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Urban Climate Health Risks and Resilience

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Abstract

The effects of climate change health impacts on urban healthcare systems and vulnerable populations are a researched topic with foundations on urban risk management, urban health methodologies, and sustainable urbanization. As climate change is a dynamic and transform-ative global issue the gap between adaptation and mitigation efforts and urban planning relies, among other things, on the limitations of previous studies of risk management structures tailored to the existing strategy to calculate the uncertainties and predict their influence on urban systems and subsystems. Moreover, Although, there is vast documentation on health and urbanization challenges facing climate change impacts, little is known about climate health risks affecting the megacities' urban poor and the available methodologies to cope with climate health risks in urban environments. Climate and health is a well-researched issue, it is also complex as the methodologies and strategic approach to minimize health risks of climate change are intrinsically contingent on risk methodologies and policy-making processes that are efficient with support of knowledge-based information. This paper emphasizes the need for strategic applications and frameworks on urban health risk management methods that identify potential opportunities, and then manage and take action to prevent adverse health effects. It also emphasizes the probability of events and their consequences, which are measurable both qualitatively and quantitatively.

Keywords: Climate Change, Health Risks, Urban Climate, Risk Health Management, Urban Resilience

1. Introduction

Human actions are changing the global environmental system. These actions have implications affecting our health as they depend on the stability of the environment, and the balanced functioning of the world's climate system [1, 2]. Presently, we are experiencing the impact of climate change and gradually densely populated urban areas, particularly in developing cou21ntries, will face aggravating existing development challenges, worsening the prevalence, intensity and persistence of poverty [3]. Nonetheless, there are several climate health risk factors affecting the urban poor population. These issues will compound existing vul-nerabilities, increase poverty levels, and affect the urban poor with more severity because these inhabitants live in vulnerable conditions such as crowded living situations, and lack of access to basic services, including health care and safe housing structures [4].

2. Materials and Methods

In pursuing these complex issues, research was conducted using the case study method to ex-plore climate change's health impacts on the urban poor in megacities. Case study methods allow us to identify gaps, and areas of urban systems' vulnerabilities and assess different ge-ographic locations and programs in the megacities under study with a moving-forward ap-proach for continual improvement. These methods were published in Marolla, presenting climate change risk assessments in London, Beijing, Mumbai, and Rio de Janeiro [5]. The climate change risk assessment form is not meant to be prescriptive but may be tailored to specific climate impacts. These frameworks may be used as a prior risk assessment, reviewing current ones for continual improvement of processes, in addition to supporting actions to manage risks.

The research looked at practical and theoretical cases, differentiated by geographic, demo-graphic, and socioeconomic factors. The literature referred to in this narrative review was found on Google Scholar, PubMed, and books related to climate, health, urban poor, and ur-banization by scholars. The literature search was performed using combinations of keywords including 'climate change', 'human health', 'health', 'urban poor', 'megacities', 'urbaniza-tion', urban climate risk management', and 'climate health risks. Only peer-reviewed, English language articles published between 2000 and 2024 were shortlisted in the literature search because between this time frame the published studies show a concise and strategic process of recognizing risks, identifying their causes and effects, and taking the relevant actions to mitigate them that align with emerging global risks such as climate change.

2.1. Climate Change Health Risks

A changing climate can alter the pattern of diseases, mortality, human settlements, food, wa-ter, and sanitation. Air quality will adversely affect health and safety and present a risk for all-cause mortality and specific diseases. Some of these specific outcomes are stroke, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer, pneumonia, and cataracts in household air pollution [5, 6]. These health outcomes translate into health risks exacerbated among those who are heat sensitive. The vulnerabilities of the urban poor will be intensified by heat fatalities due to poor air circulation in overcrowded, precarious households and lack of access to air conditioning [7]. Moreover, as changing patterns in temperature, precipitation, and other extreme events increase the geographic range of diseases, they may influence the transmission of many diseases, including water-related illnesses, such as diarrhea, and vector-borne infections, including malaria. Malnutrition is another factor that is highly considered as it has far-reaching effects on how food is produced and may have health impacts from increasing rates of malnutrition [8. 9]. Flooding affects roads, telecommunica-tion networks, and power supplies and housing communities, destroying essential infrastruc-ture that supports the urban system. Heavy rains will force stormwater discharge systems to empty waste and lead to a build-up of debris in outdoor drains, which often clogs the under-lying pipes.

Another issue is the rising sea levels impacting coastal megacities and their population, which consequently will result in the salination of freshwater supplies, loss of productive land, and a change in coastal dwelling mosquitoes' breeding [10-12]. The concentration and range of pollen is also affected by higher temperatures, exacerbating asthma-related health impacts [13]. A global increase in the distribution and incidence of infectious diseases is projected. The lifecycles of pathogens and the animals that carry and transmit them are influenced by these climatic changes that affect land use and land cover. Malaria and other vec-tor-transmitted diseases get most of the attention from climate-change scientists and health professionals. The intertwined between climate change and malaria is related to the tempera-ture and rainfall which are key parameters of climate change, with fluctuations in temperature influencing the spread of the disease by affecting its rate of transmission. The latitudinal, al-titudinal, seasonal, and inter-annual connection between climate change and disease, along with historical and experimental evidence, leads to the conclusion that climate, in addition to other causes, significantly influences infectious diseases in a nonlinear fashion [14, 15].

Climate change will alter the patterns and spread of malaria transmission. Rainfall affects malaria, acting not only on persistent bodies of water but also on the physical and biochemical characteristics of aquatic environments. Heavy rains and flooding are known to cause major malaria outbreaks in semiarid or arid lowlands; at the same time, spatial, and temporal variations in rainfall determine the nature and scale of malaria transmission in highland areas [16]. Furthermore, Chagas disease is one of the most significant climate-sensitive vector-borne diseases in South America, and it is spreading throughout the continent. The globalization of the disease through climate change as well as other factors, such as migration (it can be increased by climate change impacts in certain regions), blood transfusion, and so forth, is a concern for developed countries, and these aspects are modifying and accelerating the transmission rate and distribution of the disease [17, 18]. The relation between Chagas disease and temperature change has been studied almost since the beginning of the disease's parasitological, clinical, and epidemiological description. Direct impacts such as thermal stress, floods, and storms; and direct impacts such as borne-vector diseases, waterborne pathogens, water quality, air quality, and food availability and quality are concerns for urban populations.

The socio-economic situations of the urban residents as well as the environmental conditions of the city are important factors that amplify the impacts of climate change on the popula-tion's health [19].

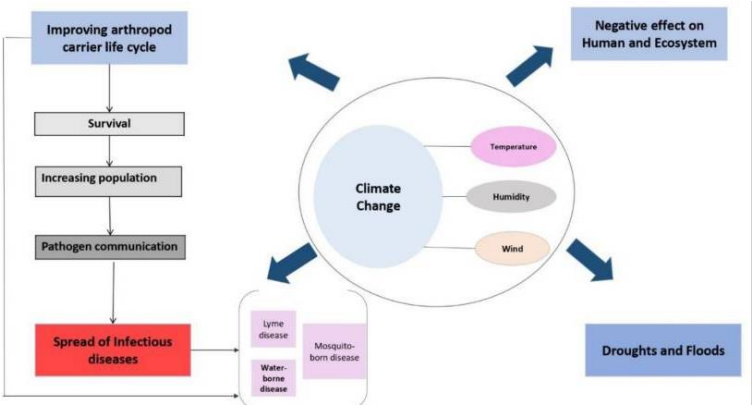

Figure 1: Climate Change on Vector-Borne Diseases and Spread of Infectious Diseases Alongside with Other Negative Impacts on Human's Health and Environment [20]

Climate change and rapid and unplanned urbanization create risk factors in the urban envi-ronment and population, for example, poor housing conditions and lack of health care service accessibility, that can lead to the proliferation of insect vector diseases and profoundly limit socio-economic status and development in countries with the highest infection rates, particu-larly in developing countries [21]. Another factor to assess the vulnerability and health risks of populations is the existing city's

adaptation and mitigation strategies and the viability of the institutions, technology in place, and risk management planning to be implemented when the city's leaders need to act upon the situation [22]. Although little work has happened to lessen climate change's impact on public health and its propagation into the urban ecosystem, the awareness of risk management has been emphasized considerably in the government and the private sector. The devastating consequences for densely populated urban areas of large-scale disasters present challenges to urban infrastructure, communication networks, supply chains, and public policy [23, 24]. Climate change impacts on health present a unique outline of risks that grow to be active threats because they extend their effects across global systems. These threats expand along the urban ecosystem resulting in health, environmental, social, or financial risks.

2.2. Health Impacts and Urbanization

According to the latest United Nations report between 2007 and 2050, the urban areas of the developing world are expected to absorb an additional 3.1 billion people while the overall population will grow by just 2.5 billion people [25]. Urbanization is dynamic and transforma-tive and in developing countries, unplanned expansion of housing projects exposes a greater number of urban residents to climate change health risks. The health impacts will depend on the geographic region, susceptibility of populations, socio-economic conditions throughout the different class levels of their society, and the capability of societies to adapt and mitigate the impacts [26]. Urban areas face rapid migration and population growth that demand basic services such as health care, availability of drinking water, and other resources. The urgency of developing an effective urban risk management framework that provides guidance and strategic planning to cope with climate risks and for maintaining and delivering essential ser-vices becomes urgent in today's climate uncertainties [27, 28]. Cities need to consider the issues of climate change and urban health by evaluating related risks to identify, plan, and improve feasible programs in their preparation and management processes of the system [29]. Susceptibility to climate change and its effects on health increases as the concentration of economic activity and population density worsens the health situation in the world's major cities. The impacts of climate change on health are magnified in urban populations [30]. The capacity of the urban poor to adapt is weak in comparison because of inadequate housing, poor nutrition, overcrowded living, and population displacement. Resources and information are scarce, and the urban poor cannot respond efficiently to take actions to mitigate climate change effects; this situation creates a gradual exposure to health risks. The poor population's vulnerability will be exacerbated by exposure to severe weather effects and lack of ability to adapt to climate change [31]. Rising sea levels make cities vulnerable to drastic environmental changes and exacerbate the economic risks faced by poor residents. Inland cities also have susceptibilities to climate change, including urban settlements on steep slopes in hazard-prone areas, and the heat island effects [32]. Sea-level rise and other coastal implications, such as changes in storm frequency, put populations at risk of climate change effects.

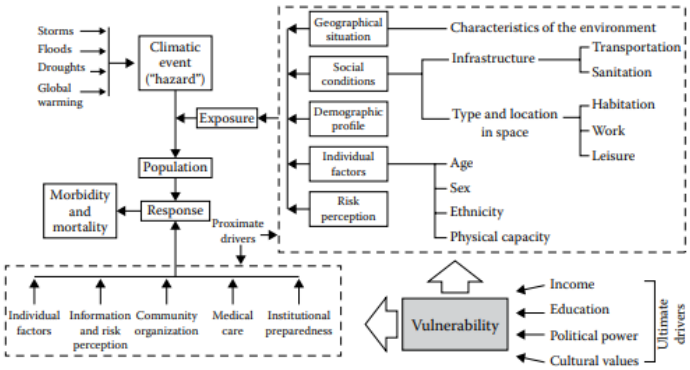

Figure 2: Vulnerability to Climate health impacts. (From Confalonieri, U. et al., 2009, Public Health Vulnerability to Climate Change in Brazil, Climate Research, 40(1), 175–186.) [33].

The rapid urbanization experienced in the 20th century and the expansion observed today have already created 20 coastal megacities. In contrast, in the 1990s there were a total of seven coastal megacities in Asia (excluding Japan) and two in South America [34]. The fra-gility of the sedimentary strata where the megacities are located is a concern that adds to cli-mate change impacts on urban populations. The repercussions of climate change on megacities are varied and require each city to have an independent assessment to mitigate and adapt to climate change [35]. Urbanization has implications, both positive and negative, for the in-habitants and the environment. These environments are in constant motion, mostly through construction and development but also through the destruction of urban elements. While for-mal development is a process with long planning periods and private and public partnerships, informal settlements seem to be subject to high dynamics, social, economic and/or environ-mental, in their ever-fragmentary urban form. Acute shocks and chronic stresses have reper-cussions and long-term impacts on human development. Population's vulnerabilities to severe shocks are closely related to poverty and the detrimental effects are exacerbated by these impacts [36].

Physical Effects of Climate Change Identified by Cities

Effect	% of Respondents	Top 3 Sectors Affected
Temperature increase/heat waves	85%	Human health, energy, water
More frequent/intense rainfall	79%	Buildings, water, transport
Sea-level rise	67%	Buildings, waste, transport
Storms and floods	58%	Human health, buildings, water
Drought	42%	Water, human health, energy

Table 1: Climate Effects and Urban Settings Affected by Impacts [37, 38].

Table 1 shows the physical effects of climate where most of the cities' responses are temper-ature increases impacting health, water, and energy. Climate has always affected our health, and the growing acknowledgment of climate change and its consequences on health is build-ing up consensus on addressing and coping with climate health risks. Four factors influence the outcome of climatic events on health:

- Population growth,
- Urbanization,
- Land use reduction,
- and freshwater resources [34].

These factors affect the population's health, but the impacts are not felt equally across the different demographics and socio-economic levels [39]. Because of the elements affecting the urban population's health from climate change, the poorest people in the world will suffer the worst consequences. Concerning the socio-economic status of the population, the rural popu-lation's migration to major cities creates a steady growth in urban settlements with high-density, human-created structures that are unsafe, exacerbating their exist-ing health-related problems. As the climate changes, health issues faced by the urban poor will create stressors for the healthcare system and directly and indirectly weaken the urban system [40, 41]. Climate change will increase the exposure of the urban poor to malnutrition, disease, and other health risks due to reduced food security; compromised drinking water; and water-rodent-borne diseases associated with floods, droughts, and the correlation of high temperatures and heat stress [42]. Economic and social inequality will be affected and will gradually increase, affecting future generations' health and maximizing their risk factors [43-45].

3. Climate, Health, and the Urban Poor

Several publications highlighted the links between climate change, the urban poor's vulnera-bilities, and health risks, particularly in low and middle-income countries [46]. The urban poor are susceptible to direct health impacts because they often inhabit the least desirable land with precarious housing and flood zones, which makes them vulnerable to severe climate risks. Frequent flooding also tends to cause an increase in the insect population, which causes an increase in vector-borne diseases like malaria. Moreover, extreme rainfall variability impacts crops with an effect on food prices, affecting the poor the most [47, 48]. Today, economic and environmental systems are at risk of collapsing, and these challenges dissuade any initiatives to develop and implement concise climate change resilience frameworks. The economic diffi-culties experienced globally are exhausting financial resources as the impact of climate change is more evident with rising temperatures and more frequent extreme weather events. Structural changes and strategic investments in cities' operational infrastructure are crucial to calling attention to the perils of climate change for the urban poor's health and well-being [49, 50].

The impacts of climate change on health are a major threat recognized by the Intergovernmental Panel on Climate Change's Sixth Assessment Report [51]. The changing climate is already affecting cities, and the effects will exacerbate as megacities across the world are facing climate change impacts affecting communities and urban infrastructure. Cities are motionless and vulnerable to the impacts of severe weather events and climate change [52, 53]. As the occurrence of extreme weather events increases year after year, the acute vulnerability of urban populations, especially children, the elderly, and the poor, will be exacerbated by climate change. The interruption of critical supplies to urban populations is a serious threat that is aggravated by the megacities' dependency on food imports [54]. Currently, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050 [55].

The remarkable growth of megacities during the past century has motivated a continuing series of scientific inquiries, as many of them are in developing countries, and their high population density and dependence on complex infrastructure and networks make them particularly vul-nerable to the impacts of climate change events. The transformative and dynamic operations of megacities and the risks of climate change are building an urgent need to develop methodol-ogies and adaptation programs for their evolving environments [56]. Urban design and planning can make a significant difference to the health outcomes of urban dwellers [57]. Henceforth, the urban system developing adaptation programs must include public health system advocacy for policy, forecasting of climate health risks, and urban agendas aimed at the urban population's vulnerability to severe weather events and climate change. In this context, health systems should be prepared for climate-related disasters, which are expected to exacerbate the frequency and severity of existing diseases [58]. In this case, megacities will experience magnified effects due primarily to their high population densities.

Key Climate Hazards and Potential Impacts

Key Climate Hazards	Potential Impacts
More frequent and extreme high temperatures and humidity	Increased risk of heat-related ailments particularly outdoors, higher cooling costs, decreased utility reliability, damage to buildings
More frequent and intense droughts; seasonal shifts in water cycle	Reduced water availability, higher water costs, saltwater intrusion, groundwater changes
More intense precipitation events	More frequent flooding of low-lying indoor and outdoor areas
Sea-level rise	Loss of usable land, inundation of coastal ecosystems
More frequent and intense coastal flood	Coastal erosion, safety implications for events in surrounding communities

Table 2: Climate Hazards and Potential Impacts Faced by Megacities. National Aeronautics and Space Administration (NASA), 2014, 2014 Climate Risk Management Plan: Managing Climate Risks and Adapting to a Changing Climate [59].

Megacities have certain characteristics that make them more susceptible to climatic health risks, such as impermeability of hard surfaces, urban heat-island, and increased pressure on local ecosystems for housing developments, network infrastructures, and waste, air pollution, and urban slums in developing countries [60]. These factors affect the entire urban system and present obstacles to the megacities' public health systems to promote physical and mental health and prevent disease, injury, and disability [61]. Managerial responsibility for climate health risks in cities is fundamental to maintaining a balanced socioeconomic and environmental equity and achieving good health for residents.

Higher temperatures put pressing stressors on cities' operations and a proactive approach to coping with health risks. These shocks result in a broad spectrum of interdependent effects on people, infrastructure, and urban systems. The economic disadvantage of the urban poor also influences their vulnerability. Low-income populations are more susceptible to the impacts of climate change. Their socio-economic status, lack of air conditioning, land use hazards, and precarious housing structures, in addition to a poorly prepared city response and inadequate health care system, exacerbate their existing health conditions [63].

3.1 Megacities case study

Marolla (2016) outlines a comprehensive assessment of megacities' case studies in developed and developing countries, addressing climate health risks. Some of the findings throughout the cases are the ill-prepared adaptation and mitigation programs in response to rapid-onset dis-asters. Most of the climate change and disaster management strategies remain largely ad hoc, reactive, and working in silos, making them inefficient to cope with climatic events and dis-asters with the urgency required, leading to untimely actions and gaps in the decision-making process to minimize climate risks. The framework developed offers a systematic and stand-ardized means to assess and monitor risks to identify and deter detrimental impacts and find opportunities for adaptation and resilience of urban systems [5].

Megacity	Level of Confidence	Level of Likelihood	Level of Consequence	Climate Health-Related Risks Projected Impact
London	Medium–high confidence (>70%)	Likely to occur sometimes (occurred infrequently).	Major and widespread decline in services and quality of life within the community. Infrastructure and communication network severely damaged. Distribution of foods and other basic services paralyzed and can lead to a chaotic state.	Summer overheating potentially contributing to heat-related health problems. Premature deaths due to hotter summers are projected to increase and quickly overwhelmed public health and social care services. Increases in the frequency of flooding affecting people's homes and vulnerable groups (e.g., those affected by poverty, older people, people in poor health, and those with disabilities). Climate change implications affect public health, the continuity of health and social care services both within the National Health System and beyond, the resilience of local emergency services, and the most socially vulnerable (Walker, 2014).
Mumbai	Very high confidence (>90%)	Likely to occur many times (occurred frequently). It will be continuously experienced unless action is taken to change events.	Severe and widespread decline in services and quality of life within the community. Severe, semipermanent, and widespread loss of environmental amenity and likelihood of irrecoverable environmental damage. The region would be seen as very unattractive, moribund, and unable to support its community.	Death and injury due to flooding; reduced availability of fresh water due to saltwater intrusion. Contamination of water supply through pollutants from submerged waste dumps; change in the distribution of disease-spreading insects. Health effect on the nutrition due to a loss in agriculture land and changes in fish catch; and health impacts associated with population displacement (Patil and Deepa, 2007).

(*Continued*)

Table 3: Megacities Under Study: Risk Management Assessment [5].

Megacity	Total Population (millions)[a]	Adaptive Capacity and Risk Management Strategy in Place	Health Impacts	Critical Services Interruption	Likelihood Score	Consequence Score
Beijing	10.85	China and in this case Beijing are making big efforts toward mitigation and adaptation strategies with concrete actions. Conversely, actions to offset climate change have initially been slow and uncoordinated. High population density and intensified economic activities are exacerbating environmental issues and climatic impacts on public health. Furthermore, researchers emphasized that the lack of funding for climate adaptation, and the overall absence of a national plan for climate adaptation, has resulted in uncoordinated actions at local government level.	Severe health crisis (incapacity beyond 3 months).	Prolonged suspension of work; additional resources required; performance affected.	3	4
Rio de Janeiro	11.62	An adaption strategy is in place and the megacity is actively seeking ways to develop and improve the existing strategies. However, the poor living in informal settlements (favelas) are often driven to reside in dangerous locations due to their inability to pay rent elsewhere, and in order to make a living. Wisner et al. (2003) argue that if residing in a hillside "slum" will lead to economic opportunities; people will choose to live there almost regardless of the disaster risk. Therefore, economic well-being and resilience must be developed conjunctively. Poor urban planning and governance are still a challenge and the urban poor will suffer the most, stressing the habitat and health systems to a collapse.	Severe health crisis (incapacity beyond 3 months).	Prolonged suspension of work; additional resources required; performance affected.	4	4

Table 4: Megacities Under Study: Adaptive Capacity [5].

Adaptive capacity can be considered as an analog of disaster management preparation and adaptation. Therefore, assessing the extent of capacity for urban systems to manage climate risks across systems and sub-systems supports a concise approach to identifying impacts and determining actions. As shown in Table 4, the Beijing and Rio de Janeiro case study qualitatively assesses the risks of each of the identified health impacts to determine the prioritization to deter and/or minimize health risks in densely populated urban areas. London and Mumbai case studies represent the level of likelihood and consequence of health impacts and the degree of climate health-related risks for each megacity. The measurement of risk is assessed by risk management frameworks and risk matrix assessment (see Table 4.5). Moreover, the framework assessment supports a methodology to quantify the risk level to consider the future conse-quences of the impact. This method requires a proactive approach and continual improvement and can be tailored to an existing adaptation program to consider the potential future outcomes [64- 66].

Consequence Score		Population Affected	Reasons for Categorization
5	Catastrophic	>1,000,000	• High death toll • Significant asset destruction or other financial loss • Catastrophic long-term environmental/public health harm • Total cessation of operations
4	Major	50,000–1,000,000	• Multiple serious injuries and death • Acquired illness resulting in hospitalization for more than four weeks • Loss of asset or other financial loss • Significant long-term environmental harm
3	Moderate	500–50,000	• Serious injury or illness resulting in hospitalization for 3 days to 4 weeks • Loss of asset or other financial loss greater than $50,000 up to $1 million • Significant release of pollutants with midterm recovery • Total cessation of operations for less than 2 days
2	Minor	50–500	• Injury or illness resulting in time away from workplace or less than 3 days in hospital • Loss of asset or other financial loss from $5,000 to $50,000 • Minor transient environmental harm • Minor disruption to services
1	Negligible	<50	• No injuries or minor injuries requiring first aid • Minor loss of asset or other financial loss of less than $5,000 • Brief pollution but no environmental harm • No disruption to service

Table 5: Risk Management Consequence Score [5].

Previous research demonstrates there is no consensus on frameworks for assessment of complex climate change risks [67]. Based on the guidelines and risk assessments previously discussed, we recommend the development and implementation of a risk management framework that comprises a comprehensive understanding of the urban system's vulnerabilities and level of resilience. Managing climate risks requires a systematic process enabling risk management tools to assist the decision-making process and to deliver the best options to categorize a better understanding of how to manage potential outcomes. The following steps support the risk management framework to anticipate risks and identify threats to the urban systems and sub-systems functions and operations (table 5).

• Develop evidence-based protocols and guidance as tools to appropriately respond to climatic events and public health risks
• Institute concrete, defined procedures for identifying sources of key information for rapid risk assessment and identify the efficient use of those procedures
• Identify and maintain lists of named individual experts
• Ensure well-trained personnel [5].

3.2 The Nexus between Climate, Health, and Risk Management

Risk management serves to identify potential opportunities, assess, and develop concise actions to prevent adverse effects. It also emphasizes the probability of events and their consequences, which are measurable both qualitatively and quantitatively. These characterizations also apply to climate change, health risks and urban planning, and disaster events [68, 69]. Risk management frameworks address the full spectrum of challenges in areas such as planning, strategy, operations, finance, and governance with an emphasis on minimizing, transferring, and adapting to risks. In the context of urban health resilience, it supports the identification of the likelihoods and opportunities of the city's different departments and functions as well as the potential impacts of parallel threats and events.

The systematic analysis and management of health risks through a well-planned strategic ap-proach to integrating recovery measures, preventing and mitigating risks, and identifying a population's vulnerabilities are significant challenges for urban areas to lessen climate health risks. As population growth in urban areas keeps increasing exponentially, city leaders must assess the opportunities and concerns in both internal and external environments. After that, the focus is to apply the best available scientific data and resources to plan and implement strategies and programs so that they can achieve medium- and long-term goals. Oppenheimer [70] presented three questions related to the cities' strategic approach to climate risks:

• Where are we? • Where do we want to go?

• How do we get there? In this context, the management and planning for the health sector and the megacities' leadership answer three fundamental questions:

• How do we identify climate change hazards and their locations? Hazards can be identified using global and regional scenarios developed by climate scientists. It is noteworthy that climate scientists still face uncertainty, even though this is a known science and fairly investigated [71].

Many efforts are being developed to reduce these uncertainties and support healthcare systems, city policies, plans, and programs. The following is a series of questions to help identify po-tential risks:

• How do we mitigate those hazards? To mitigate health hazards, cities should identify, plan, implement, and monitor strategies that can reduce the emission of greenhouse gases. Unfortunately, the reduction of emissions in one city does not mean that the effects of climate change will be reduced by the same proportion. Managers should always look to adopt mitigation strategies that consider co-benefits for the health of city dwellers, for example, transportation strategies.

• How do we prepare the city to prevent or reduce the impacts considering those hazards? The term adaptation refers to the process of designing, implementing, monitoring, and evaluating strategies, policies, and measures intended to reduce climate change impacts and to take ad-vantage of opportunities [72].

These measures are described in the following key components of the management system plan:

➢ Policy
➢ People with defined responsibilities
➢ Management processes relating to
• Policy
• Planning
• Implementation and operation
• Performance assessment
• Management review
• Improvement
• Documentation providing auditable evidence [73].

In public health, the analogous term is prevention. Adaptation generally entails understanding system vulnerability, and planning and managing systems in response to an anticipated change [74]. Vulnerability has many different definitions. The most common, according to Adger [71], is that vulnerability consists of exposure and sensitivity to disturbances or external tensions and the ability to adapt. Adaptation strategies adopted by different sectors may reduce impacts on the healthcare system. It is noteworthy that effectively responding to climate change is a pro-cess, not a one-time assessment of risks and likely effective interventions [75, 76, 77]. It is necessary to periodically assess the adequacy of the results on the way to achieving the goals set. Climate risk management practices tailored to adaptation build pathways to reduce risks by managing hazards and potential effects that can exacerbate the vulnerability of communities and landscapes and increase their resilience [78]. Climate resilience programs integrate a climate projection approach to screen for climate change and the overall assessment of potential risks. Table 6 shows a step-by-step analysis of evaluating adaptation strategies to enhance climate resilience in urban areas.

Access Project Exposure and Criticality	Determine Performance Indicators
Assess Climate Vulnerabilities	Establish Climate Baselines and Projections
Develop and Evaluate Strategies	Analyze Project Performance
Recommend a Course of Action	Assess Vulnerability

Table 6: Climate Resilience of Urban Health Care Systems Frameworks [79].

As climate change exacerbates the healthcare systems' vulnerabilities in care and treatment for individuals and communities, it is primordial to focus on increasing access to healthcare ser-vices, and the efficient implementation of the urban care system strategy is measured through various health performance indicators, including the number of children immunized, the per-centage of vulnerable populations exposed to climate health risks, and the number of people receiving health, nutrition and population services in comparison to the overall population [80]. Moreover, the assessment of health care facilities capable to providing services requires additional indicators such as the percentage of healthcare facilities that provides a minimum standard of quality, meet the community's needs for a quality health service, and accessibility and time for treatment [81, 82]. It is critical to run a PDCA (plan-do-check-act) cycle.

The PDCA framework is an iterative four-step management method used for the control and continual improvement of processes and programs. It can also be used to understand the weaknesses of their measures and make necessary improvements to the process, which is es-sential to make progress and identify gaps throughout the implementation process [83].

Figure 3: PDCA Cycle [84]

Figure 3 shows a step-by-step process model that can be used to improve quality management in healthcare. The PDCA cycle assessment should follow these steps:

• Plan: Based on the analysis/evaluation results, it is requested to develop preservation, and utilization plans to stipulate how the targeted area should be preserved and used, and who takes what action in which time frame.

• Do: Following this stage, actions should be taken for preservation activities and sustainable use based on these preservation and utilization plans.

• Check: To understand accurately how many wild animals and plants live and grow in which location inside the targeted area.

• Act: Then, it is essential to carry out analysis and evaluation based on this study and moni-toring data and to understand the status and the time-related changes [85].

Risk health assessment is one of the key stages in the risk management process and involves the identification, assessment, and analysis of risk stressors and detrimental events and setting priorities in risk management in many fields, including health care management [49].
The following are considerations to evaluate a healthcare systems management plan for ad-aptation:

• Historical—Identifying severe weather events within the urban area from records

• Geographic—Level of impact considering the geographical location and vulnerabilities to climate change and disasters

• Structural—Factors affecting the functional ability and management of healthcare operations in urban settings

• Human factors—Considerations to minimizing human-caused emergencies that can result from inadequate training, supervision, or negligence [86, 87].

Impact			
	High impact; outlier result with little or no evidence that conditions are possible	High impact; many results within this range of values	High impact; many modeled results within this range of values, evidence from historical records
	Medium impact; outlier result with little or no evidence that conditions are possible	Medium impact; many results within this range of values	Medium impact; many modeled results within this range of values, evidence from historical records
	Low impact; outlier result with little or no evidence that conditions are possible	Low impact; many results within this range of values	Low impact; many modeled results within this range of values, evidence from historical records
		Likelihood	

Table 7: Risk Matrix Assessments [88].

Table 7 presents an illustrative example of a risk matrix assessing likelihoods and impacts (consequences) where higher impacts and higher likelihoods lead to higher levels of risk [88, 90]. When assessing the climate resilience and adaptation program, the identification of vul-nerabilities through the implementation phase is crucial to highlight those at higher levels of risk that should advance to the next step of the framework to examine whether the project's resilience is effective and needs improvement.

The risk is the likelihood of harm occurring, together with an indication of how serious that harm could be.

Risk rating = Likelihood score × Consequence score

As described earlier, the potential projected health impact can be evaluated through a qualita-tive and quantitative risk rank analysis and assist in mitigation and adaptation measures. The framework applies to public health events that require an immediate response and are poten-tially caused by more than one hazard. It also classifies each potential health effect (very low, low, moderate, and high risk) and they are ranked in order of highest concern by health im-pact [91, 92].

The Consequence Score

	Likelihood				
Consequence	**Rare (1)**	**Unlikely (2)**	**Possible (3)**	**Likely (4)**	**Almost Certain (5)**
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Negligible (1)	1	2	3	4	5

Table 8: The Consequence Score [92].

The Risk Score

Risk Score	Risk	Description
1	Very low risk	Local investigation where appropriate.
2	Low risk	Contributory factor(s) to be identified; discuss with city's management the need for any changes in current and future adaptation strategy, practice, policies, procedures, education, or training.
3	Moderate risk	Report incident immediately to manager/head of department. Identify contributory factors. Discuss at the city's governance meeting the action plans to be implemented. Assess existing strategies and monitor centrally.
4	High risk	Report incident immediately to manager/head of department. Inform risk manager. Full investigation to be undertaken including interview with staff and identification of root causes. Action plans to be monitored and reported to central government. Put in place a continuity management system to operate under catastrophic levels of disruption.

Table 9: Assessing the Risks Score [92].

The healthcare risk assessment team should decide on a series of initiatives related to their development of a strategy to address climate change's impacts on public health. Therefore, leaders must define the scope of the assessment and ensure that all the relevant information is collected. The World Health Organization (WHO) developed a manual to guide rapid risk assessment of acute public health risks from any type of hazard in response to requests from member states. It aims at reducing or preventing disease in affected populations and minimizes negative social and economic consequences that exacerbate the population vulnerabilities [93].
Additional benefits include:

- Defensible decision-making
- Implementation of appropriate and timely control measures
- More effective operational communication
- More effective risk communication
- Improved preparedness [93].

As urban dwellers and local governments face more intense climate impacts and are forced to cope with rising incidents of disasters, risk assessments have become an important part of the strategy to reduce risks, loss, and damage. Using risk frameworks is an important tool to create a stronger, more resilient community. This methodology determines the nature and extent of risks by analyzing potential hazards and evaluating existing conditions of vulnerability. This answers the fundamental question: What would happen if a health hazard event occurred in my city? [94].

Assessing risk based solely on past events does not provide a comprehensive current state of risks faced by the megacity. Urbanization and rapid population growth are creating high-risk-prone urban areas. Risk management and strategic planning help to improve under-standing of climate change patterns and their effects on human health and potential outcomes. These changes can now be better understood and scenarios for the future can be developed, allowing policymakers to identify adequate strategies for response and adaptation [95].

4. Risk management, climate resilience, and healthcare system adaptation

Risk management frameworks can be embedded into a healthcare system adaptation based on a structured approach to managing risks. Therefore, risk management frameworks can support the identification of exposure and vulnerability of the health care system's risks and provide risk-informed decision-making by using risk acceptability and prioritization [96].

Table 10 describes the relationship between risk management and healthcare sys-tems adaptation and resilience:

1. Assesses cost-effectiveness of healthcare facility adaptation to climate change by quantifying the benefits and costs of implementing new or improved measures to address risks
2. Capitalizes on opportunities to learn and increase awareness about climate change, its impacts, and co-benefits of sustainable practices
3. Builds and enhances climate change knowledge capacity as it relates to hazards of concern for the healthcare facility
4. Ensures adequate leadership and allocation of staff roles and responsibilities in efforts to increase resiliency
5. Builds climate change adaptive capacity through partnerships and by securing mutual support

Table 10: Climate Change Resiliency Indicators for Health Care Facilities [97].

Resilience is the capacity of a system to deter, absorb, and minimize disturbance and reor-ganize to retain "normal functions" after the shocks [98]. A poorly prepared healthcare system compromises access to and delivery of care through facility damage or closure, network and power disruptions, hospital evacuations, and improper delivery of supplies and patient care. The nexus between risk management and health care systems has a foundation in climate-risk assessments impacting infrastructure, networks, and patients. The strategic approach to achieving resilient healthcare systems is to accelerate regulatory constraints, facilitated by access to knowledge-based information and scientific evaluation of different risk scenarios.

4.1 Rapid Risk Assessment for Healthcare

Risk assessment is a crucial step in managing public health risks. Rapid risk assessment is a systematic process that enables a risk management process during an acute public health event and assists decision-making and operations to improve processes and deliver efficiency while making the best use of the limited time available [99]. Strategic planning and preparation to identify threats ensure that potential risks are categorized for a better understanding of how to address, assess, and manage outcomes.

There are important steps to take to be well-prepared and to anticipate any risk that threatens a megacity's functionality of operation and public health:

• Develop evidence-based protocols and guidance as tools to appropriately respond to climatic events and public health risks
• Institute concrete, defined procedures for identifying sources of key information for rapid risk assessment and identify the efficient use of those procedures
• Identify and maintain lists of named individual experts
• Ensure well-trained personnel [100].

The level and severity of climate change's impact on human health depends on many factors that would transpire through pathways of varying complexity, scale, and directness, and with different timing. The actual health impacts, however, are not uniform across countries and regions [101]. Taking into consideration the changeable nature of the climatic system and its impacts, during a catastrophic event, a rapid, concise, and efficient response is crucial to save lives and minimize health risks and damage to the megacity's infrastructure. First responders and well-trained personnel must assess risks promptly and make decisions based on priorities to reduce hazards. It is important to have a prior evaluation of science-based risk assessments for an accurate identification of health impacts to address the potential adverse effects on human health and make projections of the extent and duration of these effects. The rapid risk assessment tool will be understandable and applicable to the emergency management com-munity and would be an asset during any climate disaster [102, 103].

5. Discussion

There has been considerable thought and investigation about the health implications of climate change on urban dwellers. This paper identified and explored key links between climate change, urbanization, and the urban poor's health risks, and the results affirm a correlation between observed climate change impacts and the prevailing health conditions of the urban poor. Moving forward, there is ample evidence to signal both direct and indirect linkages between climate-induced weather events and the prevalence of diseases, increasing the risk of deaths, communicable and non-communicable diseases, as well as the emergence of novel diseases. A robust risk management assessment, continuity management systems adaptation, and decision-making under deep uncertainties with unknown outcomes are recommended.

6. Conclusion

The study, ultimately, indicated that analyzing and characterizing uncertainty using likelihood and consequence can be a very efficient approach for the selection and prioritization of pre-ferred adaptation policies to reduce future climate-related health risks and succeeds in demonstrating the nexus of climate change, natural disasters, health, and urbanization and the urgent need of a risk management strategy for the healthcare sector in addressing and mini-mizing climate health risks in urban areas affecting the most vulnerable urban population.

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