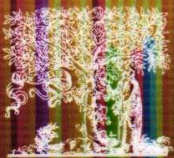


Christopher Grant Kirwan  
Zhiyong Fu

# Smart Cities and Artificial Intelligence

Convergent Systems for Planning, Design, and Operations



ELSEVIER

Elsevier

Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands  
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom  
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States

Copyright © 2020 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: [www.elsevier.com/permissions](http://www.elsevier.com/permissions).

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

### Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

### Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

### British Library Cataloguing-in-Publication Data

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

ISBN: 978-0-12-817024-3

For information on all Elsevier publications visit our website at  
<https://www.elsevier.com/books-and-journals>

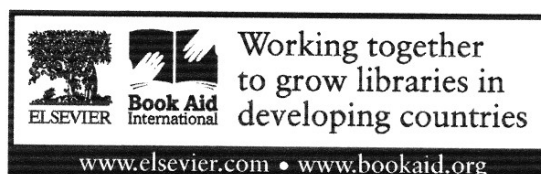
*Publisher:* Joe Hayton

*Acquisition Editor:* Brian Romer

*Editorial Project Manager:* Michelle W Fisher

*Production Project Manager:* Selvaraj Raviraj

*Cover Designer:* Alan Studholme



Typeset by TNQ Technologies

# Contents

Preface	xiii
Acknowledgments	xv
Introduction	xvii
Description of each section	xxvii
Info system (Fig. 0.0)	xxxii

## 1. Evolution of cities/technologies

1.1	Overview of smart city concept and context	2
1.2	The evolution and integration of technology, AI, and cities	4
1.2.1	Evolutionary strategies	7
1.3	City DNA narratives	9
1.3.1	Beijing—the radiating megacity	10
1.3.2	London—the cosmopolitan hub	11
1.3.3	New York—the media metropolis	12
1.3.4	Dubai—the iconic branded city	13
1.3.5	Songdo—the new digital city	14
1.3.6	Masdar—the new sustainable city	15
1.3.7	NEOM—the future city	16
1.4	The dimensions of the city and potential for convergence	17
1.4.1	Physical/environment dimension	18
1.4.2	City systems, infrastructure dimension	19
1.4.3	The human dimension	19
1.4.4	Culture, society, and governance dimension	19
1.4.5	Digital infrastructure dimension	20
1.4.6	The ubiquitous dimension	20
1.5	How convergence theory applies to smart cities	21
1.6	Conclusion	22
	References	23
	Further reading	24

## 2. City as living organism

2.1	The city as a living organism	25
2.1.1	Concepts of space and representation	26
2.1.2	Dynamic, self-regulating systems in nature	28
2.1.3	Biomimicry	29

2.1.4	Biomimicry applied to human anatomy	30
2.1.5	City as extension of the human body	31
<b>2.2</b>	<b>Principles of collective intelligence</b>	<b>33</b>
<b>2.3</b>	<b>City DNA</b>	<b>36</b>
2.3.1	Cities as global brands/destinations	37
<b>2.4</b>	<b>The role of data collection and mapping</b>	<b>39</b>
2.4.1	Mapping the system	39
2.4.2	Mapping as the basis of smart cities	41
2.4.3	Real-time behavioral data	42
<b>2.5</b>	<b>Conclusion</b>	<b>43</b>
	<b>References</b>	<b>44</b>
	<b>Further reading</b>	<b>45</b>
<b>3.</b>	<b>Strategies, planning, and design</b>	
<b>3.1</b>	<b>Criteria for planning and design of smart cities</b>	<b>47</b>
3.1.1	Strategic goals	48
3.1.2	Outcome-based modeling	51
<b>3.2</b>	<b>New approaches to innovation for planning and designing smart cities</b>	<b>52</b>
3.2.1	Cities as living labs	53
3.2.2	City as hubs of innovation/innovation-driven cities	54
3.2.3	Co-design	56
3.2.4	Citizen-centric cities	56
3.2.5	Design thinking	59
<b>3.3</b>	<b>Convergence methodologies</b>	<b>60</b>
3.3.1	Human-machine collaboration	60
3.3.2	Real-time visualization	61
3.3.3	Information architecture and Philosophy of Information	62
3.3.4	Real world/virtual simulation	62
3.3.5	Generative design and metadesign	63
3.3.6	Convergence Development Method: strategy, planning, design, and operations process	64
3.3.7	Convergence design method: design thinking/machine learning	65
3.3.8	Convergence application method: outcome-based AI scenario modeling	65
<b>3.4</b>	<b>Conclusion</b>	<b>66</b>
	<b>References</b>	<b>66</b>
<b>4.</b>	<b>City Operating Systems</b>	
<b>4.1</b>	<b>Overview of operating systems</b>	<b>69</b>
<b>4.2</b>	<b>The language and representation of systems architecture</b>	<b>71</b>
4.2.1	The role of meta-architecture, information architecture and technical architecture in the design of smart city operating systems	73
4.2.2	Meta-architecture—principles and guidelines	74

4.2.3	Operating systems planning considerations	74
4.2.4	Operating systems design considerations	76
4.2.5	Information architecture and technical architecture	77
<b>4.3</b>	<b>Representational hierarchy of cities as operating systems</b>	<b>78</b>
4.3.1	City ecosystem	78
4.3.2	Smart city framework—the smart city mandala	80
4.3.3	OS Behavioral Typologies	81
4.3.4	Anatomy of operating systems	83
4.3.5	Smart city operating system flow	84
<b>4.4</b>	<b>What is the correct OS?</b>	<b>85</b>
<b>4.5</b>	<b>New constructs—convergence-based city OS</b>	<b>87</b>
4.5.1	Convergent OS	88
4.5.2	Co-development/open source/open data	90
4.5.3	Self-regulating systems	91
<b>4.6</b>	<b>Conclusion</b>	<b>92</b>
	<b>References</b>	<b>93</b>
	<b>Further reading</b>	<b>93</b>
<b>5.</b>	<b>Connectivity</b>	
<b>5.1</b>	<b>Introduction</b>	<b>95</b>
5.1.1	Connectivity itself will become intelligent	96
5.1.2	All living organisms are related within a frequency spectrum	97
<b>5.2</b>	<b>Evolution of connectivity</b>	<b>97</b>
<b>5.3</b>	<b>The electromagnetic spectrum, frequencies, and bandwidth</b>	<b>99</b>
5.3.1	Electromagnetic patterns, frequencies, and human energy fields	99
5.3.2	Electromagnetic spectrum	101
<b>5.4</b>	<b>The role of machine learning and deep learning in intelligent connectivity</b>	<b>101</b>
5.4.1	Radio Frequency Machine Learning Systems	101
5.4.2	The role of evolutionary algorithms in connectivity	102
<b>5.5</b>	<b>Connectivity anatomy</b>	<b>103</b>
5.5.1	The human body and neural networks as models of connectivity	103
5.5.2	The brain	104
5.5.3	Other organic models of connectivity	105
5.5.4	The backbone of connectivity—telecommunication networks	106
5.5.5	The sensorial layer of connectivity	107
5.5.6	Mobile connectivity	108
<b>5.6</b>	<b>Integrated networks and services</b>	<b>108</b>
5.6.1	Industry 4.0—the basis of connectivity	108
5.6.2	Convergence connectivity	109
5.6.3	Intelligent connectivity using combination of 5G AI and IoT	110

5.6.4	Connectivity singularity	111
5.6.5	Smart objects	111
5.7	<b>Conclusion</b>	113
	<b>References</b>	114
	<b>Further reading</b>	114
6.	<b>Interface</b>	
6.1	<b>City-wide interface—the city is an interface</b>	117
6.1.1	City interface as an extension of the city OS	118
6.1.2	The city as an ecosystem—scale, boundaries bridging global and hyperlocal	120
6.1.3	Infrastructure as interface	121
6.2	<b>City interface functions</b>	121
6.2.1	Urban navigation	122
6.2.2	Urban media	124
6.2.3	Urban sensing	125
6.2.4	Urban interaction	126
6.3	<b>City interface design practices</b>	128
6.3.1	Theory and method of city interface design	129
6.3.2	Urban user experience	129
6.3.3	Urban interaction design	131
6.3.4	Urban simulation and gaming	131
6.4	<b>Collective intelligence interface</b>	133
6.4.1	Collective intelligence	133
6.4.2	Collective intelligence participation/interaction	133
6.4.3	Dynamic frames of reference	134
6.4.4	Human to human, human to machine, machine to machine and machine to nature	134
6.5	<b>Convergence Urban Interface</b>	135
6.5.1	Total interface solution—AI/sensors/big data/pattern recognition	137
6.6	<b>Conclusion</b>	137
	<b>References</b>	138
	<b>Further reading</b>	138
7.	<b>Smart City Scenarios</b>	
7.1	<b>Introduction</b>	141
7.2	<b>Theory of systems change</b>	143
7.2.1	Multi-level perspective	143
7.2.2	Convergence application	145
7.3	<b>Smart mobility</b>	146
7.3.1	Past—present—future	146
7.3.2	Object—action—outcome	149
7.4	<b>Smart environment</b>	150
7.4.1	Past—present—future	150
7.4.2	Object—action—outcome	151

7.5	<b>Smart people</b>	152
7.5.1	Past—present—future	152
7.5.2	Object—action—outcome	154
7.6	<b>Smart governance</b>	155
7.6.1	Past—present—future	155
7.6.2	Object—action—outcome	156
7.7	<b>Smart economy</b>	157
7.7.1	Past—present—future	157
7.7.2	Object—action—outcome	158
7.8	<b>Smart living</b>	159
7.8.1	Past—present—future	159
7.8.2	Object—action—outcome	160
7.9	<b>Conclusion</b>	161
	References	161
	Further reading	162
<b>8.</b>	<b>Smart city functions</b>	
8.1	<b>Introduction</b>	164
8.2	<b>Smart city enablers (hardware infrastructure)</b>	165
8.2.1	Collection: IoT and low energy consuming sensors	166
8.2.2	Processing: scalable computing power and storage through edge and cloud computing	166
8.2.3	Transmission: network infrastructure—5G	167
8.2.4	OS: AI smart city operating systems	167
8.3	<b>Introduction to AI, AI applications and capabilities (software infrastructure)</b>	168
8.3.1	Capabilities-based AI	169
8.3.2	Functionality-based AI	169
8.3.3	Computer Vision	170
8.3.4	Natural language processing	170
8.3.5	Machine learning	171
8.3.6	Predictive analytics	171
8.3.7	Robotics	171
8.4	<b>The convergence of AI applications within smart cities</b>	172
8.4.1	Convergent applications	172
8.4.2	Hierarchy framework for scale and scope of smart city functions	173
8.5	<b>Smart city functions</b>	173
8.5.1	Smart environment	174
8.5.2	Smart government	177
8.5.3	Smart mobility	179
8.5.4	Smart economy	182
8.5.5	Smart people	184
8.5.6	Smart living	186
8.5.7	Convergence of smart city functions	188
8.6	<b>Conclusion</b>	191
	Further reading	192

## 9. Smart city business models

9.1	Introduction	193
9.2	The smart city/Artificial Intelligence market	194
9.2.1	Business models and risk mitigation	194
9.2.2	A Marxist analysis of smart cities	195
9.2.3	Smart city movement marketing	196
9.3	Innovation-led economics	198
9.3.1	Innovation as the driver	198
9.3.2	Intellectual property as the new asset	199
9.3.3	China—USA race, India rising	201
9.3.4	Cities as living labs	203
9.4	The new economy	205
9.4.1	Planetary accounting	205
9.4.2	Strategy shift	206
9.4.3	New forms of digital currency	207
9.4.4	Blockchain	207
9.4.5	Holochain	207
9.5	New forms of business exchange	208
9.5.1	Flow	208
9.5.2	Channeling on demand	209
9.6	Bringing it together	210
9.6.1	Convergent economies	211
9.6.2	Collaboration	211
9.6.3	Self-regulating systems	212
9.7	Conclusion	212
	References	213
	Further reading	214

## 10. Conclusions

10.1	From theory to practice	217
10.2	East-West Collaboration	219
10.3	The human factor	222
10.4	Wide-spread automation	223
10.5	Consequences of embracing convergence	224
	Further reading	226

Appendix	227
Glossary of Terms	233
Index	237