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Runming Yao *Editor*

Resilient Urban Environments

Planning for Livable Cities

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Professor Runming Yao contributes the chapter Outdoor Thermal Comfort and Heat Exposure Risks with Xizhen Huang, Tiantian Xu, and Yuening Zhu, and contributes the chapter Modelling Urban Microclimates with Wenbo Wang.

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Foreword by Prof. C. Alan Short

It is a great pleasure to be invited to write the foreword for this epic scaled, thoroughly interdisciplinary assault on the problem of adapting and remaking cities across all climate types to become benign and health-giving. This is an immense challenge which requires the intense and meaningful collaboration of very many disciplines and professions, some surprising and apparently peripheral but as the following twenty chapters demonstrate, all are indispensable. Here are contributions from urban designers, architects, social scientists, social anthropologists, academics in environmental and more broadly in public health, environmental engineers, air quality scientists, energy physicists, computational modelers, acousticians, hydrologists, earth scientists, specialists in respiratory disease and air quality, all at the top of their professions across some of the world's most prestigious institutions. One must commend Professor Yao for her indefatigable wrangling of such a broad list of authors in the pursuit of excellent contributions. The book is burgeoning with content.

The fact is that 'cities', the dense 'downtowns' so beloved of the *flaneurs* and 'architectural philosophers' reacting against the post-war planning mantra of land use zoning and atomized city centers robbed of spontaneous life, can turn nasty. Increasing density through policy, opportunism or the self-replicating phenomenon of informal settlement through a regionally changing climate amplified by the self-generation of localized heat islands will harm the very old, the very young, vulnerable and disadvantaged. As I write this the President of France is promoting UNESCO recognition of the zinc-covered mansard roofs of Paris beneath which so many died in the 2003 heatwave, the decidedly non-interdisciplinary collision of historical geography with the physics of climate change, exactly what Prof. Yao sets out to avoid with this carefully edited volume.

I must echo Prof. Yao's thanks to China's Ministry of Science and Technology which has supported the National Centre for Sustainable Development in Buildings and Built Environment in its pursuit of knowledge and understanding of these extraordinarily complex problems within a truly global interdisciplinary context.

May 2023

Prof. C. Alan Short
MA, Dip.Arch., Ph.D., Litt.D. (Cantab)
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Foreword by Prof. Baizhan Li

I am much honored to be invited to write a foreword for this book *Sustainable and Resilient Urban Environments—Planning for Livable Cities.* I, as Prof. Runming Yao's colleague at the National Centre for International Research on Low-carbon and Green Buildings, am very proud of such delicate and meaningful work. I witnessed Prof Yao's tireless work on the proposal, structuring and forming the author team and her enormous communications and discussions with her team authors over the past couple of years. The book was completed and to be on the shelf soon after Prof. Yao and her team's hard work. I would like to take this opportunity to congratulate her and all chapter authors.

This is truly a production of international and multidisciplinary teamwork. The authors include urban planners, environmental scientists, social scientists, health scientists, building designers and environmental engineers from academia and practice in the UK, Europe, India, Japan and China.

The book sets out a clear aim and focused themes that help readers to be aware of the impact of climate change on health and well-being and understand modeling technologies. The book focuses on the heat, air, noise, water and flood-related urban environments. The evidence shows that advanced modeling technologies play a pivotal role in providing evidence-based support to environmental interventions. Urban green infrastructure contributes to supporting biodiversity, urban ecosystem, carbon sequestration, Urban Heat Island mitigation and flood protection so as to enhance urban resilience.

Climate change is caused by the excessive use of fossil fuels. The deployment of renewable energy particularly in cities is challenging but it is a very trendy topic. Low-carbon city is one of the important elements of a resilient city. Policies play an essential role in climate change mitigation strategies. Case studies for achieving United Nations Sustainable Development Goals particularly demonstrate the successful stories in transforming resilient cities and regions.

I am confident this is a very timely and useful reference book for readers who are willing to commit to a resilient city development career. The book is particularly suitable for people including researchers, students and practitioners, who engage in the field of urban resilience study.

December 2023

Prof. Baizhan Li
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Preface

The urban environment is a human-made setting to accommodate human activities. Global urbanization accelerated the adverse climate impact. Cities' urban microclimates accordingly are changing. Extreme weather events such as heatwaves and flooding occur frequently, and air pollution, heat stress and noise significantly affect people's living quality and become a threat to vulnerable groups of people. It is important to take steps to ensure a city is capable of delivering a cleaner and greener city through urban environmental interventions to make cities more sustainable and resilient.

The book *Resilient Urban Environments* aims to provide evidence of the impact of climate change and urbanization on cities' urban environments, thus on human health and well-being. It introduces principles and methods for the improvement of the resilience of a city to extreme weather and long-term climatic changes through case studies. The book focuses on the following three themes:

(1) The urban environment and its impact on human health and well-being.
(2) The analysis of adaptation and mitigation measures through modeling technologies.
(3) Cases studies of the implementation of the concept of sustainability and resilience in cities.

In summary, the book *Resilient Urban Environments* is the collective production of the authors from inter-disciplines of urban planners, social and health scientists and building and urban engineers, from academia and professional practitioners. We hope readers will benefit from gaining knowledge in creating and assessing sustainable and resilient urban environments in the context of improving living environments, thus benefiting human health and well-being. We hope the case studies in mitigation and adaptation of climate change impact will help students, academics and practitioners to be useful in their learning and teaching and practicing in the real world. I would like to thank all chapter authors for their contributions. I would like to thank the financial support from the Chinese Ministry of Science and Technology of the People's Republic of China for the International Collaboration Programme for the project titled 'Low carbon resilient cities and built environment'. I would

like to thank the administrative support from the National Centre for International Research—Sustainable Development in Buildings and Built Environment (SuDBE) based at Chongqing University, China.

Chongqing, China Runming Yao
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June 2023

Contents

Editor and Contributors

About the Editor

Prof. Runming Yao [Ph.D., M.Sc., B.Eng., C.Eng. FCIBSE, FRSA, FCIOB, FHEA, MASHRAE] is currently Global Expert Professor, Lead Academic of Design and Management of Sustainable Built Environments at Chongqing University and Professor of the Sustainable Built Environment at the University of Reading, at the School of the Built Environment, University of Reading. She is Fellow of the Chartered Institution of Building Services Engineers (FCIBSE), Member of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Fellow of the Chartered Institute of Building (FCIOB) and Fellow of Higher Academy (FHEA). She has been invited as Visiting Fellow of Clare Hall at the University of Cambridge. She has broad research interests in the sustainable built environment with a focus on energy efficiency and the environmental quality in buildings and urban environments. She has successfully led and completed numerous research projects funded by the UK, EU and China. The most recent one is the largest Chinese national R&D project on the solutions for heating and cooling of buildings in the Yangtze River region (125 million Yuan). She published numerous refereed journal articles in the areas of thermal comfort and well-being, building performance assessment, urban environment, energy modeling and energy systems and management. She has been frequently invited to present her research at conferences, seminars and lectures internationally. She has been International Reviewer for numerous research funding bodies and served as International Assessment Panelist for major research projects internationally. She is Co-editor-in-Chief of the *Journal of Building Engineering (JoBE).*

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Introduction

Runming Yao

Abstract This introductory chapter sets the scene for the book, providing an overview of sustainability and resilience in the urban environment. It illustrates the impact of climate change on the living environment, thus affecting people's health and well-being. Interventions to mitigate the impact through instruments of policy and technical solutions are provided. Computer modelling and simulations provide tools for scenario analysis to assist risk forecasting and decision-making of mitigation strategies. Case studies provide examples of sustainable and resilient urban design and policy implementation which are hoped to be useful to the readers.

Keywords Sustainability · Resilience · Health and well-being · Heat stress · Modelling · Air quality · Noise · Biodiversity · Green infrastructure · Flood · Water · Policy

1 Background

Nowadays, more than half of the population is living in cities, and it is estimated that the number will reach 60% by 2030 and further increase to 68% by 2050 (UN 2015). Citizens' daily activities in a city are relying on living environment conditions and resources like pleasant temperatures, clean air, clean water, flood resilience, acceptable acoustic environment, sufficient energy supplies, affordable living supplies and so on (IPCC 2018). Those elements are fundamental for providing a healthy environment for people to live in and maintaining city sustainability and resilience.

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Temperature

Climate change increases the likelihood of heatwave events, posing great threats to human health as well as resulting in increased mortality and human thermal discomfort. Extreme temperature events have been classified as one of the most dangerous global disasters (WMO 2021). Between 1998 and 2017 more than 166,000 people died due to extreme temperatures, and especially in 2003 over 70,000 people were killed in heatwaves in Europe (CRED and UNISDR 2018). In the UK, heatwaves, in June and August 2020, caused more than 2000 deaths (PHE 2020). Heatwaves would make the Urban Heat Island (UHI) intensity substantial, bringing heat-related health issues for city dwellers worldwide (Macintyre et al. 2018; Iping et al. 2019; He et al. 2022).

Heat has direct and indirect impacts on health issues (Fig. 1). Excessive heat can directly cause dehydration and even the development of emergency hospitalizations and require immediate management, such as heat stroke, heat exhaustion and heat syncope (WMO and WHO 2015). Indirectly, it can alter human behaviours, increase the transmission of diseases, disrupt critical infrastructure and so on. Thus establishment of the protection in addressing the above issues is very necessary, as does increasing the resilience of the city as well as protecting citizen health.

Air

Air pollution is the presence of toxic chemicals or compounds (including those of biological origin) in the air, at levels that are one of the greatest environmental risks to health (Seinfeld and Pandis 1998). Epidemiological studies revealed that air pollution is a risk factor for diseases of public health importance such as cardiovascular diseases for instance stroke and ischaemic heart disease, cancers and respiratory diseases

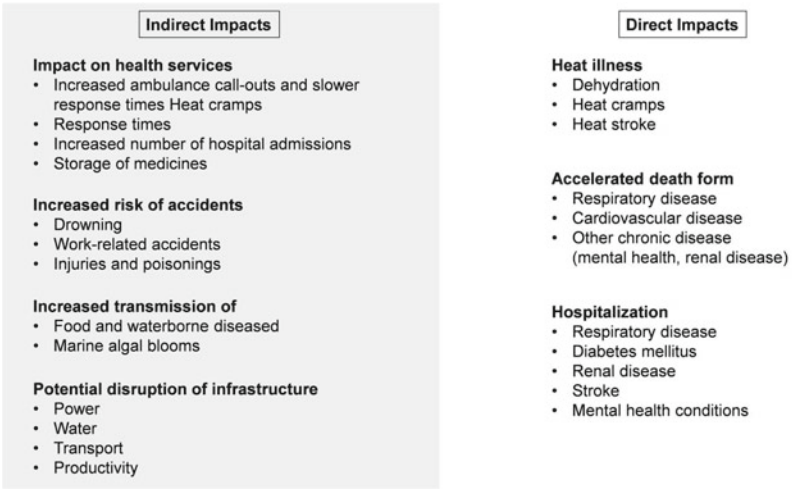

Fig. 1 Impacts of extreme heat on health (WHO 2023c)

(Cohen et al. 2015). Ambient (outdoor) air pollution is estimated to have caused 4.2 million premature deaths worldwide in 2019 (WHO 2023a).

World Health Organization (WHO) data show that almost all of the global population (99%) breathes highly polluted air that exceeds WHO limits (WHO 2023b). WHO aggregates global particulate matter data and collates them into reports. Figure 1 shows the annual mean concentration and the coverage of the ground measurements of PM2.5 for countries around the world from 2010 to 2016. It shows that countries with low and middle income suffer from the highest exposures.

Referring to sources of air pollutants, the burning of fossil fuels, motor vehicles and power stations are the major source, which is one of the biggest causes of air pollution in developing countries. As a typical large developing country, China's growing energy consumption, reliance on coal and rapidly increasing vehicle population cause severe air pollution. Air pollution concentration levels tend to increase appreciably or even rise sharply if no effective measures are taken when economic development reaches an intermediate stage (WHO 2013). Hence, there is a growing need to create better living spaces and ensure human well-being. Sustainable urban planning and climate control measures are required to maintain and improve public health.

As shown in Fig. 2, the location of the PM2.5 concentration in more than 4000 monitoring stations was listed on the map. Particulate matter (PM), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) are the main pollutants of major public health concern (WHO 2023c). Harmful pollutants exposure is proven to be associated with respiratory illness, hospital admission and premature death (Huangfu and Atkinson 2020). The health impacts of ambient PM2.5 have become a great concern worldwide. Epidemiological investigations have shown that PM2.5 exposure contributes to cardiopulmonary morbidity and mortality, the incidence and development of diabetes mellitus and adverse birth outcomes (Feng et al. 2016). Considering the significant health risks posed by pollutants, interventions at regional, national and international levels are needed to reduce levels of air pollution.

Water

Water in urban is necessary in terms of human daily activities needs and sanitation needs. The water quality and quantity played a vital role in city resilience. Hygiene behaviour by using clean water can significantly reduce respiratory infections (Howard et al. 2020). Water quantity is limited, freshwater accounts for only 2.5% of the global water (Tang et al. 2022), and the reliability of the water is heavily connected with human well-being. United Nations Sustainable Development Goals emphasize the sanitation and quantity needs for water in the city, to satisfy SDG 6, the Guidelines for Drinking Water Quality (GDWQ) provide the recommendations of the World Health Organization for managing the risk from hazards that may compromise the safety of drinking water and assist water and health regulators and policymakers to maintain public health by supporting the development of national regulations and standards.

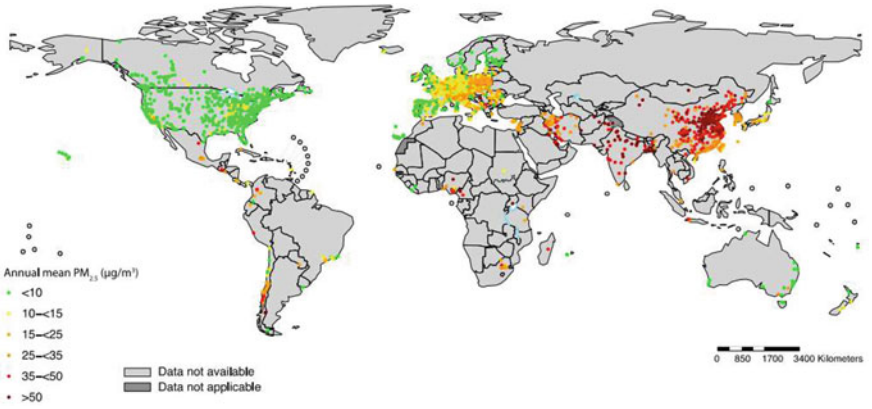

Fig. 2 Location of the monitoring stations and PM2.5 concentration in more than 4000 human settlements, 2010–2016 (WHO 2018a, b)

Flood

Over the last 20 years, flood events have occurred in 49 countries in the WHO European Region. These have caused more than 2000 deaths, other health effects, property losses, damage to health facilities, displacement and enormous economic costs estimated at €70 billion (WHO 2017). Flooding is widely regarded as extreme water stress or land loss disaster in urban or rural areas on the mainland. Understanding flooding and increasing the robustness capacity against flood risk are important for human well-being. Flooding effects included accident and injury risk; diarrhoeal/respiratory diseases and skin/eye infections; chemical poisoning; stress; and negative health effect linked to overcrowding (WHO 2017). The second effect can occur after floods, for example, damage to health care infrastructures, living supplies, water shortage, communication crash, destruction of property and vital community facilities, damage to crops, disruption of food supplies and disruption of livelihoods and income. A flood warning measures system is, therefore, very necessary for city resilience, strengthening the monitoring of flood hazard points, establishing and improving monitoring systems, observing models, forecasting models, and early warning systems, group measurement and prevention work are now considered as potential solutions.

Acoustic

Noise pollution in urban environments caused by traffic is nowadays recognized as one of the top public health threats across all ages (UNEP 2022). Prolonged exposure to high levels of noise impairs human health and well-being. Traffic and other urban noises affect not only human well-being but also disturb and endanger the survival of species crucial to the urban environment (Francis and Barber 2013).

Estimates suggest that in Europe 22 million and 6.5 million people suffer from chronic noise annoyance and sleep disturbance, respectively (EEA 2020). The

Table 1 Prevalence of hearing loss (of moderate or higher grade) across WHO regions (WHO 2021)

Area	Quantity/million	Proportion (%)
Americas	62.7	6.2
African	39.9	3.6
European	57.3	6.2
Eastern Mediterranean	22.1	3.1
Southeast Asia	109.4	5.5
Western Pacific	136.5	7.1

Table 2 Illustrative combined direct, indirect and intangible costs of hearing loss (in billion dollars) (David et al. 2021)

Area	Health	Education	Productivity	Intangible	All costs
Americas	88.6	3.8	44.1	125.3	262
African	7.3	3.6	3.5	12.4	27.1
European	74.5	3.2	21.1	125.6	224.5
Eastern Mediterranean	9.0	1.6	5.2	13.9	29.8
Southeast Asia	32.2	7.0	29.7	38.7	107.7
Western Pacific	101.8	7.4	78.5	140.5	328.3
World	313.6	26.8	182.4	456.5	979.6

elderly, pregnant woman and shift workers are among those at risk of noise-induced sleep disturbance (Halperin 2014). Noise-induced awakenings can trigger a range of physiological and psychological stress responses because sleep is necessary for hormonal regulation and cardiovascular functioning (Münzel et al. 2014). There is increasing evidence that traffic noise exposure is a risk factor for the development of cardiovascular and metabolic disorders such as elevated blood pressure, arterial hypertension, coronary heart disease and diabetes (Münzel et al. 2018).

Table 1 shows the prevalence of hearing loss across WHO regions, the highest proportion is Western Pacific (accounting for 7.1%, 136.5 million), and the lowest is in Southeast Asia (3.1%). Also, European and the Americas should concern due to the relatively high index.

Table 2 indicated hearing loss has a considerable economic impact on society as a whole. WHO data reveal that the overall global cost of unaddressed hearing loss is greater than $980 billion annually.

2 Energy and Environment

With the rapid urbanization and urban sprawl, global demand and consumption of energy by cities are constantly increasing. Cities consume approximately 67% of the world's energy, and their carbon emissions have surpassed 70% of the global

total (IEA 2021). It is estimated that by 2040, the building sector will account for 35% of the global electricity demand growth. The rapid increase in urban energy consumption and carbon emissions is of concern, and there is an urgent need to take measures to promote energy conservation and emission reduction in cities.

Fossil fuel combustion is the main contributor to carbon emissions to meet urban energy demand. The combustion of carbon-based substances causes a large amount of carbon dioxide emissions into the air and bring potential negative health effect on the human. Mitigation of carbon emissions needs to implement a zero-energy building policy. Clean and renewable energy is the most important issue for a city's sustainability and resilience.

Human activities and urbanization have a negative impact on biodiversity comparing its original nature elements. Landscape plant species with their notable influence on human well-being are important components of the urban ecosystem. Urban greening is expected to avoid biotic homogenization. This will help the urban designer thinking as well as the decision-making on protecting human well-being and environmental biodiversity. Urban biodiversity study can determine the practical relevance of tools for different types of audiences, including designers, planners and ecology working in different stages of urban development and design processes.

3 Sustainability and Resilience

Urban sustainability consists of appreciating and balancing the three pillars of sustainable development (economic, social and environmental), while also being inclusive and equitable. While city resilience indicates the city's capacity to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies. A sustainable and resilient city is the development path for future cities facing increasingly unknown urbanization challenges. Responding to climate change, policies are recognized as mandatory guiding decisions that can safeguard the fair interests of the majority of people and thus play a vital role in society. United Nations Sustainable Development Goal (UN SDG) is promoted for providing a sustainable index and goals for humans, requiring people in all stages together to build a sustainable world for humans and the next generation. The target of 'Good health and well-being' is one of the United Nations' 17 Sustainable Development Goals.

The holistic system thinking approach is considered in the improvement of urban living environments. Cities require a systems approach for planning, design and management. The living environment as a whole in a city covers all aspects like a community unit together as a pyramid, and it needs intelligent structures and infrastructures, social provision, amenities and basic property rights for its citizens. It is essential to set a vision for all the stakeholders, so they feel comfortable and have easy access to clean, sufficient and daily needs. The sustainable and resilient city should have functions of providing sufficient energy, clean air and water, flood resilience

and be accessible to everyone. System thinking is a key improvement in an urban living environment.

4 Summary

The liveable cities include factors affecting liveability; ecological and biophilic cities; economic values; health and well-being; and opportunities for people. There is a basic human need for a social dynamic, and cities provide this for people. Cities are like organisms pulsing with life bounded by economic, ecological, health, and well-being requirements. Physical and social health is addressed in the context of resilient cities in Chapter "Outdoor Thermal Comfort and Heat Exposure Risks". This chapter defines the features of sustainable liveable cities and reviews how cities can function in a climate change-respectful way but also be joyful places for people to be.

People in cities use outdoor space for a wide range of activities such as exercise, rest and socializing. Climate change, Urban Heat Islands and extreme heatwave events are threats to pedestrians' health and well-being. Good urban planning and design can provide a high-quality urban living environment by meeting the need for outdoor thermal comfort and thermal resilience. Chapter "Liveable, Joyful and Soulful Cities" presents the human adaptation mechanism for achieving outdoor thermal comfort, the factors that influence it, strategies for thermal resilience, the management of heat risk and thermal comfort assessment methods to use.

Heatwaves and high temperatures are associated with increased mortality risks, and the burden may keep rising in the future. Chapter "Mortality Risks and Burden of Heatwaves and High Temperature" provides evidence of climate change and the mortality risks of heatwaves and high temperatures. This study examined the population's vulnerability to heatwaves and high temperatures, including demographic and climatic modifications, highlighting the necessity for adaptation measures against heat stress to contribute to the reduction of the heat-related mortality burden. The method of estimating the city-specific risks has been presented.

The computer modelling method is one of the effective measures that can help assess urban environments and decision-making of urban intervention strategies for the improvement of people's health and well-being. It plays an important role in the resilience of cities. It has been widely conducted in many aspects including assessment of outdoor thermal comfort, Urban Heat Islands, urban air quality, urban flooding, urban ventilation design, urban acoustic and flooding. It can assist policy-makers, urban designers and city managers to work collaboratively to deliver sustainable urban planning and regeneration from the earliest stage. Chapter "Modelling Urban Microclimates" introduces a robust and fast-running tool that can be used to simulate urban solar radiation, surface temperatures and air temperature. It can be used in a variety of scenarios to assist in the assessment of urban planning/building design projects related to the outdoor thermal environment. The case study presented briefly demonstrates some of the functions that can be used in the planning

and design phase. Chapter "Predictive Modelling in Urban Environments" presents the challenges of modelling complex physical phenomena in terms of the prediction of characteristics and evolution with adequate accuracy and reliability. Data assimilation techniques incorporate information from experiments and observations to reduce uncertainties in numerical prediction that has been presented. The resolutions of modelling techniques on an urban scale have been demonstrated with case studies of simulations of urban air pollution, urban green–blue infrastructure, land surface thermal dynamics and urban flooding forecasting.

Inhabitants of high-rise and high-density cities are at greater risk of severe environmental hazards, such as air pollution. Typically, high-density cities have high pollutant emission rates, attributable to high traffic volume per unit area. Urban ventilation is one of the practical measures through proper urban and building design that can mitigate urban heat and air pollution. Chapter "Urban Design to Reduce Air Pollution Exposure in High-Rise and High-Density Cities" presents six design principles that can improve urban ventilation in high-density cities and therefore reduce air pollution exposure. By incorporating climate-sensitive design strategies, high-density cities can potentially reduce both indoor and outdoor exposure to air pollution, leading to improved sustainability and resilience. Chapter "Urban Ventilation" presents the impact of the urban context in terms of air and thermal pollution on ventilation strategies. Three case studies of the performance evaluation of buildings in urban areas are presented.

The acoustic quality of living and working environments can affect the health, well-being and quality of life of building occupants. Chapter "Balancing Outdoor and Indoor Soundscapes in a Warming Climate" introduces the soundscape methodologies that provide a comprehensive characteristic of acoustic perception by people in a specific context, thus guiding the design of built environments to shape resilient cities, able to address the main global challenges posed by global warming. The consideration of soundscape aspects from the earliest stages of urban planning and building design would favour conditions that allow for the adoption of passive ventilation (and cooling) strategies for occupants' health and well-being.

Rapid urbanization has greatly affected global biodiversity. Human preferences for the plant species of urban greening have greatly facilitated the spread of non-native species, resulting in the homogenization of landscape plant communities across spatial scales. Chapter "Biotic Homogenization and Rewilding of Urban Greening" explores the climatic suitability and sustainability of landscape plants for urban biodiversity. The application of biodiversity-friendliness spontaneous urban plants (SUPs) has been proven an effective way to urban diversity in 59 major cities in China.

Nature-based measures like green infrastructures have been regarded as a multifunctional approach to urban resilience and sustainability for capturing particulate matters and mitigating the impact of Urban Heat Islands at the city scale, acting as nature-based solutions to abate the impact of natural hydro-meteorological hazards such as flooding and heatwaves, to indirectly foster biodiversity. Chapter "Urban Green Infrastructure" summarizes the design principles and the role of green infrastructure (GI) in the abatement of air pollution, urban heat and natural hazards. The

GI method has been proven to contribute to improved health and well-being in terms of sustainable and resilient cities.

Floods threaten cities in various forms whose magnitude and frequency are likely exacerbated by climate change and increasing urbanization. Chapter "Urban Flood Resilience" explains their causes, consequences, observation methods, hazard modelling techniques and mitigation infrastructures relevant to urban flood resilience. It introduces hybrid infrastructure (grey, green and blue) systems for urban resilience to flooding. It is addressed that flooding risk has to be managed through resilient and sustainable planning, especially in fast-developing areas.

The global success of mitigating climate change is dependent on transitions to net zero carbon energy systems. The increasing urbanization of global populations inevitably increases the energy demand for working, living and improving living environments, transportation, entertainment and so on. Chapter "Energy Demand and Cities: Understanding the Complexity of Reduction Potential" presents the relationship of different causal pathways (top-down and bottom-up) to demand reduction in cities. It presents a matrix of the five demand reduction sectors and seven demand reduction trends as of the Low Energy Demand Scenarios (CREDS) for the potentials of energy demand reduction in the context of urban sustainability.

Mitigation of carbon emissions needs to implement a zero-energy building policy. Clean and renewable energy is the most important issue for a city's sustainability and resilience. Chapter "Clean and Renewable Energy" introduces the applications of renewable energy including solar water heating, space heating and cooling systems, photovoltaics and hybrid photovoltaic and solar thermal (PV/T) systems which provide both thermal and electrical energy and the geothermal energy systems which employ ground heat exchangers in combination with heat pumps. Renewable energy systems are used not only in buildings directly but nowadays are also used in district heating and cooling networks in the urban/community context for a sustainable future.

The evolution of policies by setting frameworks plays a pivotal role in the delivery of sustainable and resilient cities. Chapter "Global Policies and Practices for Transforming Resilient City-Regions" presents examples of implementations of policies and sustainable development guides as well as tools in cities towards a more resilient, sustainable and liveable future. It includes exemplary cases from London, Shanghai, Accra, Singapore, Amsterdam and Melbourne. These include urban forests, urban agriculture, water storage and reuse, flood management using nature-based solutions, walking, cycling and electric public transport for mobility and using waste as a resource.

The case study of the implementation of energy policy for zero-carbon cities (communities) in Japan has been introduced in Chapter "Zero-Carbon City and Community in Japan—Policies, Proposals, and Examples". The proposals made by the Architectural Institute of Japan and the Science Council of Japan regarding zero-carbon cities and communities are explained and discussed. An overview of the decarbonization efforts in 26 regions selected as decarbonization leading areas and specific examples of four regions is provided. It further demonstrates the policy's role in delivering sustainable cities.

The scarcity of freshwater across the world has become one of the major crises exacerbated by a growing population, changing consumption patterns and the rise in irrigated agriculture. Chapter "Urban Maintenance and Robustness" presents the developing country, Indian case studies of household end-use water demand and the innovative decentralized water system, which combined rainwater harvesting (RWH) with wastewater. Guidance of five points for urban water resilience has been proposed to increase city resilience in the context of end-user and management through scenario analysis.

A long-term integrated approach is crucial in planning and implementing green and liveable cities. On the one hand, this requires cross-departmental and multidisciplinary collaboration, as well as wider citizen engagement; on the other hand, it requires a long-term strategy that considers the whole lifecycle of creating sustainable and resilient places starting from visioning, planning, implementation, enforcement, management and maintenance, as well as monitoring and feedback. Chapter "A Long-Term Integrated Approach to Plan and Implement Green and Liveable Cities: Case Studies in the UK" introduces two UK case studies to discuss how the long-term integrated approach can be utilized: the first case study of Cornwall Council is focused on its inclusive and integrated policymaking process; the second case study of Milton Keynes is focused on the long-term strategy of planning and implementing its city-wide green infrastructure.

Chapter "Wellbeing and Social Health in the Built Environment" looks beyond well-recognized factors like thermal quality, addressing lifestyle and balance and social influences on 'well-being in use', including location, spatial scale, biophilia, 'active by design', community and social memory. This has been demonstrated by drawing on the author's rich repertoire of research and practical experience in people's use of buildings and urban spaces. It implicitly proposes a breadth of professional expertise to shape healthy environments.

Chapter "Reading, UK: A Case Study in Urban Futures" addresses the importance of city governance in shaping the future of a city. It introduces the overall concept of urban future thinking. The Reading case study in the UK demonstrates that the cities with the most robust and effective 'hard' and 'soft' climate change and governance structures will be the cities that continue to attract investment. The key points are addressed that can be learned by other cities and towns in achieving sustainable and resilient cities, towns and communities. They include integrated approach, role of stakeholders, power relations, R&D opportunities, COVID-19, resilience and net zero. Ultimately people, businesses, local government, academia and other key city stakeholders must all be part of helping shape that future.

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Outdoor Thermal Comfort and Heat Exposure Risks

Runming Yao, Xizhen Huang, Tiantian Xu, and Yuening Zhu

Abstract People in cities use outdoor space for a wide range of activities such as exercise, rest and socializing. Climate change, Urban Heat Islands and extreme heat-wave events are threats to pedestrians' health and well-being. Good urban planning and design can provide a high-quality urban living environment by meeting the need for outdoor thermal comfort and thermal resilience. People's thermal sensations and perceptions are greatly affected by the local microclimate and their thermal experience while, in turn, outdoor thermal comfort affects the decisions on whether to use a space. This chapter presents the human adaptation mechanism for achieving outdoor thermal comfort, the factors that influence it, strategies for thermal resilience, the management of heat risk and thermal comfort assessment methods to use. Finally, a case study for evaluating thermal perception in public squares is introduced.

Keywords Climate change · Urban Heat Islands · Outdoor thermal comfort · Urban planning and design · Thermal stress · Physiological adaptation

1 Introduction

Outdoor thermal comfort is important in the context of sustainability and resilience. A pleasant microclimate contributes to the quality of outdoor spaces and attracts outdoor activities, such as walking, cycling, rest, exercise and socializing. In this section, the main factors that impact on the comfort of outdoor environment will be presented.

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