Ming Hu

Smart Technologies and Design For Healthy Built Environments

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Foreword: Smart Technologies for a Healthy Built Environment

As an architect and neuroscientist I consumed Professor Ming Hu's new book, on smart technologies and the built environment, with interest and pleasure. The book proves timely and strategic on numerous fronts, including through its comprehensive coverage of pressing issues concerning public and population health as well as its thought-provoking connections between design and wellness. Professor Hu methodically crafts and unfolds a compelling story concerning the responsibilities of architects to meaningfully foster the health of users of the built environment, while revealing vital links between design, technology, and duties around societal well-being.

Beginning with early historical actors such as Hippocrates (do not harm) and Vitruvius (site, wind, light water), and ending with remarkable case studies of seminal contemporary buildings, Prof. Hu takes us on a rich journey across the centuries as architects endeavored to connect the ways we design with the impacts on people's lives. Along this path many stories are told that capture and convey the development of architecture, and architects' roles, in the promotion of health as a key objective of building construction and community design. Through illuminating the major advancements in the science of building over the generations Professor Hu gives us an understanding of the critical function of architecture in the nurturing of our physical and psychological health, and the power of cities to improve us societally. Health and shelter are fundamental human rights. Ming explores the intersection of these two realms, demonstrating how the provision of shelter can and must promote the improvement of health.

A stream of my own research considers systems theory and the positive consequences around holistic posturing in design and planning. In reviewing Prof. Hu's book I was impressed with her strong arguments linking design of the built environment with enhanced health and improved quality of life. She highlights the recent rise of green building and sustainable design movements, then moves on to consider the largely untapped potential of information technology to demonstrably advance individual health and community well-being. In particular Prof. Hu presents state-of-the-art developments in technology that hold promise to move us from more predictable models of monitoring environments to more remarkable

means of responding to user needs, assessing human conditions, and facilitating better health. She correctly covers then transcends physical and physiological dimensions to crucially delve into the nurturing of our mental, social, and spiritual wellness via more thoughtfully designed worlds.

Professor Hu challenges us to consider the potency of design, the deployment of advanced technology-based systems (intelligent buildings, smart cities), and the promise of emerging tools to dramatically alter the relationship between people and the environments they inhabit. In an increasingly turbulent world, where we confront unprecedented and unfathomable crises including climate change and global pandemics, Ming helps us to grasp how new ways of thinking about design can precipitate transformation and proffer hope. Churchill, in reflecting on the rebuilding of post-war Britain, mused that "We shape our buildings; thereafter they shape us." In many ways our modern world is facing dire outcomes, on numerous fronts, if we cannot meaningfully and measurably alter our behavior, our architecture, and our built environments. Professor Hu, in her new book, sets her sights on connecting people, design, technology, and place, all with an eye to heightening our health, healing our world, and improving our future. Across this innovative voyage she explores economics, considers medicine, examines design, invokes science and highlights art—embracing an interdisciplinary perspective on advancing architecture, cultivating wellness, and improving our communities.

Calgary, Canada Dr. Brian R. Sinclair

Preface

Smart, Healthy, and Sustainable

"Architecture is more than the art of constructing individual buildings, it is also the creation of environment. Buildings do not exist in isolation. They not only impose their character on their surroundings but also have an incalculable effect on the lives of human beings who inhabit them" [1].

In the past couple of decades, we have witnessed sustainable buildings bring about a market transformation, turning many sustainable building solutions into standard and expected minimal design criteria [2]. Many sustainable design principles and approaches had their origins in a desire for energy and water conservation, and in this way, the use of natural resources and the improvement of indoor environmental quality have become major concerns, if not standard practice. As the sustainable building movement becomes widely accepted, the benefits of sustainable design, such as improvements in occupants' health, well-being, and productivity, are increasingly being recognized by building owners and tenants, and presumably could drive the market in the future.

In recent years, as sustainable building solutions that conserve energy have become standardized, we have seen two further developments in the building industry. The first is a shift in the market toward designing, operating, and maintaining "healthy buildings" [2]. As people spend more than 80% of their time indoors, creating a healthy built environment is of critical importance. A healthy building is a building that not only meets its occupants' physical and physiological needs but could also benefit their mental health and productivity. The second development is the transformation of today's sustainable buildings into smart buildings, through ubiquitous computing and the Internet of Things (IoT) [3]. More and more buildings are being equipped with smart sensors, actuators, and nano-embedded systems, for the collection and analysis of data from occupants. Smart control systems then adjust the built environment through automatic commands, or commands made remotely by occupants to meet their particular needs.

If we identify the period from the 1990s to the present day as an era of sustainable building, then the next couple of decades could be the era of healthy and smart buildings. This book is about connecting **smart technology** to a **healthy built environment** that builds upon the sustainable building movement. We use smart technologies in our daily life (iPhones, smart sensors, and voice-activated systems), but we have no clear picture of a smart built environment. A smart built environment takes full advantage of the potential of smart objects and other innovative systems which adapt to the needs of occupants and changing external climatic events. **Smart buildings can lead the transformation of the public health market by turning buildings into responsive, user-focused, health-conscious, and interconnected systems**. These systems will provide better living and working environments. To apply smart technologies appropriately, where they are most needed, the first step is to describe them, including their advantages and disadvantages, and their potential applications to enhance occupant health.

Firstly, this book provides a snapshot of state-of-the-art smart technologies being applied in the built environment. It covers a broad spectrum of smart technology categories, ranging from dynamic operability, energy efficiency, self-regulating and self-learning systems, to responsive systems. Secondly, this book provides in-depth analysis of the four primary components of health (biological, physical, physiological, and psychological); their effects on well-being and cognitive performance are introduced as well. Thirdly, it connects smart technologies to those health-influencing factors by reviewing three completed smart building projects. This book can also serve as a basis for education and discussion among professionals and students of diverse backgrounds who are interested in smart technologies, smart building, and healthy building.

Chapter 1 sets the stage for understanding the built environment's effects on human health in history, worldwide. It provides readers with a basis for understanding the relationship between the built environment and public health. It also introduces the diverse factors that play a critical role in forming the concept of healthy buildings.

Chapter 2 establishes the context for understanding the synergies and disconnections between public health and built environment planning and design. It serves as a foundation, to transition to the in-depth analysis in Chap. 3 of the built environment's effects on human health.

Chapter 3 outlines the key factors of health problems emanating from the built environment: physical, physiological, biological, and psychological. It then examines how the current building codes and regulations address those factors.

Chapter 4 investigates the indoor variables that contribute to the key factors outlined in Chap. 3. The detailed explanation builds a foundation for understanding the necessity to apply smart building technologies to solve built environment problems.

Chapter 5 starts to connect smart building technologies to primary health causes in the built environment, then gives a brief history of smart building development and

outlines three sets of key smart technologies that are critical for the improvement of occupants' health.

Chapter 6 points out the future shift in priorities and the effect on smart building technologies. It describes future smart building through a detailed explanation of five unique abilities the future smart building would possess.

Chapter 7 closely examines the three most advanced smart and healthy buildings in the world: Edge in Amsterdam, the Gator-Tech Smart House (GTSH) in Florida, and the CASA smart home in Washington state, to demonstrate the five smart abilities introduced in Chap. 6.

Chapter 8 synthesizes the preceding chapters to derive a final framework that integrates the healthy and smart building practices. The benefits and future potential of this integrated approach is outlined and emphasized.

College Park, USA Ming Hu

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Chapter 1
A Brief History of Health and the Built Environment

This Chapter provides readers with a broad view of the relations between health concerns and the built environment through history. The purpose of this chapter is not to cover a detailed history of the development of healthy buildings but to instead illustrate the historical development from two perspectives: public health and building design and construction. It also outlines and explains the diverse factors that play important roles in shaping the concept of healthy buildings and a healthy built environment. This chapter is organized based on the chronological development of relations between the built environment and public health (Fig. 1.1).

1.1 The Pre-industrial Era: Vitruvius and *Feng Shui*—Western and Eastern Approaches

Early evidence that links human habitation to health dates back to Greek and Roman times. Hippocrates (460–370 BC), "the father of modern medicines" [1], advocated the health implications of the wind, air, water, and other components of habitants in his book *On Air, Waters and Places*. Hippocrates believed each city's unique setting in the landscape, and even its inhabitants' areas, should be considered most attentively in order to protect the habitants' health [2]. One of the oldest infectious diseases is malaria, which has a Latin origin meaning "bad air" and is based on the assumption that decaying vegetables in markets were responsible for the disease [3]. In response to the concerns that Hippocrates raised about unhealthy air and wind, hundreds of years later, Marcus Vitruvius Pollio (80–15 BC) suggested that not only the buildings' orientation but also the street patterns should be laid at an oblique angle to break harsh wind [4] so that bad air would not be able to travel far through the wind. Marcus Vitruvius Pollio was regarded as the first architect and planner in history to address environmental health issues. Commonly known as **Vitruvius**, he was a military and civil engineer and architect who designed and built protective facilities, such as castles

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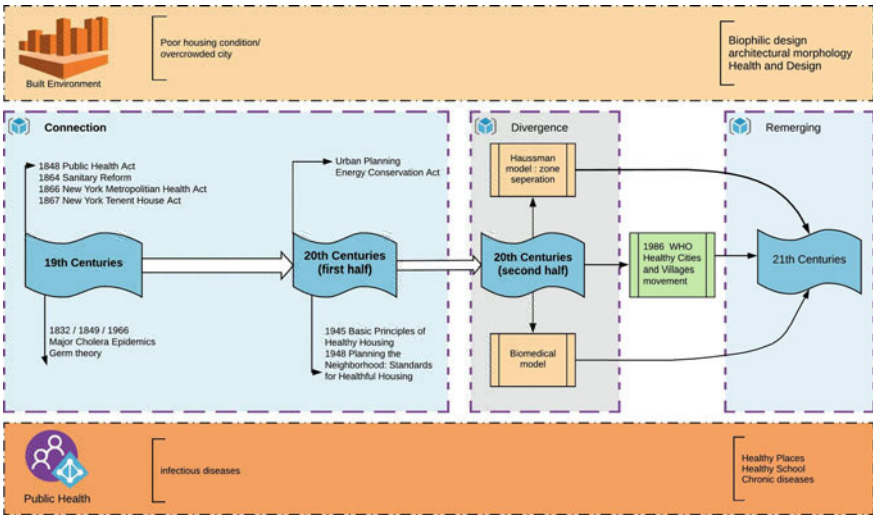

Fig. 1.1 Historical development of the built environment and public health

and shelters. He described many technological and building innovations with the aim to improve people's living conditions, some which are still applicable to today's environment. For instance, in his famous book *De Architctura*, known today as *The Ten Books on Architecture*, Vitruvius described the development of the *hypocaust,* the prototype of ancient "central heating," which supplied hot air through the floor and inside of walls to buildings and public baths. In the same book, he suggested several key environmental health concerns which are still applicable in today's world and are considered the principles of modern sustainable design. The first key concern is *site*; Vitruvius suggested that cities could maximize their access to sea breezes, thus minimizing the health effects originating from foul-smelling swamps. The second concern is *wind;* he suggested the street layout should be designed in a way to prevent the wind from blasting dwellings. He also advised against placing alleyways parallel to the winds, which could bring in and spread odors and disease through the town [5]. The third key concern is *light*; Vitruvius recognized the "regenerative" quality of lights and, therefore, suggested that bedrooms should face east, presumably to help awaken inhabitants, while temples face west so that worshippers could behold the morning sun from the east. The purifying effect of light was later recognized by the medical community around the turn of the twentieth century, at the discovery that sunlight could kill bacteria [6]. The fourth key concern is *water*; there was an ancient belief that "all things depend upon the power of water." In book seven, Vitruvius developed techniques to locate water resources and restore and filter rainwater in order to provide clean and healthy water to people.

Vitruvius's influence in architectural and engineering design was profound. In book five, he designated one chapter to climate influence on house design, stating, "If our designs for private houses are to be correct, we must at the outset take note of