



**SMART04**

# **INTEGRATING INNOVATION IN ARCHITECTURE**

**Design, Methods and Technology for  
Progressive Practice and Research**

Ajla Aksamija

**WILEY**

# INTEGRATING INNOVATION IN ARCHITECTURE

Design, Methods and Technology for  
Progressive Practice and Research

WILEY

Ajla Aksamija

This edition first published 2016  
Copyright 2016 Ajla Aksamija  
Published by John Wiley & Sons, Ltd

Registered office  
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ,  
United Kingdom

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at [www.wiley.com](http://www.wiley.com).

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley publishes in a variety of print and electronic formats and by print-on-demand. Some material included with standard print versions of this book may not be included in e-books or in print-on-demand. If this book refers to media such as a CD or DVD that is not included in the version you purchased, you may download this material at <http://booksupport.wiley.com>. For more information about Wiley products, visit [www.wiley.com](http://www.wiley.com).

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty: while the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that the publisher is not engaged in rendering professional services and neither the publisher nor the author shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

A catalogue record for this book is available from the British Library.

ISBN 978-1-119-16482-1 (hardback)  
ISBN 978-1-119-16571-2 (ePDF)  
ISBN 978-1-119-16481-4 (ePub)  
ISBN 978-1-119-16480-7 (O-BK)

Executive Commissioning Editor: Helen Castle  
Project Editor: Miriam Murphy  
Assistant Editor: Calver Lezama

Page design by Emily Chicken  
Cover design and page layouts by Karen Willcox, [www.karenwillcox.com](http://www.karenwillcox.com)  
Printed in Italy by Printer Trento Srl  
Cover image © Synthesis Design + Architecture  
Image page 250 © Rob Ley and Joshua G. Stein



# ACKNOWLEDGEMENTS

I would like to acknowledge all the valuable time, comments and feedback I have received, during the preparation and writing of this book from individuals, firms and organisations. They have worked closely with me, helping me to capture the essence of projects, design methods and approaches featured here in the case studies, projects, building systems and installations. I thank them all for their involvement, support and advice.

I would like to extend my gratitude to Phil Harrison for providing his perspective and for writing the foreword.

My research assistants, Yi Wang, Christopher Mansfield and Tom Forker deserve special recognition for their help.

I would also like to thank the Wiley editorial and production team, particularly Helen Castle, Calver Lezama and Miriam Murphy.

Lastly, I would like to acknowledge Zlatan, Nur and Iona Aksamija for their undivided love and support.

# FOREWORD

## TOWARDS A RESEARCH-BASED DESIGN PRACTICE

PHIL HARRISON

We are entering an age of serious design thinking.

The dominant modes of design over the last two centuries have been decoration, tectonics, theory, systematisation and intuition, among many others that have tended to be rooted in the past and the present. All have yielded beauty in various ways, and these foundational modes of thinking should and will remain part of modern practice, as designers embrace a richly layered approach to conceptualisation. But today, designers and their patrons are increasingly seeking proof that design will live up to expectations in the future. This yearning for predictability is pushing designers to balance their humanistic focus on what has been and what is, with a scientific rigour that attempts to establish what will be. This accelerating move towards fact-based predictive design thinking is revolutionising our creative process far beyond the limited aim of reducing risk, towards a new form of design practice that bristles with empirical discipline in balance with imagination.

Why? There are compelling economic, environmental and social reasons for this evolution. Economically, buildings simply cost more today than ever before, and building owners are demanding more from their capital investments. Environmentally, resource scarcity is similarly driving us all to do more with less. And socially, there is an increasing recognition that human performance and well-being are far more valuable than bricks and mortar. In all these, there is a growing awareness that design can answer these challenges. Design thinking is, in fact, the best answer to all these, because designers have the unique skill of using synthetic thinking to solve increasingly complex problems in simple and powerful ways.

But we have a problem. Modern design practice is not rooted in the kind of serious research-based thinking that is at the core of so many other innovative disciplines, such as medicine or engineering. To truly transform design practice to be stunningly innovative, we need to develop our own kind of intellectual rigour – a new type of design practice that is research-based and that is fundamentally conceived to yield breakthrough results.

This is an ambitious goal, and in my experience, this goal has been front of mind with many design educators and practitioners for at least the past decade. However, most have hesitated to move forward with meaningful action due to the uncertainty of the terrain of design research. What are the important research questions? How do we transform our profession, which is so rooted in history and intuition, and embrace a more scientific approach? How do we preserve what we love about the art of architecture with a new evidence-based approach; or, how do art and science mix for us?

How can the historically separate realms of the academy and the profession engage in research together?

Enter Ajla Aksamija and her book *Integrating Innovation in Architecture*. The following pages are at once a template, a primer and a call to action for serious research in architecture. The first step towards tackling any significant challenge is to simply understand it. The first three chapters of the book rigorously march through the various dimensions of architecture: materials, processes and technologies. Aksamija scans the global design market and reveals countless examples of innovative possibilities occurring all over the world. She succinctly explains each innovation and links each to relevant examples of their application, proving that these are not dreams but seriously useful and impactful innovations. This part of the book gives us the 'what', and anyone passionate about design should use the examples cited as an itinerary for their future travels. But Aksamija goes further in the second part of the book where she outlines the 'how' of research. I believe this part of the book is the most important, as it will provide practitioners with a prototype business strategy to develop their own research-based practice and the courage to do so.

Design practice is extremely difficult. Architects, interior designers, planners and landscape architects are historically less well compensated than other professional service providers. As such, our profession chronically skates on the edge of financial viability, even as the market grows increasingly demanding of our time and energy with more intense legal, regulatory, environmental and other pressures. In this predicament, it is understandably difficult for designers to find the energy to change their practices. Change is intimidating, but Aksamija's book helps break this down for us, and makes the prospect of change much less abstract. By explaining the 'what' and the 'how', she provides designers with an invaluable toolkit.

The key message of this book is action. The most important thing to do is to start something. By demystifying the challenge and breaking it down into smaller pieces, firms and design schools can find seeds of possibility and start incrementally. Aksamija's book title suggests that 'integrating' research into practice can be done as an evolution, not as a radical step. Our profession simply cannot afford to think about research in the manner of the pharmaceutical industry, for example. Instead, we can get there by reallocating current resources and establishing new degrees of rigour in our work. The evolution into research-based practice can be a subtle shift, but it needs to be a serious and purposeful one. Importantly, *diversity and transparency* will help our industry get further faster.

Here is what I mean by diversity: while Aksamija gives us a broad tableau of research possibilities, each designer, school and firm should craft their own research agendas that are more narrowly defined and have specific goals. Indeed, the possibilities are so broad and rich, there are virtually no limits to the work ahead

of us, and so a diversified approach to investigation is the right model for the design industry. This idea is the opposite of a singularly focused 'moon shot' mentality; it is a divide and conquer approach. We should pursue many smaller goals because there are so many important areas of inquiry, and tackling smaller research problems will be inherently more economically feasible for us. But then we need to share what we learn. Diversity requires transparency. Unlike the pharmaceutical industry, we should not think about our research as a means to developing competitive advantage. Instead, we should take the leap of faith that sharing knowledge in a transparent approach will lead us to more innovation, more rapidly, and that this will ultimately make a stronger design industry in which we all can thrive.

But first, please read this excellent and important book, and please use it productively. I hope you enjoy it.

*Phil Harrison, FAIA, LEED AP, is a Principal and Chief Executive Officer at Perkins+Will. He is responsible for the firm's strategic focus and business performance. He is directly involved with quality initiatives including design excellence, sustainability, research and technical delivery.*

# CONTENTS

## ACKNOWLEDGEMENTS 7

## FOREWORD 9-11

by Phil Harrison

## INTRODUCTION

### INNOVATION IN ARCHITECTURE (WHAT, WHY AND HOW) 12-19

What is innovation? 13

Why innovate in architectural design? 16

How to innovate in architecture? 17

### 1 INNOVATIVE MATERIALS 20-59

Advances in concrete 23

Advances in glass 27

Advances in metals 37

Biomaterials 39

Composite materials 41

Electrochromics 45

Shape-memory alloys 45

Self-healing materials 47

Sensors and controls 48

Phase-change materials 49

Photovoltaics 51

Thermoelectrics 55

Conclusion: the impacts of advanced and smart materials on architectural design 57

### 2 INNOVATIONS IN COMPUTATIONAL DESIGN 60-127

Advances in computational design 63

Tools and methods 77

BIM in design 88

BIM in virtual construction 91

BIM in facility management 95

Environmental simulations and energy analysis 98

Structural analysis 101

CFD analysis 105

Digital fabrication and methods 111

Design to fabrication 121

Conclusion: the integration of advanced computational technologies with design and research 125

### **3 TECHNOLOGICAL INNOVATIONS 128-169**

Advances in facade systems 131  
Advances in HVAC systems 135  
Advances in lighting 145  
Building automation systems 151  
Prefabrication and modular construction 156  
Automation in construction 159  
Robotics in construction 162  
Smart and responsive buildings 163  
Conclusion: the integration of advanced technologies in design  
and construction 167

### **4 INNOVATIONS IN THE DESIGN PROCESS AND ARCHITECTURAL PRACTICE 170-183**

Motives and goals for innovation 171  
Organisation and roles 172  
Integration of research and design practice 174  
Research methods for innovation 176  
Financial factors and investments for innovation 177  
Value of innovation 179  
Innovations in project delivery 179  
Risk management in innovative design practice 181  
Conclusion: strategies for integrating innovation 183

### **5 BUILDING INTEGRATED INNOVATIONS AND METHODS (CASE STUDIES) 184-245**

Center for Design Research, University of Kansas 187  
Umwelt Arena 191  
King Fahad National Library 199  
Hanjie Wanda Square 205  
Collaborative Life Sciences Building and Skourtes Tower 211  
Shanghai Natural History Museum 219  
The Yas Hotel 229  
Health Sciences Education Building, Phoenix  
Biomedical Campus 233  
Conclusion: lessons learned from case studies 243

### **FUTURE OUTLOOKS: CONCLUDING REMARKS 246-249**

### **SELECT BIBLIOGRAPHY 250-253**

### **APPENDIX: CASE STUDIES INDEX 254-259**

### **INDEX 260-264**

INTEGRATING  
INNOVATION IN  
ARCHITECTURE





# INTEGRATING INNOVATION IN ARCHITECTURE

Design, Methods and Technology for  
Progressive Practice and Research

WILEY

Ajla Aksamija

# CONTENTS

## **ACKNOWLEDGEMENTS 7**

## **FOREWORD 9-11**

by Phil Harrison

## **INTRODUCTION**

### **INNOVATION IN ARCHITECTURE (WHAT, WHY AND HOW) 12-19**

What is innovation? 13

Why innovate in architectural design? 16

How to innovate in architecture? 17

### **1 INNOVATIVE MATERIALS 20-59**

Advances in concrete 23

Advances in glass 27

Advances in metals 37

Biomaterials 39

Composite materials 41

Electrochromics 45

Shape-memory alloys 45

Self-healing materials 47

Sensors and controls 48

Phase-change materials 49

Photovoltaics 51

Thermoelectrics 55

Conclusion: the impacts of advanced and smart materials on architectural design 57

### **2 INNOVATIONS IN COMPUTATIONAL DESIGN 60-127**

Advances in computational design 63

Tools and methods 77

BIM in design 88

BIM in virtual construction 91

BIM in facility management 95

Environmental simulations and energy analysis 98

Structural analysis 101

CFD analysis 105

Digital fabrication and methods 111

Design to fabrication 121

Conclusion: the integration of advanced computational technologies with design and research 125

### **3 TECHNOLOGICAL INNOVATIONS 128-169**

Advances in facade systems 131  
Advances in HVAC systems 135  
Advances in lighting 145  
Building automation systems 151  
Prefabrication and modular construction 156  
Automation in construction 159  
Robotics in construction 162  
Smart and responsive buildings 163  
Conclusion: the integration of advanced technologies in design  
and construction 167

### **4 INNOVATIONS IN THE DESIGN PROCESS AND ARCHITECTURAL PRACTICE 170-183**

Motives and goals for innovation 171  
Organisation and roles 172  
Integration of research and design practice 174  
Research methods for innovation 176  
Financial factors and investments for innovation 177  
Value of innovation 179  
Innovations in project delivery 179  
Risk management in innovative design practice 181  
Conclusion: strategies for integrating innovation 183

### **5 BUILDING INTEGRATED INNOVATIONS AND METHODS (CASE STUDIES) 184-245**

Center for Design Research, University of Kansas 187  
Umwelt Arena 191  
King Fahad National Library 199  
Hanjie Wanda Square 205  
Collaborative Life Sciences Building and Skourtes Tower 211  
Shanghai Natural History Museum 219  
The Yas Hotel 229  
Health Sciences Education Building, Phoenix  
Biomedical Campus 233  
Conclusion: lessons learned from case studies 243

### **FUTURE OUTLOOKS: CONCLUDING REMARKS 246-249**

### **SELECT BIBLIOGRAPHY 250-253**

### **APPENDIX: CASE STUDIES INDEX 254-259**

### **INDEX 260-264**



# ACKNOWLEDGEMENTS

I would like to acknowledge all the valuable time, comments and feedback I have received, during the preparation and writing of this book from individuals, firms and organisations. They have worked closely with me, helping me to capture the essence of projects, design methods and approaches featured here in the case studies, projects, building systems and installations. I thank them all for their involvement, support and advice.

I would like to extend my gratitude to Phil Harrison for providing his perspective and for writing the foreword.

My research assistants, Yi Wang, Christopher Mansfield and Tom Forker deserve special recognition for their help.

I would also like to thank the Wiley editorial and production team, particularly Helen Castle, Calver Lezama and Miriam Murphy.

Lastly, I would like to acknowledge Zlatan, Nur and Iona Aksamija for their undivided love and support.

