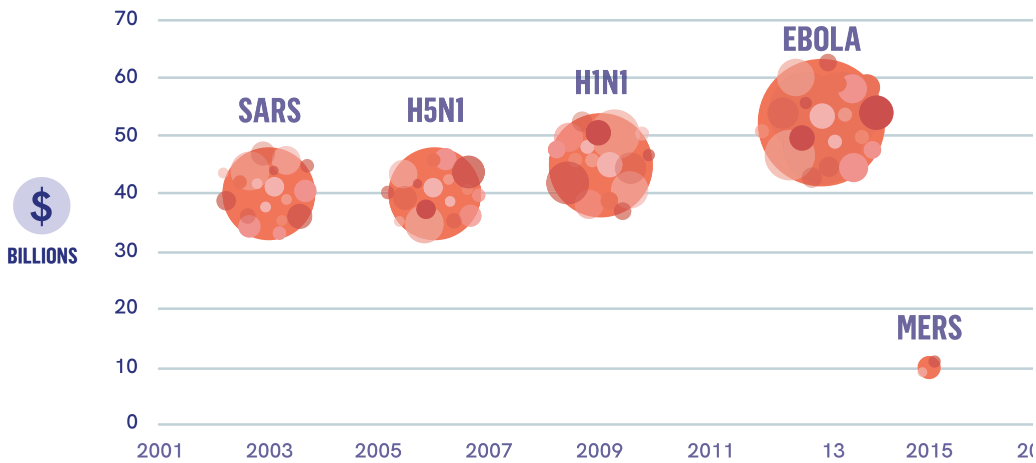

Figure 2
Estimated costs of selected epidemics in US$ billions (copied with permission [19])
Source: Resolve to save lives

The economic consequences of epidemics reach beyond the health care sector and have a major effect on other sectors such as tourism, travel, trade, and labour markets. The Middle Eastern Respiratory Syndrome (MERS) outbreak in South Korea was limited to the urban area of Seoul, but resulted in an estimated US$2.6 billion loss in tourism revenue throughout the country; much higher than the health care costs related to MERS (US$12 million) [20]. The economic impact of the COVID-19 outbreak is already visible, with large stock market losses globally [21, 22] and huge impacts on the travel industry, with projected losses of up to US$314 billion for airlines in 2020 [23]. The annual global cost of moderately severe to severe pandemics is projected to be approximately US$570 billion [24] representing over 1.0% of global gross domestic product (GDP) [25]. The World Bank prepared a report on the importance and benefits of financing to strengthen preparedness [26-28]. Investing in health care systems and surveillance will not only reduce the impact of epidemics but will also provide other general health benefits. In almost every country, urban areas account for a disproportionately large share of GDP. Therefore, outbreaks in these areas could have a large local and regional economic impact, perhaps even global impact.

Chapter 2
Urban vulnerabilities for outbreaks with high-impact respiratory pathogens

Xining, China. Photo: Robert Paetz

Epidemics in urban environments present public health challenges that affect local, national and global health security as much as having a sizeable impact on society and the economy. In this chapter, we identify factors specific to urban areas that increase the spread of high-impact respiratory pathogens (Table 1). They are related to the population, environment and inequity [6, 29-32]. Many of these factors are interconnected and may differ between cities (examples in Figure 3). We will focus on the factors that are more universally applicable for urban preparedness. Factors will vary, even within a city, and local governments should always consider specific local factors such as governance, structure of the health care system, sociocultural norms, climate and geographic location in epidemic preparedness and response

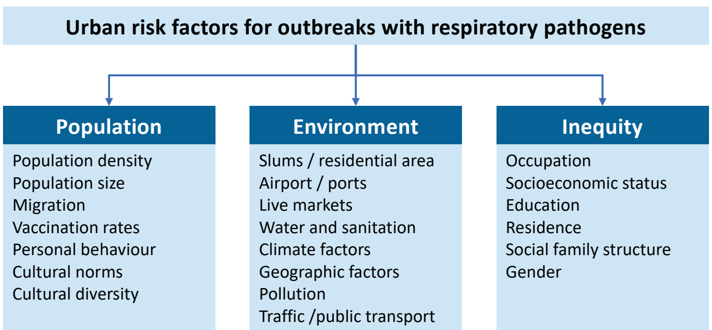

Figure 3
Overview of urban factors that affect the spread of outbreaks with respiratory pathogens [30] *Norwegian Institute of Public Health*

Population size and density

Population size and density are important urban risk factors for respiratory pathogens such as influenza, measles and tuberculosis. Crowding increases the number of people breathing the same air, with increased contact with surfaces touched by many people, resulting in a more rapid transmission of diseases [6, 29-38]. Crowded urban settings such as large events, markets, transport hubs and church congregations act as hotspots for disease transmission. Wet markets (i.e., markets that sell live and freshly slaughtered domesticated and wild animals) are a particular risk factor for the introduction of novel pathogens and cross-species transmission of infectious diseases, as seen with avian influenza, Severe Acute Respiratory Syndrome (SARS) and possibly COVID-19 [32, 37, 39-47].

Migration, commuting and transport hubs

Urban populations are often highly mobile, increasing the risk and transmission of pathogens in several ways [29, 37, 38, 48-56]. Many people commute to work, often by public transport; such large movements of people increases both the individual risk as well as he geographical spread. Urban settlements are often transport hubs and promote rapid national and global spread of infectious diseases, and have a higher probability of importing diseases from other areas [38, 53-55]. With the speed and volume of current travel, high-impact respiratory pathogens can be a potential global threat almost immediately after they first appear and can quickly become uncontrollable [31, 57-59]. Modelling studies have shown that air transport is a major contributor to the spread of epidemics with respiratory infections, and major cities are the first targets, as seen with outbreaks of influenza A(H1N1), SARS and COVID-19 [56, 60-69]. The global spread of COVID-19 resulted in localized transmission, especially in large urban settings (e.g. Milan, New York, Tehran) [69].

Vulnerable populations and urban inequity

Most urban settings are heterogeneous with inequalities in economic, social and living conditions, often coinciding with health inequity and lower access to health care services [29, 30]. Urban populations are more likely to include homeless, refugee and displaced populations. In addition, they often include sub-populations with low socioeconomic status, people living in informal settlements, or those who are dependent on the informal economy for their livelihoods. They may be disproportionately affected in the event of health emergencies, due to a combination of political, sociocultural, economic, and legal barriers. Informal settlements, like slums, remain a large and growing feature of the urban landscape [5, 37, 70-74]. Approximately one billion people live in slums, which are typically defined by poor housing quality, overcrowding and inadequate access to safe water and sanitation [31, 70, 72, 75]. These conditions can increase the risk of spread and the severity of outbreaks, as well as complicating prevention and response. Social and economic equity result in better health (measured by overall and infant mortality, and life expectancy at birth) [74, 76, 77]. Lack of internet access for information, as well as a means to provide social support, can increase an individual's vulnerability, especially among the homeless and the elderly who have fewer options to seek help.

Pollution

Air pollution is an important urban environmental health risk factor for respiratory diseases. It has been associated with the development or exacerbation of adverse respiratory outcomes with increased susceptibility to respiratory pathogens and increased risk for upper respiratory tract infections as well as acute lower respiratory tract infections [78-88]. Experimental studies identified possible mechanistic explanations including increased susceptibility to virus and bacteria when exposed to pollutants [86, 87]. Ozone is one of the most abundant components of air pollution in urban areas, increasing susceptibility to respiratory infections, including influenza [89, 90]. In a recent study, exposure to larger airborne particulate matter was associated with increased hospitalizations for respiratory syncytial virus bronchiolitis among infants in Lombardy, Italy [91]. Additionally, indoor pollution and air ventilation can also affect the risk of exposure to respiratory pathogens [92]. Exposure to indoor air pollution from solid fuels has been linked to many diseases, including acute and chronic respiratory diseases. In 2000, indoor air pollution was responsible for more than 1.5 million deaths and 2.7% of the global burden of disease [93]. Additionally, individuals with lower socio-economic status also tend to live disproportionately in areas with high air pollution, these spatial inequities can exacerbate the impact of outbreaks with respiratory pathogens, such as seen with higher COVID-19 mortality in more polluted areas [94, 95].

Nosocomial spread

Urban areas have a large range of health care facilities, including referral and tertiary hospitals. Inadequate infection prevention and control (IPC) measures enable the transmission of infectious diseases in health care facilities. Transmission is facilitated by the close contact between patients and staff, large number of patients during outbreaks, the presence of families visiting the sick, the vulnerability of patients due to underlying medical conditions and the connectivity between health care facilities found in urban areas. The importance of robust IPC practices has been shown by large nosocomial transmission for MERS, SARS, COVID-19 and Ebola [96-100, 102-107]. Health seeking behaviour and organization of health care affects outbreak spread. For example, in China, referral from primary health facilities is not mandatory in order to visit tertiary hospitals and people tend to prefer hospital services. During the COVID-19 outbreak, this resulted in an initial overflow at hospitals, before fever clinics for triage were established [108] and dedicated hospitals were built [109, 110]. The high risk of transmission in urban health care settings became evident during the SARS and MERS outbreaks. For example, the importation of one SARS case in Toronto led to at least 128 cases through spread in a single local hospital [97, 111]. One MERS importation into Seoul led to spread within health care settings in the city due to patient movement, resulting in nosocomial transmission at 16 clinics and hospitals infecting 184 people [98-100, 112]. One of the first COVID-19 cases in Norway was an ophthalmologic doctor returning from vacation, which resulted in an outbreak among health care workers at the hospital in March 2020 [113].

Tabell 1
Overview of urban factors that can affect the risk and spread of respiratory pathogens

Characteristic	Consequence	Effect on outbreak	Ref.
Population			
Population size and density	Larger number of contacts Closer physical contact between individuals Many people breathing in the same air; higher exposure to respiratory pathogens	Rapid spread of disease High total number of people exposed	[6, 29-31, 33, 36, 37]
Commuting	Increased crowding at specific times during the day, especially in public transportMobility to and from residential areas	Increased spread of disease	[29, 37, 48-50]
Vaccination coverage	Heterogenic in urban areas; clustered groups with low vaccination coverage will increase the number of susceptible people	Risk of outbreaks and spread of disease within specific groups	
Elderly population	Proportion of older adults increasing in many countries; more vulnerable to infection, less access to health care and information (internet)	More rapid spread within vulnerable groups Higher disease morbidity and mortality	[36]
Environment			
Informal settlements	Close contact; more people in confined spaces Less access to and lower uptake of health care services Poor living conditions and limited access to clean water and sanitation result in overall poorer health	Increased spread of disease Late recognition of outbreaks Higher disease morbidity and mortality	[37, 72, 73]
Wet markets	Live and slaughtered wild and domesticated animals; risk of transmission between animal species, and/or humans Crowded hotspots	Risk of spillover and introduction of novel pathogens Risk of spread of disease between animals Increased spread of disease due to crowding	[39, 41-44]
National/international transport hubs	Large transient population Global connectivity within days	Increased risk of national and global spread	[31, 57]
Pollution	High pollution increases the risk of infection and deteriorates disease outcomes	Increased spread of disease Higher disease morbidity and mortality	[89, 90]
Health care system	Interconnectivity of many health care facilities, vulnerable population, close contact with symptomatic individuals. Without operational IPC guidelines and well-trained staff, the health care facilities will be effective hubs of pathogen transmission to patients of health care workers and the community. If systems have no primary health care, patients go directly to hospitals	Higher infectiousness; increased spread of disease Higher disease morbidity and mortality	[96-100]
Inequity			
Socioeconomic factors	Heterogenic in urban areas; areas with lower socioeconomic status will have less access to and lower use of health care; effect on prevention, treatment and survival	Late recognition of outbreaks Increased spread of disease Higher disease morbidity and mortality	[29, 30]
Education level	Heterogenic in urban areas; clustered groups with lower educational level can result in lower uptake of preventive measures and treatment	Late recognition of outbreaks Increased spread of disease Higher disease morbidity and mortality	4[29, 30, 101]

Case study
an example of urban preparedness in Oslo, Norway

Oslo during "lockdown", April 2020. Photo: Hans Kristian Thorbjørnsen

Summary

Cities around the world are challenged by the COVID-19 outbreak. Half of the world's population live in cities. Experiences and lessons learned on how cities have handled the outbreak will be useful for the way forward to improve knowledge on how to increase preparedness and make cities more resilient to pandemics. Oslo, the Norwegian capital, with 700,000 inhabitants, became the country's epicentre of the COVID-19 outbreak. Despite its small size and Norway being a wealthy country, the COVID-19 outbreak has revealed the same challenges and vulnerabilities during the initial phases of the outbreak, as in other urban areas around the globe.

Oslo: Demography of health services

Oslo has a diverse population with around 25% having an immigrant background. The city is divided into 15 administrative districts with large differences in demographics, and some districts having up to 50% of the population with an immigrant background. The most common countries of origin are Pakistan, Somalia and Poland. The city attracts substance abusers and there are an estimated one thousand people in the substance abuser population.

The national Norwegian health system is semi-decentralized: the state is responsible for specialist care and municipalities for primary health care, long-term care and social services

[114]. The specialist health care is organized into four health authorities. Oslo is part of the South-Eastern Norway Regional Health Authority, which has a population of 57% of the total population of Norway (2.9 million). Hospital care is free and primary care is highly developed with one doctor (GP) for every 1,300 citizens. In addition, several walk-in primary care emergency clinics serve the population, including out-of-office hours.

Oslo governance structure

Oslo is the capital of Norway. It constitutes a county, a *municipality* and is the country's largest city. The city has a parliamentary system of governance. The *City Government* is responsible to the *City Council* in the same way that the National Government is responsible to the National Parliament. The highest decision-making body in Oslo is the City Council. It has 59 members, elected every four years. The City Council is chaired by the Mayor of Oslo. The City Government is the executive body and consists of eight members. The Governing Mayor is the head of the City Government and appoints up to seven Vice Mayors. The decentralized public administration is organized into 15 districts with each district having an elected council.

Plans for preparedness and pandemics: from national to local level

Preparing for a pandemic at the national and local level are equally important to an effective response. The national preparedness plan for pandemic influenza was updated in 2014. In 2007, the national health preparedness plan entered into force [115]. By law, all 356 municipalities are required to have a plan for outbreak preparedness. In addition, the regional health authorities are required to establish pandemic plans, which have to be aligned between specialist care (regional level) and primary health care (municipality level) [116]. An agreement on cooperation is to be established between the two levels. Oslo has an all-hazard preparedness plan from 2019, which includes an updated pandemic plan [117].

Having an updated pandemic plan for Oslo was of high value during the initial phase of the outbreak. Although it is too early to evaluate whether the Oslo pandemic planning was successful or not, it may be noted that neither the national nor the Oslo pandemic plan contained anything on contact tracing. In the early phases of the outbreak, finding and follow-up of people who were exposed to infection has been a prioritized activity in Norway. It may be useful to gather more information and further look into whether contact tracing as an activity has been a prioritized element/plan of the national guidelines and plans, upon which all municipality plans, are based.

Timeline of outbreak in Oslo

The two first cases of COVID-19 in Oslo were confirmed on 27 February 2020. Both were related to the outbreak in Italy [118]. One was a medical doctor in the ophthalmic department at the Oslo University Hospital. The person had been to work during the symptomatic phase on 24 and 25 February, and on sick leave since 26 February. The doctor had probably been in contact with several colleagues and patients, and the outbreak investigation concluded that six health care workers were infected but no patients.

As of 27 April 2020, 2,338 cases were reported in Oslo, of in total 7,605 confirmed COVID-19 cases on the national level [118]. Cases in Oslo are currently (April 2020) showing a downward trend (see Figure 4). Of all cases, 42% are female. Of the fatal cases, 52% are female. On the national level, 62% of the fatalities have occurred in long-term care facilities. The national reference laboratory, situated in Oslo, had testing capacity from 23 January 2020, closely followed by Oslo University Hospital.

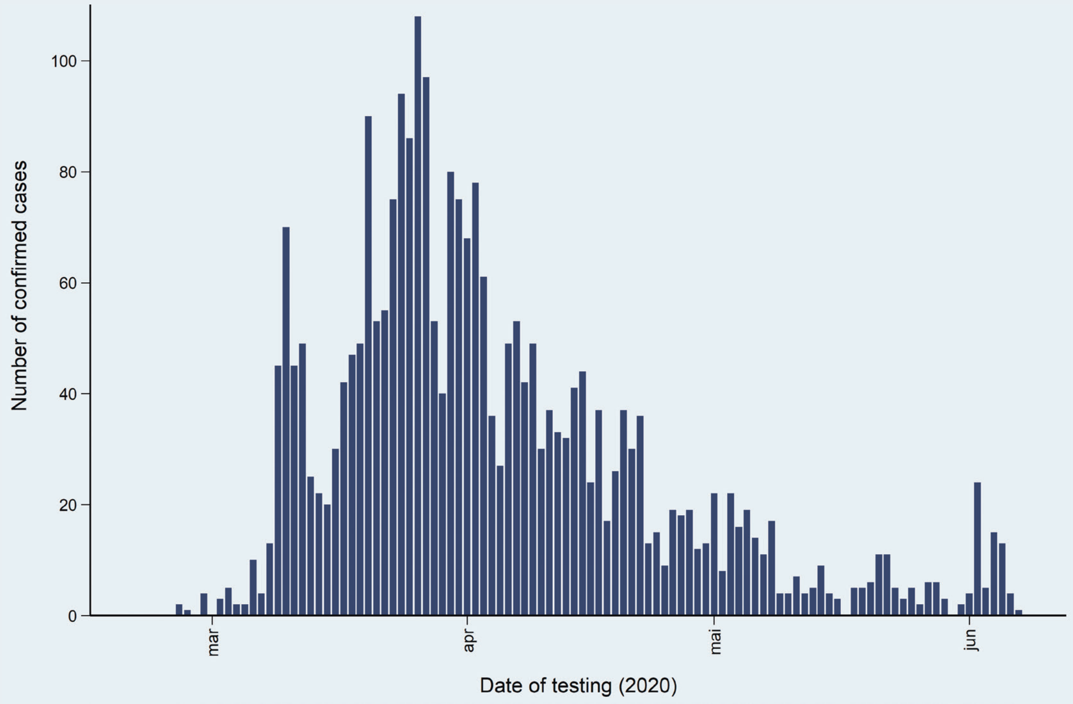

Figure 4
Daily numbers of confirmed cases of COVID-19 in Oslo, Norway, updated on 9 June 2020.
Norwegian Institute of Public Health

Distribution of COVID-19 in Oslo

Probably due to the size of the population, the population density and type of activities (bars, restaurants, etc.) in Oslo, the transmission of the coronavirus in Oslo continued and resulted in a disproportionate amount of cases compared to other areas in Norway.

Political measures: Non-Pharmaceutical Interventions

Since 28 February 2020, the City Government has been on emergency alert and since 11 March at the highest level of alert. On 13 March, the Norwegian national authorities decided to implement strict non-pharmaceutical interventions across the country, including for Oslo. These measures included closing schools and childcare centres (but still open for children of key workers), quarantine for travellers, no services with direct contact (hairdressers, dentists, opticians etc.), closing places where people gather (gyms, saunas etc.), imposing two metre physical distancing in all places, and isolation of anyone with respiratory tract symptoms. Oslo also banned alcohol being served in bars and restaurants, and all nursing homes and hospitals closed for visitors.

COVID-19 outbreak and possible impact on other health services

Each of Oslo's 15 districts provide health care services, free of charge, for all children and adolescents (aged 0-20). In Norway all vaccination is voluntary. The national Childhood Immunization Programme for children and adolescents includes vaccines against twelve different diseases. In March, the city did a survey among all the health centres and school health services which provide vaccinations. There was no indication of re-prioritization of vaccination, and there have been no indices that fewer children are being vaccinated since prior to the outbreak. However, other services were less prioritized, such as weight and measuring of heads of newborns and check-ups for 2- and 4-year-olds.

Economic Impact of coronavirus: local government vs national government

A decentralized system includes complex governance structures, systems and power relations. The City Government expressed clear concern by the end of March to the national Government and Minister of Finances about the impact on the City's budget and the need for compensation for additional expenditure and loss of revenue [119]. When the City of Oslo's institutions for the public, such as swimming pools, museums, public transport, schools and kindergartens close, income is reduced. Combined with a substantial loss of revenue from the toll roads and ticketing for public transport, it is estimated a reduction in income by several hundred million NOK every month (up to euro 100 million).

According to local authorities, the national government had indicated, by the end of March, only compensation for the loss of user-charging for kindergartens and after school programmes. The Oslo City Council has contacted the national Government to enquire about how local authorities should be compensated for extra expenditure, reduced tax revenues and loss of service charges.

Lessons learned

Was Oslo prepared? It is too early to evaluate.

What went well:

- Oslo had a well-developed and updated pandemic preparedness plan
    - Policy-makers were quickly involved
    - Early attention on vulnerable groups like nursing home residents, substance abusers, homeless people
    - Fever-control groups were quickly in place, later replaced by drive-through COVID-19 clinics
    - Coronavirus-helpline set up for triage and prioritization of individuals to be tested
    - Good coordination between the primary care sector (owned by the city) and the hospitals (state owned)

Areas for improvement:

- Late identification of COVID-19 spread among immigrant groups, in particular the Somali population
- Isolation capacity for people with small living spaces should be included in the preparedness plans
- A call centre for the public should have been established immediately. During the first weeks of the outbreak, the emergency clinic telephones and the emergency number were jammed by people who were not ill
- A national stockpile of personal protective equipment (PPE) should be considered, as insufficient PPE was available for health care workers

Chapter 3
Urban preparedness for outbreaks of high-impact respiratory pathogens

Ebola outbreak in Freetown, Sierra Leone. Photo: Hinta Meijerink

Multi-sectoral approach, interdependencies of critical sectors, prioritization and governance

The thematic Global Preparedness Monitoring Board (GPMB) report on country preparedness capacities, prepared by WHO, includes a section on preparedness in urban settings [120]. Interviews with local authorities revealed that early planning, having clear roles and responsibilities of key players, ensuring strong and clear communication at all levels, sharing best practices and having robust financing mechanisms in place are key issues for preparedness in urban settings. The public, private and not-for-profit sectors are interconnected and cooperative in terms of sharing responsibilities. This highlights the complexity of actors and disciplines involved in epidemic preparedness in urban settings [30, 38, 121-123]. Unique cultural characteristics, diversity and asymmetries within communities, political agendas and governance priorities result in differences in how policies are implemented and prioritized. The coordination of stakeholders within different sectors, and identifying their roles and responsibilities, is essential for efficient urban preparedness.

Large urban settings are likely to experience a more rapid surge of disease than rural settings. In addition, urban areas are usually more dependent on advanced technical systems that all need to be in place and functioning. Whereas in a truly rural setting one can collect water from a well or creek, chop wood for heating and cooking, and use an outside toilet, in cities the inhabitants depend upon the provided services. Consequently, urban governments need to take a multi-sectoral approach and make comprehensive plans identifying all relevant critical sectors that may be hardest hit during a pandemic and develop measures to mitigate the impact. This planning process will need to take an all-government and all-society approach involving the relevant vulnerable sectors, and mainly take into account how to address a greater demand for services when an unusually high number of skilled personnel are sick at home. Various initiatives have initiated complexity thinking and multi-sectoral interventions in urban settings [124, 125].

While critical functions may differ between countries and the size and type of urban area, many others will be similar. Important factors for preparedness and control are reducing the transmission and the economic impact on key workers. The impact on workers outside the health care system, such as financial sector, public transport, goods supply, water supply and sanitation, industrial development, local commerce, energy supply, telecom providers, and suppliers of medicines and medical equipment, need to be considered

Surveillance – detecting outbreaks, providing timely and accurate data

In any large outbreak, decision-makers are responsible for providing information to the public and front line health care providers treating infected patients [126]. Current recommendations for outbreaks of high-impact respiratory infections include surveillance guidelines for pandemic and seasonal influenza [127, 128]. Surveillance systems should be set up to detect an outbreak of disease caused by a previously unknown pathogen. Evaluations from the 2009 influenza pandemic highlighted the need for improved hospital surveillance, laboratory capacity and sharing of data internationally. Less emphasis has been on making recommendations for surveillance for urban areas, but the International Health Regulations (IHR) evaluation in 2010 mentions local capacities as an area for improvement [129].

Large and densely populated urban areas provide several challenges for infectious disease surveillance. Most surveillance systems rely on reporting from health care systems; either through primary or hospital care, or both. In a diverse urban area, subpopulations might have less access to health care and outbreaks can go undetected. In addition, some populations may rely on alternative health care services, such as traditional healers and acupuncturists, and these groups might give valuable information on emerging diseases.

In some settings, surveillance for respiratory infections can use the infrastructure for influenza surveillance already in place [130, 131]. However, for an emerging disease with a previously unknown and non-influenza pathogen, more exact numbers on infected persons are required. This requires a more exhaustive counting of cases and a large and flexible laboratory capacity with a data management system for the entire city. The International Federation of Red Cross and Red Crescent Societies (IFRC) describes how to use volunteers for detecting new events with community-based surveillance, which can add valuable information in urban settings with hard-to-reach populations [132].

Various mobile apps have been developed for self-reporting of symptoms and tracing of cases and contacts. Also, big data collected from webpages, search engines, social media and mobile providers have been used to signal outbreaks and follow the outbreak. These methods can be efficient in urban areas with a high number of potential contacts, but they have to be evaluated for ethical and privacy standards [133-136].

Laboratory detection and diagnostics

Early detection and identification of an infectious agent, and rapid sharing of its characteristics is of utmost importance to prevent or limit transmission of disease. WHO provides frameworks, tools and expertise to inform and support health authorities in strengthening their laboratory capacity, quality, safety and security [137]. Cities need to plan for a quick upscaling of testing capacity. Mapping of existing laboratories with testing capacity at biosafety level

2 and above is helpful when facing an emerging situation with a new infectious pathogen. If laboratory capacity is not available in urban areas, a system for rapid transport of samples to a national reference laboratory or other laboratory testing facilities must be in place. Real-time PCR analysis with pre-made analysis kits demands a low level of laboratory equipment and skills if the infectious pathogen can be handled in biosafety level 2. In most situations, provisional laboratories can operate on site with ease, in a relatively short time if needed, with help from the global community. In an outbreak situation, laboratory capacity may be a limited resource; that can impair the containment or mitigation of an epidemic. The development and availability of accurate diagnostic kits should be a priority. During the COVID-19 pandemic, WHO recommended upscaling of testing, but due to the large global demand there was a shortage of reagents and laboratory supplies, such as pipette tips. This shortage was compounded by many countries relying on supplies from Chinese manufacturers, who had shut down for an extended period. Additionally, new laboratory innovation may support new methods for diagnoses and surveillance, such as sample pooling for detection of community spread [138].

One Health

Emerging respiratory pathogens can be of zoonotic origin and urban areas should include zoonotic surveillance systems in locations with high risk of spillover, such as wet markets. Cooperation with the veterinary field in the framework of One Health is crucial.

Access to health care

In urban settings, the factors described in chapter 3 facilitate a rapid spread of an emerging infectious pathogen, leading to a rapid and large surge in patients and worried people seeking health care services in primary care, hospitals and public health. During the early phase of the COVID-19 outbreak, the local emergency clinics were overwhelmed by patients with mild respiratory symptoms, blocking access to the emergency numbers and exceeding the testing capacity. Under large epidemics, people have shown an increased use of health care at referral hospitals, which will further strain the already burdened health care system [139]. Consequently,

Freetown, Sierra Leone. Photo: Hinta Meijerink all health care facilities and public health systems need to have plans in place to meet a surge that is larger and faster than seen in less urban settings. As poorly transmissible as it was, SARS exposed the absence of 'surge capacity' in health care systems of the well-resourced countries it affected [140]. Additionally, urban areas are often transport hubs and therefore need plans to deal with an influx of potential cases. For example, when COVID-19 outbreaks occurred on cruise ships, they requested to dock at nearby ports. This generated many challenges for urban governments, including IPC, risk of introduction or spread within the urban area, burdening the health care system, and many were not prepared to do so [141-143].

Many large urban areas have a mix of subgroups based on ethnicity, language, religion, lifestyle, and socioeconomic status. Subgroups may have different beliefs in health and healing, have different traditions for infection prevention and control, follow the advice of peers, and may be more difficult to reach by the authorities. City pandemic preparedness plans need to include how to engage the community for efficient implementation of interventions. For example, during the Ebola outbreak in West Africa, healers were often the first to contract Ebola while also serving as a catalyst for transmission as they were not involved in the official preparedness planning. Additionally, authorities should be aware that health seeking behaviour might be affected by the implications, specifically loss of income. For example, during the COVID-19 pandemic many countries recommend extensive home-isolation and quarantine, which leads to loss in income and jobs especially among those with lower socio-economic status.

Urban governments should assess the total health care capacity in the urban setting, identify possible areas of shortages, prepare to fill the gaps in advance, and allow adjustments as the epidemic develops. Easy access to primary health care services will lower the burden on hospitals. During the COVID-19 outbreak, a lack of plans was identified for alternative placement of hospital beds for the infected and ill (cohort isolation in hotels, sports arenas, tents). Also, shortages of intensive care beds, mechanical ventilators, facilities for screening patients, laboratory capacity and supplies, PPE, medical equipment, pharmaceuticals, and skilled health care personnel were evident [110, 144-148].

A large outbreak will endanger the capacity to provide health care to other, non-infected patients. This will affect especially those with long-term and regular treatments and may also cause a delay in people seeking medical assistance (see also the Oslo case in this report). Having separate clinics for testing around the city, (i.e. fever clinics) where non-health care personnel provide care, will allow health care personnel to focus on other, more severe health issues [108, 110].

Infection control measures – protecting the population, the patients and health care workers

Infection prevention and control (IPC) in health care settings is crucial to prevent transmission to health care workers, patients and the community. All health care facilities should have a system and guidelines for IPC that are consistent with national and/or international guidelines. Staff should be regularly trained and exercises should take into consideration a rapid and large surge of patients seeking care [149, 150]. For example, in response to an increase of COVID-19 cases, Milan rapidly reorganized intensive care unit facilities [151]. In a pandemic, health care facilities will be overwhelmed by patients, while experiencing a shortage of staff, overcrowded patient facilities and a lack of PPE. These factors increase the risk of nosocomial spread to staff and patients, which in turn reduces the number of staff available to treat the growing number of patients. Places with overwhelmed health systems, such as Wuhan, New York and northern Italy, showed much higher case fatality ratio for COVID-19 than other non-overwhelmed places [152].

In 2020, the global demand for PPE due to COVID-19 exceeded the production capacity and caused a shortage. When there is shortage of PPE, the available equipment must be prioritized to use in the highest-risk situations/procedures. The correct use of PPE is a result of staff training (e.g. fit testing of N95/P3 respirators). Waste management may also be overwhelmed in a situation where PPE is used excessively. During an outbreak when the health care systems are overwhelmed, health care facilities in areas with extreme urban poverty can become dangerous, particularly if the normal standards of IPC are already inadequate. Local stockpiles of PPE distributed around the city's hospitals and primary care clinics are recommended. Entry restrictions and screening in outpatient clinics, hospitals and nursing homes can be a tool to stop the introduction of infections [110]. In China, some hospitals used robots to deliver medicines and disinfect surfaces during the COVID-19 outbreak [153].

Medical countermeasures

For most newly identified viruses, unlike influenza, there may be no available drugs or certainly no vaccine. For pandemic influenza, some antiviral drugs with variable efficacy may already be available, and a vaccine may be made available within approximately six months. Cities should consider stockpiling these antivirals and have a prioritization plan for patients. The development of a vaccine for other viruses will normally take at least 1-2 years. Symptomatic treatment will be the only option available for other viral diseases, which include hydration, oxygen and possibly assisted ventilation [154]. Antibiotics for treating co-infections or complications like bacterial pneumonia should be stockpiled for use in a large outbreak.

Affected countries could have a crucial role in producing medicines, medicine ingredients, vaccines or PPE. Reduced production capacity due to high incidence of sick leave among employees or increased consumption within the producing country can pose a risk for countries who depend on purchasing these products. A blood supply shortage could arise during an outbreak, due to sick donors or sick personnel at the transfusion services. Plans should be made to assess the availability of blood products for the city's hospitals [155]. Due to international trade and travel restrictions, as well as reduced production capacity, a stockpile of essential medicines should be in place.

How to prepare for introduction of vaccines

For respiratory diseases, vaccination has been an efficient and widespread mitigation strategy [31, 156, 157]. As vaccine development might take years, it will not be available in the early stages of a novel pandemic. Several initiatives are focusing on rapid development of vaccines against emerging pathogens, such as the Coalition for Epidemic Preparedness Innovations (CEPI) and the Biomedical Advanced Research and Development Authority (BARDA) [158-160]. Following the publishing of the SARS-CoV-2 genome, both reacted quickly and collaboratively to rapidly develop vaccine candidates against SARS-CoV-2 [127, 128] and Phase I trials were launched with record speed. Once a vaccine is developed, equitable access should be guaranteed so that distribution of vaccines is based on evidence-based need and not just financial incentives.

Two studies from the USA describe assistance to local urban policy preparedness planning, building on existing collaborations in the previous years and showing the importance of collaboration between sectors [161, 162]. The general findings support national-level models; influenza vaccination should begin before the first imported case to have a substantial effect. Prioritized vaccination including health care workers, is essential to avoid hospitalizations, deaths and financial costs. City-level models provide locally adapted quantitative outcomes, and the effect of similar immunization programmes can vary between urban settings within a country [163, 164].

Some megacities will not have an influenza immunization programme funded by the government, especially in Asia and Africa [165-167] and they will have a weak infrastructure for mass vaccination, making it hard to reach target groups in a short time frame. In low-income urban areas of Delhi, model simulations show that targeting vaccination to slum residents is most efficient [168]. However, most pandemic preparedness plans do not include socioeconomic status when preparing for mass vaccination and vaccine prioritization. Data are lacking on populations living in areas with low socioeconomic status, which complicates the estimation of size and location of target groups for vaccination. Geographical information systems have been used in vaccination campaigns and vaccine trials to generate information on spatial distribution of households, both for vaccination site selection and for outreach teams to enable easy access and communication with the population in densely populated areas [169, 170]. In addition, (seasonal) influenza vaccination could reduce the overloading of differential diagnosis during outbreaks with other respiratory pathogens, as seen with COVID-19, and lower the burden of patients needing hospital care.

Non-pharmaceutical interventions

Non-pharmaceutical interventions (NPI) refer to all measures or actions, other than the use of vaccines or medicines, that can be used to slow or mitigate the spread of disease in a population [171]. While NPIs can be implemented at any stage of an outbreak, they are often most useful during the containment phase in order to allow authorities more time to prepare and to reduce the peak burden of outbreaks. NPIs most likely to be considered in response to an outbreak due to a high-impact respiratory pathogen in an urban area are:

- Personal protective measures including hand hygiene and cough etiquette
- Personal protective equipment in health care settings, including gloves, surgical face masks, PP3 gowns
- Physical distancing measures targeting infected cases and contacts including isolation of the most vulnerable and ill people and quarantine of asymptomatic contacts [172, 173]
- Physical distancing measures targeting the general population, including interventions in educational/childcare settings, workplace interventions, public transport restrictions, and measures related to mass gatherings [172-178]
- Travel-related measures including international and domestic travel advice, travel restrictions, entry and exit screening, and border closures
- Environmental measures including enhanced cleaning and improved ventilation

Table 2 provides an overview of these NPIs, the evidence of their effectiveness and when they should or should not be recommended, based on a systematic review conducted by WHO [171]. The choice of appropriate intervention will depend on careful consideration of the epidemiological, logistical, social, economic and political dimensions [92]. In general, NPIs are most effective when implemented in a timely, sustained, and layered manner, while allowing for flexibility and modifications as an outbreak progresses and new information becomes available [108]. In urban settings, it is crucial to adapt NPIs to specific local factors and consider vulnerable groups. For example, cities like Paris and Rome had challenges implementing full lockdown for their homeless population during the COVID-19 outbreak.

Physical distancing measures are crucial, but their impact is limited when the reproductive number is high, and when asymptomatic individuals can transmit the disease [179]. Modelling studies on SARS show that prompt isolation and quarantine had a significant effect in limiting transmission [180, 181]. School closure can be effective in flattening the epidemic curve for influenza [182-185], but should be triggered early and requires timely surveillance data from schools [183, 186]. Analysis of human mobility patterns in urban areas can improve the understanding of the disease transmission within megacities and assist in guiding area-specific interventions [177, 187]. City centres and public transport hubs play an important role in the intra-city transmission of respiratory infections [177, 182, 186-193]. Analyses of the SARS outbreak in 2003 in Beijing suggest that the geographical spread was affected by population density, health care resources and public transport routes [194, 195]. Limited public infrastructure, informal employment, informal settlements, and sociocultural characteristics of urban populations can affect the pattern of transmission. Populations living in informal settlements have been shown to be important drivers for the intra-city spread, resulting in faster spread and higher peak infection case numbers during influenza epidemics [168, 196-198]. In general, international travel restrictions have little effect, but they may delay the introduction of respiratory pathogens and their spread long enough to ensure better preparedness in the health care systems or to establish an immunization programme [199-201].

National authorities may mandate some interventions that will be implemented by local authorities, such as entry screening and quarantine of contacts. This may be particularly relevant for cities that have points of entry as defined by the IHR (e.g. international airports or ports). Conversely, local authorities may be responsible for implementing some NPIs, such as school closures, independent of national recommendations or obligations. Law enforcement authorities and the military may need to enforce quarantine and isolation measures, depending on how a community chooses to implement these.

In the ongoing outbreak of COVID-19, the scale of the implemented NPIs is unprecedented. A WHO-China joint mission showed that China's approach to contain the rapid transmission of this new respiratory pathogen changed the course of a rapidly escalating epidemic and delayed the spread to allow more time for preparedness [108]. In most countries, the main objectives of the NPIs were not aimed to mitigate the outbreak, or even prevent spread, but to delay the spread of the outbreak to allow health care facilities to prepare for the surge of cases as well as spreading out the demand for (intensive) care. This approach has now been adopted by many other countries during the COVID-19 outbreak. To limit the spread of COVID-19 in the community, many countries have, in addition to hygiene measures, implemented extensive physical distancing measures, such as home-quarantine for contacts, self-isolation for those with (mild) symptoms, working from home, no physical contact and keeping 1.5 to 2 meter distance from others. Some countries, even ordered complete lockdown where people were not meant to leave their homes. However, in certain situations these control measure may not be feasible or have larger negative impacts, for example in place with no or limited access to clean water and sanitations, where people are dependent on informal employment and many people live together in small physical areas.

Table 2
Non-pharmaceutical interventions. Adapted from “Non-pharmaceutical public health measures for mitigating the risk and impact of epidemic and pandemic influenza” [171]

Measure	Recommendation	Evidence of effectiveness	When to consider this measure during an outbreak/ epidemic/ pandemic	Considerations for implementation in an urban setting
Personal protective measures				
Hand hygiene	**Recommended** as part of general hygiene and infection prevention	Moderate evidence (lack of effectiveness in reducing influenza transmission); mechanistic plausibility	At all times	Education programmes for childcare centres and schools; posters and leaflets, radio, TV, social media
Cough etiquette	***Recommended*** as part of general hygiene and infection prevention	None; mechanistic plausibility	At all times	Education programmes for childcare centres and schools; posters and leaflets
Face masks	If supplies are limited, use for symptomatic individuals should be prioritized; may increase risk of infection due to touching face to adjust mask	Moderate (lack of evidence in reducing influenza transmission); mechanistic plausibility	At all times for symptomatic individuals; may be considered in severe epidemics for asymptomatic people	Clear communication strategy about NOT using face masks for healthy people
Personal protective equipment in health care settings				
Face masks	**Recommended** as part of general hygiene and infection prevention		At all times	Training health care workers in proper use of protective equipment
Gloves	**Recommended** as part of general hygiene and infection prevention		At all times	
PPE	**Recommended** as part of general hygiene and infection prevention			
Physical distancing measures				
Isolation of sick individuals	**Recommended** voluntary isolation at home of sick individuals with uncomplicated illness	Very low (effective)	At all times	Capacity for isolation in health care facilities and alternative solutions like home-based isolation for those with mild disease
Quarantine of asymptomatic contacts	**Conditionally recommended** if asymptomatic transmission is an issue; there would be considerable difficulties in implementing it	Very low (variable effectiveness)	In extreme circumstances, to delay spread of disease and “flatten” the curve, when asymptomatic transmission might be a relatively large issue	Clear communication strategy how quarantine should be done; need for additional support
Interventions in educational settings	**Conditionally recommended**, with gradation of interventions based on severity	Very low (variable effectiveness)	Coordinated proactive school closures or class dismissals are suggested during a severe epidemic	Guidelines on when to close and open; guidance for students (no crowding); provide options for children of essential personnel

Measure	Recommendation	Evidence of effectiveness	When to consider this measure during an outbreak/ epidemic/ pandemic	Considerations for implementation in an urban setting
Prepare for home-based teaching when schools are closed				
Interventions in workplace settings	**Conditionally recommended**, with gradation of interventions based on severity	Very low (effective)	Extreme measures such as workplace closures can be considered in extraordinarily severe pandemics in order to reduce transmission	Provide support for working from home and introduce flexible working hours; identify essential personnel for response; provide software for virtual meetings
Community gathering restrictions	**Conditionally recommended**, with gradation of strategies linked to severity to increase distance and reduce density among populations	Very low (unknown)	Moderate and severe epidemics and pandemics	Identify hotspots and events with crowding
Travel-related measures				
International and domestic travel advice	**Recommended** for citizens before their travel as a public health intervention in order to avoid potential exposure and to reduce the spread	None	Early phase of pandemics	Prepare communication strategy for travellers arriving and/or departing; include practical information
Travel restrictions ("cordon sanitaire")	**Conditionally recommended** during an early stage of a localized and extraordinarily severe pandemic for a limited period of time	Very low (effective); before implementation, it is important to consider cost–effectiveness, acceptability and feasibility, as well as ethical and legal considerations in relation to this measure	Early phase of extraordinarily severe pandemics Late phase (nationally or regionally), to prevent reintroducing, causing a second wave	Ensure clear communication, control and screening when implementing travel restrictions; identify target group and/or locations for restrictions
Entry and exit screening	**Not recommended** because of lack of sensitivity of these measures in identifying infected but asymptomatic (i.e. pre-symptomatic) travellers	Very low (lack of effectiveness in reducing influenza transmission)		Avoid crowding; prepare separation and testing for suspected cases
Border closures, national or regional	**Not recommended** unless required by national law in extraordinary circumstances during a severe pandemic	Very low (variable effectiveness)		Ensure preparation of control, before implementing; clear communication for exceptions
Environmental measures				
Enhanced surface and object cleaning	**Recommended** as part of general hygiene and infection prevention	Low (lack of evidence in reducing influenza transmission); mechanistic plausibility	At all times	Consider central stockpile of disinfectants
Increased ventilation	**Recommended**	Very low (effective); mechanistic plausibility	At all times	Systematic control of ventilation specified by legislation

Research during an emerging outbreak

Collecting, analysing and sharing knowledge in an emerging outbreak situation is an international obligation. Urban areas have the advantage of available academic resources which should be mobilized from the start of the outbreak. Such data will give a better understanding of the outbreak and an improved preparedness and response for the city itself and also other cities within and outside the country. Having local data builds trust and supports risk communication to the public and health care workers. In addition, research should quickly focus on developing validated diagnostic tools, medical countermeasures and vaccines, as in the current COVID-19 outbreak [158, 159, 202-208].

In the current COVID-19 outbreak, WHO has provided several protocols for data collection and these include key demographic characteristics for surveillance efforts [209]. To be able to set up a research project in a critical and stressed situation, plans and contingencies should be in place to react swiftly after the detection of an outbreak. This includes identifying research objectives, making protocols, having ethical approvals and having the human resources to collect the data and write the publications. A collaboration with the city's public health officers and academic groups, with support of funders and/or philanthropists, will create a platform for sharing operational and academic expertise as well as data [135].

In the evolving COVID-19 situation, new and radical non-pharmaceutical interventions have been implemented, especially in urban areas. The effect of these infection control measures is uncertain and should be studied in detail to provide a better understanding on how to control future outbreaks. Both the direct effect on the spread of the disease and the effect on other sectors like finance and employment should be a research priority to provide better advocacy and evidence-based solutions for the future. Research should also include behavioural aspects that allow interventions to be adapted to the local community. To make research available to all countries, public health officers and policy makers, publications should be submitted to open access journals (gold open access) or made accessible when behind a paywall (green open access). In addition, relevant research should consider additional publications that can be understood by a non-academic public, policy-makers and local government. Translation of relevant work to other languages should also be considered because English (the most common used academic language) is not the working language in many urban settings.

Risk communication

Urban environments have social issues, including violence, migration and poverty – which can all impact the reach and credibility of communication [210]. A risk communication plan should take into consideration any relevant social structure - demographic or other relevant context issues that may help target the message, the best choice of communication channels and time of communication. During epidemics, pandemics, humanitarian crises and natural disasters, effective risk communication allows people at risk to understand and adopt protective behaviours. It allows authorities and experts to listen to and address public concerns and needs so that the advice they provide is relevant, trusted and acceptable [211]. Few data are available on the evaluation of communication strategies during outbreaks.

Understanding the target population is essential for communication as social and cultural aspects affect perception or communication of risk. Poor risk communication will destroy trust and will negatively affect the implementation of infection control measures. When evaluating well-functioning strategies from other urban areas, identifying settings with similar social structures is important [212]. The IFRC is currently working on a report on the importance of trust during epidemics for the GPMB.

Visualization is an important tool in risk communication, especially when dealing with extremely heterogenic populations with different language backgrounds. Involving key members of society to communicate risk and interventions can increase uptake of the message, if done correctly. The ongoing COVID-19 pandemic has proved how social media are used for communication. A wide range of influencers are using their position to support the governments' advice or to question the management of the situation by the authorities. However, easy internet access has also created the emergence of fake news and conspiracy theories on social media. Meanwhile, social media channels such as Facebook, Instagram, Twitter and Google are cooperating with the authorities to limit the spread of fake news and lead people to correct and official information channels.

Some particular challenges in communication with urban populations:

- Urban populations are heterogeneous: crisis-affected populations can be spread out across an urban setting, households with very different levels of vulnerability can be located close to one another.
- Impact of outbreaks creates confusion and tension, which can turn misinformation into rumours and break trust. In urban contexts, population density can encourage the rapid spread of rumours.
- The scale of the urban context, including the amount of information being communicated by and between different actors, can result in conflicting messages and a dense space for communication.
- Urban populations generally have access to a wide range of communication channels, which present their own challenges and opportunities [210].
- Actions against fake news to identify and monitor (social) media channels where rumours and fake news might arise, verifying the facts behind the rumours and engaging with new narratives and facts [213]. Update verified facts on trusted webpages and media frequently, engaging community via social media to fight fake news and misinformation.

Community engagement is an important factor in effective risk communication. These include traditional and religious leaders, civil society organizations, women's groups, survivors and other trusted members who could effectively communicate within the community and who understand how to shape culturally-sensitive messages and explain response measures and research activities. As a background for the GPMB, the IFRC prepared a report on community engagement in preparedness and response [214]

Antenatal clinic in The Gambia. Photo: Hinta Meijerink

Chapter 4
Modelling as a tool in urban preparedness

London, UK. Photo: Robert Paetz

Mathematical and statistical modelling is used to monitor infectious diseases and to understand how they spread through populations in space and time [215]. Models can provide valuable guidance to public health officials for preparedness and response planning of high-impact respiratory infections. The roles of mathematical modelling include projecting the impact of epidemics, estimating the effect of interventions and supporting preparedness planning. For example, they can be used to:

- » estimate the likely impact (e.g. number of cases, hospitalizations) of simulated outbreaks with different pathogen characteristics to project health care capacity needs
- » identify at-risk locations or groups within the urban area to target and prioritize preparedness efforts
- » project the impact of intervention strategies to prioritize target groups/locations, response efforts and interventions [216]
- » provide early warning systems to alert on potential outbreaks and activate response
- » predict the spread of disease within and between cities based on local demographics and transport networks

The use of “what if?”-based analyses can provide policy-makers with estimations on expected outcomes and opportunities available to combat epidemics. These analyses, in combination with health-economic evaluations, yield a transparent framework for decisions on resource allocation. Once the emerging outbreak is detected, the already established models can use real-time surveillance data to identify and forecast future developments in different locations and provide daily insights about the effect of infection control measures. However, especially for emerging diseases, it is incredibly difficult to create meaningful and robust models as the knowledge base changes continuously. For example, Imperial College in the UK created a COVID-19 model to estimate the effects of various interventions on the outbreak progress [217].

Urban-level models are commonly complex. They allow for differences in dynamics within and between cities and can help to identify targeted interventions and hotspots. Reliable data at residential level, including geographical distribution of social classes and transport routes is essential to simulate spread and the effects of interventions. The benefit of employing urban models is their ability to capture the local reality with a higher level of granularity than national-level models. For example, integration of information about the geographic location and bed capacity of hospitals within the city will give urban policy-makers detailed insights about the need for health resources, and relocation of patients [218]. Various data sources can be used to provide information for models and inform policies. For example during the start of the COVID-19 pandemic, models were based on mobility data from mobile phone providers could show the impact of quarantine on movement, and was able to predict spread of the outbreak and identify risk patterns [219].

Mathematical models require the input of specific parameters, such as transmissibility, contact rates, size of susceptible population, incubation period and fatality rates. Many respiratory pathogens transmit readily and quickly; the early reproductive number (R0) is typically 1.2-1.8 for influenza, 2.2 - 3.6 for SARS and is estimated to be 1.4 - 4.7 for COVID-19 (average 2.2) with an incubation time of 5-6 days similar to SARS [51, 220-231]. This leaves little time to contain the outbreak in urban areas, as they will be hit early and will see faster transmissions. Knowledge about early-phase spread and the urban characteristics are crucial to inform policy-makers about the interventions.

Strengthening the use of modelling in urban preparedness planning

Implementation of effective and scientific-based public health policies requires an integrative approach across the scientific, administrative and political spheres. For models to be relevant in urban preparedness planning, it is important that they address relevant operational policy questions, and that they are able to provide rapid assessment of different options, once an epidemic is underway. Collaboration between modelling groups and urban health authorities before emergencies arise will foster trust and allow explanation of both the political needs, and the possibilities and limitations of models [232]. Even though modelling can be useful in both outbreak preparedness and response, it is important to identify the challenges, limitations and the uncertainties of models and communicate these sufficiently to policy-makers [233]. Models cannot be expected to give an accurate prediction of the outcome but can be a useful tool to prepare for various outbreak scenarios by comparing different interventions and simulating different scenarios. Long-term projections of epidemics based on early data without assuming any interventions or change of behaviour in the population provide (unrealistic) worst-case scenarios that tend to attract attention in news media and create fear. For example, in 2014, the Centers of Disease Control and Prevention (CDC) developed a model projecting 1.4 million Ebola cases in West Africa by January 2015 [234].

Timely access to high-quality, local data is key to carrying out the objectives of mathematical and statistical modelling. Development of local infrastructure to support the rapid dissemination of data would significantly enhance the ability of models to aid in decision-making, both during preparedness and response. More new data sources for surveillance are becoming available; traditional surveillance data are supplemented with high-resolution genetic information and real-time serological diagnostic tests. Additionally, novel techniques using big data can also be used as proxy, such as over-the-counter medication sales, internet search queries, work/school absentee data, (public) transport usage, and social media [52, 235-238]. Surveillance systems in resource-poor urban settings are commonly lacking and it is therefore important to develop ways, for example using participatory or voluntary surveillance methods, in order to validate digital data sources [239]. It is important to be aware of the particular way in which local data is collected to avert misleading comparisons; for example, if the data collected in two cities are based on different criteria for testing or reporting, the outcomes cannot be compared. Testing criteria for COVID-19 differed between countries and changed as the outbreak progressed, due to a developing knowledge base and changing epidemiology, as well as testing capacity [240, 241].

Chapter 5
Monitoring vulnerabilities and preparedness in urban areas

Tokyo, Japan. Photo: Robert Paetz

In 2018, WHO launched a new framework for monitoring and evaluation of the 13 IHR core capacities, with four components; mandatory annual reporting, voluntary external evaluations, post-action reviews and simulation exercises [242]. For annual reporting, countries are asked to report their level of IHR implementation using the State Parties Self-Assessment Annual Reporting (SPAR) tool [243]. This tool consists of 24 indicators for the 13 IHR capacities needed to detect, assess, notify, report and respond to public health risk and acute events of domestic and international concern. For the voluntary external evaluations, guidelines for Joint External Evaluation (JEE) have been developed by WHO [244] and include 49 indicators, within 19 technical areas, to measure the status of each capacity. The indicators are further broken down to a few elements called attributes, which further define the indicator at each level.

The results of the SPAR and the JEE tend to reflect the national status and do not provide specific guidance for improvements at sub-national levels, nor are there any indicators specifically linked to urban preparedness and response. For example, to achieve the fourth level (demonstrated capacity) of the indicator R.1.1. *"National multi-hazard public health emergency preparedness and response plan is developed and implemented"*, countries must have 'emergency preparedness measures implemented at national, sub-national and local levels by public health, animal health and other relevant sectors'. A review of the recommendations from 10 JEE reports for this indicator from selected countries with major urban areas[1] found that priority actions were

[1] Cambodia, Democratic Republic of Congo, Indonesia, Japan, Nigeria, Pakistan, Saudi Arabia, Somalia, Thailand, USA

recommended at sub-national levels in only four countries. These highlighted the need to involve stakeholders from all levels in public health planning and preparedness exercises [245]. None of the priority actions referred specifically to urban areas. While several studies have summarized the lessons learned from the JEEs [246-252], there is limited focus on sub-national contexts, including urban areas. Similarly, a recent desk-review of reports containing recommendations for strengthening health emergency preparedness found that of all 231 high-level recommendations, only 47 were found to be targeted at the national or sub-national level [120, 252]. During the COVID-19 outbreak, the SPAR in combination with Infectious Disease Vulnerability Index (IDVI) was used to look at preparedness in relation to risk of introduction in African countries, although it did not specifically address urban settings [253].

Urban Health Equity Assessment and Response Tool

The Urban Health Equity Assessment and Response Tool (Urban HEART) is a guide for policy and decision-makers to identify inequities in health between people living in various parts of cities, or belonging to different socioeconomic groups, as well as to facilitate decisions about effective strategies, interventions and actions that should be used to reduce health inequities (see Appendix VI; Figure 4). The tool can be completed using a traffic light colour scale to allow easy identification of areas to address and compare between cities [254]. Urban HEART also provides five response strategies: a) incorporate health in urban planning and development; b) emphasise and strengthen the role of urban primary health care; c) strengthen the health equity focus in urban settings; d) put health equity higher on the agenda of local governments; and e) pursue a national agenda [254].

Assessment of Urban Health Security

The Center for Global Health Science and Security at Georgetown University developed a self-assessment for urban health security; the Rapid Urban Health Security Assessment (RUHSA). This tool includes 20 capacities and 46 indicators, which are scored on a three-point, colour coded Likert scale based on technical questions. The capacities are divided into four preparedness areas: prevent, detect, respond and other considerations (See Appendix VI; Table 7).

Chapter 6
Recommendations for Urban preparedness for outbreaks with respiratory pathogens

As discussed throughout this document, urban areas are heterogeneous and therefore implementation of the recommendations will be determined by a city's available resources, current preparedness, as well as adjusting them to local needs and characteristics. The recommendations are based on available literature, experiences from previous outbreaks, the current COVID-19 outbreak, NIPH's own experts and feedback from reviewers.

Multi-sectoral approach, including financial, political and governance

1. All cities should have an updated pandemic preparedness plan. The plan should be approved by the city's highest political level.
2. Authorities in large urban areas need to develop an overarching contingency plan taking an all-of-government approach. This includes identifying critical functions and services for the cities that may suffer due to increased demands and a large proportion of workers becoming ill.
3. All cities should map their vulnerabilities, for example by using the HEART tool, in order to identify populations at higher risk, with less access to care and that are harder to reach.
4. Cities should evaluate their preparedness, for example using the RUHSA tool, to identify elements in their preparedness plans that should be addressed.
5. City governments should be prepared to compensate financial loss due to implemented infection control measures, particularly for vulnerable groups with an irregular income.
6. All businesses, public and private, should be prepared for their staff to work from home to minimize commuting and the number of people in the office during the outbreak. Schools should have plans for home-based teaching.
7. All cities should have a high-level, multi-sectoral committee to coordinate implementation of non-pharmaceutical interventions. Any negative effects of control measures should be addressed by the committee.
8. Cross-sectoral exercises and workshops should be held regularly to test the pandemic preparedness plan and identify vulnerabilities.

Access to health care

1. Cities should have plans for establishing dedicated clinics for testing and triage. Testing should be available for everybody and hard-to-reach populations should be offered testing by mobile clinics or other providers. Testing areas must take into consideration available PPE for the health care workers and have enough space to avoid crowding.
2. All cities need to invest in putting in place a well-functioning primary care system.
3. Testing and treatment for the disease causing the outbreak should be free of charge.

4. All available hospital capacity in the city, including intensive care units and human resources, should be mapped and there must be plans for scaling up capacity.

5. Cities must identify facilities that can be used for cohort isolation and quarantine.

6. Cities must plan for providing the population with medical care for needs unrelated to the outbreak.

7. Cities should develop an overarching contingency plan for all health care services, including primary health care services and hospitals, public and private services, and both mainstream and subculture-specific services, in order to be able to meet a larger and more rapid surge of infected patients and concerned inhabitants than expected, for countries as a whole.

8. All cities should have a stockpile of critical medicine and medical equipment.

Non-pharmaceutical interventions (NPI)

1. Develop criteria in local pandemic plans for implementation of NPIs, including when they should begin and end, which (human) resources are needed for implementation and how the NPIs will be implemented for vulnerable groups.
2. Review existing legislation for NPI, including isolation and quarantine, to identify legal basis and actors responsible for implementing measures at different levels of authority.
3. Establish the capacity to monitor NPI prospectively in order to adjust measures if an outbreak continues over an extended time period.
4. Develop guidelines for social distancing for educational institutions and workplaces in order to ensure ease and consistency in implementation.
5. Use electronic portable devices to help implement close contact tracing while respecting privacy, together with a traditional tracing approach depending on the interviewee's memory.

Kathmandu, Nepal. Photo: Robert Paetz

Infection prevention and control

1. Cities should have a centralized stockpile of PPE.
2. All health care providers need to have in place a system and guidelines for infection prevention and control. Hand hygiene and cough etiquette should be taught routinely to all health care workers. Health care workers should have regular practical training in the proper use of PPE and other infection prevention and control measures.
3. All children in childcare centres and schools should be taught the importance of hand hygiene and cough etiquette.
4. Hand sanitizers should be made available in workplaces when hand washing facilities are not available.

Outbreak surveillance

1. Train local health care workers to notify on local outbreaks with an unknown cause and establish reporting lines for such events in the community, primary care and hospitals.
2. Establish a network of people who can report on events in hard-to-reach populations, for example based on the community-based surveillance system from IFRC.
3. Have an established cooperation between human and animal disease surveillance. In locations with wet markets, disease surveillance should be set up to quickly detect outbreaks among both humans and animals.
4. Have established clinical surveillance systems for respiratory pathogens with data sources from all parts of the city. The number of tests performed, and positive tests, should be reported.
5. Have an IT capacity, including data management, for collecting large amounts of data from all areas of the city. Identify the authority which is responsible for collection, cleaning, analyses and reporting of city level data.
6. Prepare for the use of electronic patients records and ICPC and ICD codes.
7. Mortality surveillance should be in place, and fatalities associated with the outbreak should be mandatorily notifiable.
8. Have plans to identify any negative health effects of NPIs.
9. Make sure the surveillance data can be used by modellers to project the outbreak.

Laboratory preparedness

1. Prepare for rapid and extensive upscaling of test activity throughout the city.
2. Have a stockpile of necessary equipment, reagents and laboratory supplies to scale up testing activity.
3. Map the city's laboratory test capacity, available diagnostic test methods and human resources.
4. Depending on the city's organization, have laboratories with a dedicated responsibility for rolling out test capacity to the city within a short time span.
5. Validation of testing outside the reference laboratory must be done before testing is implemented. A national reference laboratory should assist with providing positive samples.
6. Run training and simulation exercises for laboratories to prepare for introduction of new tests.
7. Maintain a good cooperative relationship with national and international reference laboratories.
8. Test new assays during the outbreak for decision–making.

Mass vaccination plans

1. Have city-level plans for mass vaccination according to WHO's guidance and relevant national plans, including the need for human resources.
2. Groups prioritized for vaccination should be identified, including subcultures within the city with potentially increased risk for severe disease. Key workers for functions critical to society should be identified for vaccination. Estimate how many people need to be vaccinated and how to reach them, especially hard-to-reach population, such as those living in slums, and homeless people.
3. Vaccination should be free of charge.
4. Secure supply chain management, including cold chain, transportation, storage capacity and security within the city.
5. Create partnerships with local corporations and private companies for potential collaboration in the vaccination campaign (private health clinics, mobile phone companies, media companies, NGOs).
6. Ensure that critical immunization programmes (measles, polio, in particular) continue as planned.
7. Regularly test the city's mass vaccination plans using existing immunization programmes (seasonal influenza, measles etc.).

Communicating with the population in a health crisis

1. Identify all varieties of livelihood, cultural contexts and languages used in the city in order to identify groups who need targeted information, including visualization, posters etc.
2. Make plans to set up call centres for the public, with 24/7 availability, and with live chat facilities for low threshold contact.
3. Establish a local communication platform to build well-known sites where people seek information.
4. Identify and cooperate with local cultural experts/influencers to disseminate facts and advise the government.
5. Cooperate with local NGOs for both fact finding and communication
6. If useful, perform a Knowledge, Attitude and Practices (KAP) survey, in particular in sub-populations and hard-to-reach populations in order to customize any measures.
7. Have a system to send text messages or emails to the entire population to inform them about measures taken.
8. Be actively present in social media to observe and combat the emergence of fake news.
9. Prepare communication plans with disabled people and cooperate with peer organizations which could reach out to those population groups.
10. Proactively reduce the risk of overreaction, abuse and stigmatization of individuals or population groups and build trust.

Modelling the outbreak

1. Establish collaboration groups between modellers, epidemiologists and public health decision-makers to improve communication; realistic expectations of what models can and cannot do; identify key questions for models to address; proper interpretation of models; ensure data availability.
2. Develop a local network of modellers who are dedicated to study infectious disease modelling in urban settings.

3. Identify available data sources that are useful for surveillance and modelling of respiratory infections in urban settings.
4. Provide the necessary infrastructure to ensure sharing of data with modellers during epidemics.
5. Establish collaborations with organizations outside of the health care sector which might be collecting data relevant for models.
6. Make dissemination plans of modelling results to local policy-makers, the international scientific community and the public.

Research during an emerging outbreak

1. Prepare protocols for investigation and publication of the first few hundred cases.
2. Research into the effect of the local control measures should be prioritized, including the economic aspects.
3. Serological studies should be planned in order to inform on the attack rate in the population.
4. Submit data to Gold and Green open access journals.

Recommendations to World Health Organization

1. Recommendations for urban preparedness should be developed in the years to come, including specific tools and guidelines.
2. IHR Monitoring and Evaluation Framework should consider including urban preparedness.
3. The Joint External Evaluations should integrate indicators that would measure sub-national capacities, including in urban settings.
4. Set up collaboration networks between megacities to share experiences, data and tools in order to prepare preparedness plans.

Appendices

I. Abbreviations

Abbreviations	
ABM	Agent-based models
BARDA	Biomedical Advanced Research and Development Authority
CDC	Centers for Disease Control and Prevention
CEPI	Coalition for Epidemic Preparedness Innovations
COVID-19	Coronavirus infectious disease 2019
GDP	Gross Domestic Product
GPMB	Global Preparedness Monitoring Board
IATA	International Air Transport Association
IDVI	Infectious Disease Vulnerability Index
IFRC	International Federation of Red Cross and Red Crescent Societies
IHR	International Health Regulation
IPC	Infection prevention and control
JEE	Joint External Evaluation
MERS	Middle Eastern Respiratory Syndrome
NPI	Non-Pharmaceutical Interventions
PIP	Pandemic Influenza Preparedness
PPE	Personal Protective Equipment
R	Reproductive number
RUHSA	Rapid Urban Health Security Assessment
SARS	Severe Acute Respiratory Syndrome
SPAR	State Parties Self-Assessment Annual Reporting
Urban HEART	Urban Health Equity Assessment and Response Tool
WHO	World Health Organization

II. Megacities in 1950, 2020 and 2035

Country or area	Urban Agglomeration	Population (millions)		
		1950	2020	2035
Japan	Tokyo	11.3	37.4	36.0
India	Delhi	1.4	30.3	43.3
China	Shanghai	4.3	27.1	34.3
Brazil	São Paulo	2.3	22.0	24.5
Mexico	Ciudad de México (Mexico City)	3.4	21.8	25.4
Bangladesh	Dhaka	0.3	21.0	31.2
Egypt	Al-Qahirah (Cairo)	2.5	20.9	28.5
China	Beijing	1.7	20.5	25.4
India	Mumbai (Bombay)	3.1	20.4	27.3
Japan	Kinki M.M.A. (Osaka)	7.0	19.2	18.3
United States of America	New York-Newark	12.3	18.8	20.8
Pakistan	Karachi	1.1	16.1	23.1
China	Chongqing	1.6	15.9	20.5
Turkey	Istanbul	1.0	15.2	18.0
Argentina	Buenos Aires	5.2	15.2	17.1
India	Kolkata (Calcutta)	4.6	14.9	19.6
Nigeria	Lagos	0.3	14.4	24.4
Democratic Republic of the Congo	Kinshasa	0.2	14.3	26.7
Philippines	Manila	1.5	13.9	18.6
China	Tianjin	2.5	13.6	16.4
Brazil	Rio de Janeiro	3.0	13.5	14.8
China	Guangzhou. Guangdong	1.0	13.3	16.7
Pakistan	Lahore	0.8	12.6	19.1
Russian Federation	Moskva (Moscow)	5.4	12.5	12.8
United States of America	Los Angeles-Long Beach-Santa Ana	4.0	12.4	13.8
China	Shenzhen	0.0	12.4	15.2
India	Bangalore	0.7	12.3	18.1
France	Paris	6.3	11.0	12.1
Colombia	Bogotá	0.6	11.0	12.8
India	Chennai (Madras)	1.5	11.0	15.4
Indonesia	Jakarta	1.5	10.8	13.7
Peru	Lima	1.1	10.7	13.0
Thailand	Krung Thep (Bangkok)	1.4	10.5	12.7
India	Hyderabad	1.1	10.0	14.2
Republic of Korea	Seoul	1.0	10.0	10.3
United Kingdom	London	8.4	9.3	10.6
China	Chengdu	0.6	9.1	11.2
Iran (Islamic Republic of)	Tehran	1.0	9.1	10.7
China	Nanjing. Jiangsu	1.0	8.8	11.5
Viet Nam	Thành Pho Ho Chí Minh (Ho Chi Minh City)	1.2	8.6	12.2
China	Wuhan	1.1	8.4	10.0
Angola	Luanda	0.1	8.3	14.5
India	Ahmadabad	0.9	8.1	11.3
China	Xi'an. Shaanxi	0.6	8.0	10.4
Malaysia	Kuala Lumpur	0.3	8.0	10.5
India	Surat	0.2	7.2	10.8
Iraq	Baghdad	0.6	7.1	10.8
United Republic of Tanzania	Dar es Salaam	0.1	6.7	13.4

III. Literature search strategies

For the chapter "Urban vulnerabilities for outbreaks with high-impact respiratory pathogens", we performed a literature search on 24 January 2020 and repeated the same search on 3 April 2020 to add newly published papers. The search was performed by using a combination of terms shown in Table 3 to examine various databases: Embase, Web of Science, Cinahl, PsycINFO, Ovid MEDLINE®, Cochrane, and Scopus. The first search identified 1014 unique papers. After a selection based on title and abstract, 245 papers remained, of which 144 were relevant after screening full text. In addition, we added relevant references from those manuscripts. An update on 3 April resulted in 26 additional papers; 10 proved to be relevant.

Table 3
Overview of search strategy used to identify literature on urban vulnerabilities for outbreaks of respiratory pathogens

General term	Search terms used
Epidemic	Epidemic; Pandemic; Disease outbreak;
Respiratory pathogen	Influenza; Airborne infection; SARS; MERS; Ebola; Respiratory pathogen; Droplet transmission; Coronavirus;
Urban area	City; Urban area; Urban population; Urban health; Urbanization; Megacity; Metropolitan; Urban environment; Urban setting; Urban;
Preparedness	Preparedness; Preparation; Prepared; Readiness; Disaster planning;

We also performed a literature search (Table 4) on 24 January 2020 to identify manuscripts describing models used in urban preparedness. In total, we found 380 manuscripts, after screening the titles and abstracts, we read the full text of 171 papers and we identified 47 relevant papers. In addition, 22 articles were identified and included.

Table 4
Overview of the search strategy used to identify literature on modelling outbreaks in urban settings

General term	Search terms used
Epidemic	Epidemic; Pandemic; Disease outbreak;
Respiratory pathogen	Influenza; Airborne infection; SARS; MERS; Ebola; Respiratory pathogen; Droplet transmission; Coronavirus;
Urban area	City; Urban area; Urban population; Urban health; Urbanization; Megacity; Metropolitan; Urban environment; Urban setting; Urban; names of all megacities
Modelling	Statistical models; Machine learning; Theoretical models; Mathematic models; Spatial Analysis; Urban scale mobility data; Agent based; Individual based; simulation;

Lastly, we performed a literature search (Table 5) on 8 April 2020 to identify manuscripts that describe aspects of preparedness related to COVID-19. In total, the search identified 177 manuscripts. After screening the titles, abstract and full text, we identified 78 relevant papers.

Table 5
Overview of the search strategy used to identify literature on COVID-19 in urban settings

General term	Search terms used
COVID-19	2019-nCoV; COVID-19; SARS-nCoV; SARS-CoV-2; Wuhan pneumonia virus;
Urban	City; Urban area; Urban population; Urban health; Urbanization; Megacity; Metropolitan; Urban environment; Urban setting; Urban; names of specific cities (all megacities and known for outbreaks)
Preparedness	Preparedness; Preparation; Prepared; Readiness; Disaster planning; Surge capacity; Quarantine; Isolation; non-pharmaceutical intervention; Outbreak response

IV. Overview of models and type of data needed for urban preparedness

Table 6
Overview of models and type of data needed for urban preparedness for respiratory pathogens

Basic modelling of overall effect	Type of data
Modelling and data collecting prior to an outbreak	
Surveillance data	Laboratory-confirmed case data Syndromic surveillance data Hospital-based data Serologic data Virological data Clinical case data Work absence data Mobile phone/web-based surveys
Demographic data	Population size Age structure Household size and composition Hospital sites; bed size and ICU capacity Income distribution Vaccination status Underlying conditions/smoking etc.
Behavioural data	Transportation data (public and private) Mobile phone data Social contact studies (POLYMOD)
Health care capacity	Hospital locations, beds; ICU beds GP offices and capacity (public and private)
Planning for data to be collected during an outbreak	
Situational awareness	Confirmed cases Syndromic surveillance Sale of over-the-counter drugs
Transmission	Outbreak investigations Serological surveys Whole genome sequencing
Severity	Number of severe cases Number of critical cases Number of deaths All-cause mortality Prescription drugs
Behavioural data	Mobile app questionnaire Mobile phone data Transportation data (public and private) Consumption data (internet vs. shops)

V. Overview of evaluation tools

The Urban Health Equity Assessment and Response Tool (Urban HEART):	Figure 5
Rapid Urban Health Security Assessment Tool (RUSHA):	Table 7

Figure 5
Overview with core indicators of the Urban Health Equity Assessment and Response Tool (Urban HEART) [254]

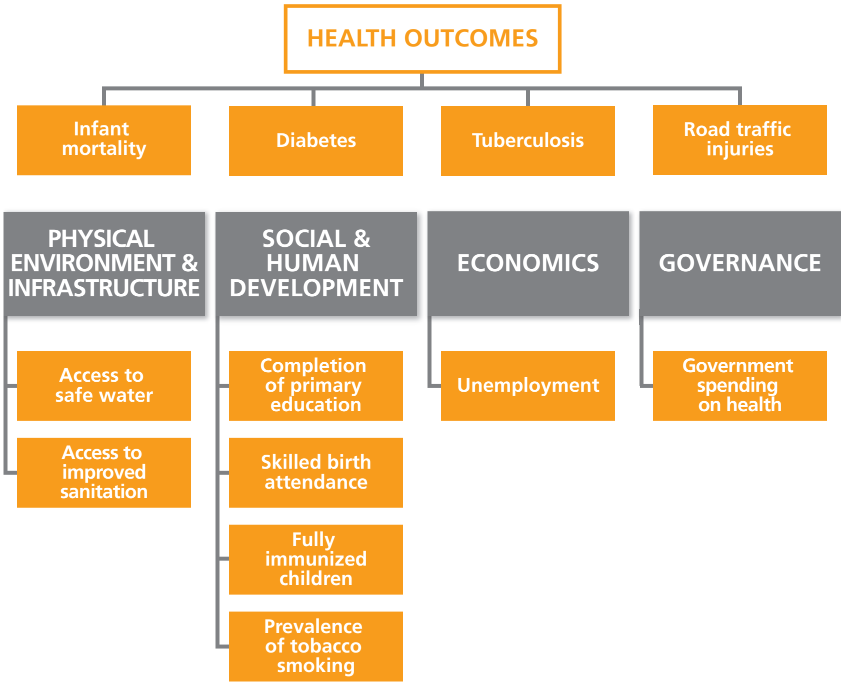

Table 7
Overview of capacities per area of the Rapid Urban Health Security Assessment Tool

Areas	Capacities
Prevent	Legislation, policy, and administrative frameworks Financing and resources Multi-sectoral coordination and communication Multi-hazard risk assessment Immunization
Detect	Laboratory systems Surveillance systems Reporting protocols, systems, and networks Human resources for health security
Respond	Municipal emergency preparedness Municipal emergency response and incident management systems Non-pharmaceutical interventions Health care delivery Medical counter-measures and health care personnel deployment Risk communication Human resource management Recovery and rehabilitation
Other	Points of entry Mass gathering events Specific hazard surveillance and response plans

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