

Towards the establishment of a District Information Modeling

*Original*

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# ADVANCES IN CONSTRUCTION ICT AND E-BUSINESS

EDITED BY  
SRINATH PERERA,  
BINGUNATH INGIRIGE, KIRTI RUIKAR  
AND ESTHER OBONYO



# Advances in Construction ICT and e-Business

This internationally conducted study of the latest construction industry practices addresses a broad range of Information and Communication Technology applications. Drawing on research conducted in the US and UK, this book presents the state of the art of various e-business processes, and examines BIM, virtual environments and mobile technologies.

Innovation is a theme that runs throughout this book, so in addition to the direct impact of these new technical achievements, it also considers the management styles that helped them to emerge. Examples from industry are illustrated with case studies and presented alongside research from some of the best known academics in this field.

This book is essential reading for all advanced students and researchers interested in how ICT is changing construction management and the construction industry.

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# **Advances in Construction ICT and e-Business**

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Srinath Perera, Bingunath Ingirige,  
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# Contents

<i>List of figures and tables</i>	vii
<i>List of contributors</i>	xii
<b>1 Introduction</b>	1
SRINATH PERERA, KIRTI RUIKAR, BINGUNATH INGIRIGE, AND ESTHER OBONYO	
<b>2 Exploiting e-commerce in construction</b>	12
PATHMESWARAN RAJU AND GERALD FELDMAN	
<b>3 Advances in electronic procurement for the construction industry</b>	33
ROBERT EADIE AND SRINATH PERERA	
<b>4 Drivers for electronic procurement and building information modelling in the construction industry</b>	65
ROBERT EADIE AND SRINATH PERERA	
<b>5 Building information modelling and management</b>	87
DAVID GREENWOOD	
<b>6 BIM in practise – industry case studies</b>	106
TRISTAN GERRISH, KIRTI RUIKAR, MALCOLM COOK, MARK JOHNSON, AND MARK PHILLIP	
<b>7 Manchester Central Library and Town Hall Extension Project: the BIM journey so far of a public sector client</b>	131
JASON UNDERWOOD, JOANNA CHOMENIUK, LIAM BRADY, AND DAVID WOODCOCK	
<b>8 Project extranets and developments in project collaboration</b>	153
ERIC LOU AND ANAS BATAW	

<b>9 Transforming policy documents into intelligent three-dimensional collaboration tools</b>	182
ALAN REDMOND AND MUSTAFA ALSHAWI	
<b>10 Impact of collaboration tools and shaping the future of data exchange – A model for BIM communication waste</b>	213
GEORGE CHARALAMBOUS, PETER DEMIAN, STEVEN YEOMANS AND TONY THORPE	
<b>11 Towards the establishment of a district information modelling</b>	245
SARA MOGHADAM, PATRIZIA LOMBARDI, AND JACOPO TONIOLO	
<b>12 Capability maturity modelling of construction e-business processes</b>	263
SRINATH PERERA AND ANUSHI RODRIGO	
<b>13 e-Business infrastructure and strategic frameworks</b>	296
YONGJIE CHEN, KIRTI RUIKAR AND PATRICIA CARRILLO	
<b>14 Innovation in e-business: issues related to adoption for micro and SME organisations</b>	316
ERIC ADZROE AND BINGUNATH INGIRIGE	
<b>15 Application of social media in the construction industry</b>	340
PAUL WILKINSON	
<b>16 Social media in construction: an exploratory case study</b>	376
SRINATH PERERA, MICHELE VICTORIA AND SAMUEL BRAND	
<b>17 Mobile computing applications within construction</b>	404
ZEESHAN AZIZ, AIZUL HARUN AND NAIF ALABOUD	
<b>18 Envisioning buildings: advances in construction visualisations</b>	423
EMINE THOMPSON	
<b>19 The multi-agent paradigm in construction e-business and its use in the next generation of data-driven decision-making tools</b>	450
ESTHER OBONYO AND CHIMAY ANUMBA	
<b>20 Conclusions – Summary, the status quo and future trends</b>	462
BINGUNATH INGIRIGE, SRINATH PERERA, KIRTI RUIKAR AND ESTHER OBONYO	
<i>Index</i>	471

# Figures and tables

## Figures

3.1	Methods of electronic transactions	34
3.2	Stages of e-tendering	36
3.3	Restricted procedure process and timelines	37
3.4	Simplistic e-tendering document supply and submission	44
3.5	E-awarding electronic system	45
3.6	European procedures incorporating auctions	49
6.1	The hype cycle (Gartner, 2014) and adoption lifecycle (Rogers, 2003) showing coincidental adoption phases	108
6.2	Ongoing uptake and awareness of BIM in UK AEC industry (NBS, 2011, 2012, 2013, 2014)	108
6.3	Roles and design involvement undertaken by the organisation referenced here	109
6.4	(a–c) Increasing levels of detail in object modelling	111
6.5	BIM building energy performance data attribution framework	118
7.1	Manchester City Council short-term BIM4FM vision	136
7.2	Manchester City Council long-term BIM4FM vision	137
7.3	B/555 BIM implementation maturity model	139
7.4	MCC initial BIM maturity analysis of the Central Library project	141
7.5	MCC comparative BIM maturity analysis of the Central Library project (design and construction)	143
7.6	MCC comparative BIM maturity analysis of the Central Library project (FM)	144
9.1	Conceptual map of relationships	191
9.2	(a) The origin of business rules and (b) Kind of term	194
9.3	ASHRAE data base tier – architectural design	196
9.4	Example of a BIM system and process for linking material objects with health and ASHRAE documents	199
9.5	Exchanging information via BIM XML and REST	201
9.6	BIM XML + IFC product model	202
9.7	iFM and facility life-cycle data	206
10.1	Outline of requirements engineering approach followed	227

10.2	AEC-FM process flows and BIM process flows	230
10.3	The BIM process transmission: the focal unit of analysis of WIMBIM	230
10.4	BIM process transmissions: main categories and relation to BIM process flows	231
10.5	BIM process transmission waste: the 6 different types (A–E)	232
10.6	An example of a BIM process transmission with transmission waste	233
10.7	BIM data containers, transmission media and coordination tools	234
10.8	BIM transmission waste as a result of BIM data containers, transmission media and coordination tools	235
10.9	Dimensions and waste: the two dimensions of waste are the flow type dimension and the data subset dimension	235
10.10	Interaction between BIM data container, transmission medium and transmission coordination tool	236
10.11	BIM efficiency states	237
10.12	BIM transmission/interaction representations	237
10.13	BIM transmission interaction representation lenses: scale and complexity	238
11.1	Conceptual scheme of DIM, integration of BIMs and network monitoring system	252
11.2	Representation of the DIMMER' concept	253
12.1	Structure of SW-CMM	267
12.2	Five maturity levels of SW-CMM	268
12.3	Key process areas associated with each maturity level of SW-CMM	269
12.4	Main components of CMMI	270
12.5	SPICE maturity levels	272
12.6	Typical table summarising average scores in each category with traffic light indicators of VERDICT	273
12.7	The structure of the IS/IT readiness model	274
12.8	Maturity levels and their process areas of EB-CMM	276
12.9	Tabular BIM capability maturity model	277
12.10	Interactive BIM capability maturity model	278
12.11	BIM maturity ramp	279
12.12	Components of the BIM maturity matrix	280
12.13	Structure of the CeB-CMM	282
13.1	Reviewed approaches and their relationships with the strategic framework	301
13.2	The strategic e-business framework for organisations in the construction industry	302
14.1	Six forms of e-business activities	323
14.2	Four different faces of e-business models	325
14.3	e-Business trends in construction	328

14.4	Framework for e-Business development strategy	334
15.1	Device, service, content and connectivity = complexity	341
15.2	RICS social media graphic	346
15.3	The Conversation Prism, Brian Solis	347
15.4	Image of HOKLife	358
16.1	Timeline of birth of various social media platforms	379
16.2	Impact of social media on business functions	381
16.3	Research method	387
16.4	Respondent age profile	388
16.5	Usage of social media – personal purpose	388
16.6	Usage frequency – personal purpose	389
16.7	Social media for personal use by age	390
16.8	Usage of social media – business purposes	391
16.9	Usage frequency – business purposes	391
16.10	Social media for business development by age	392
16.11	Usage of social media – career development	392
16.12	Usage frequency – career development	393
16.13	Usage pattern of LinkedIn by age	394
16.14	Level of integration of social media with organisation goals and objectives	395
16.15	Importance of social media for the case study organisation	395
16.16	Drivers and barriers of social media implementation in construction organisation	400
17.1	The application model for exploring mobile computing with information management on construction sites	409
17.2	Construction mobile application	411
17.3	The components of SiteBIM systems	412
17.4	The ENSOCS architecture	417
17.5	The display of weather data, air and noise data on ENSOCS' dashboard	419
17.6	The web form (checklist) and the sample of a surveillance report (Left: Online report; Right: Emailed report) of ENSOCS	419
18.1	Temporal representation paradigm	425
18.2	Visualisation tools for built environment	426
18.3	Animation of construction process	428
18.4	Oculus rift in use	430
18.5	Cardboard VR tool, and two slightly different images which makes up the VR environment	431
18.6	System overview; the Oculus HMD, the revit viewer plug-in and the PowerPoint remote control	433
18.7	3D point cloud data and render from the 3D model generated from scan data, Baltic Art Centre, Gateshead	437
18.8	(a) 3D point-cloud data from Gateshead Old Town Hall scan, (b) 3D model created using point-cloud data from the	

Gateshead Old Town Hall scan, (c) Photorealistic render from the 3D model of the Gateshead Old Town Hall	438
18.9 3D model construction of historical buildings	440
18.10 Virtual medieval Newcastle	440
18.11 Point-cloud data examples from Durham Cathedral scans and Revit model	441
18.12 Detail image from the 3D print virtual NewcastleGateshead model	443
18.13 Rendered image of the college house (Newcastle upon Tyne) and 3D print model	444
19.1 Construction e-business example	454
19.2 Roles of agent-based models in the highway infrastructure management systems	458

## **Tables**

2.1 Some of the e-commerce research studies in construction	18
2.2 e-Commerce technologies for construction	19
2.3 Drivers of e-commerce	22
2.4 Summary of e-commerce adoption barriers	24
3.1 2016 European financial thresholds above which the EU regulations apply	38
3.2 Timings for e-procurement	51
3.3 Time reductions due to e-procurement	51
4.1 Drivers to e-procurement identified from literature	67
4.2 Summary of the drivers for BIM in rank order	70
6.1 Case study 1 project datasheet	112
6.2 Case study 2 project datasheet	116
6.3 Case study 3 project datasheet	121
7.1 MCC Central Library and Town Hall Complex Project Awards	149
9.1 Cross tabulation of hospital dependencies and recovery mechanisms	188
9.2 Main groups of substance and their source known to cause indoor air pollution	198
9.3 Performance metrics of FUSION+GIS+ONUMA case study	204
12.1 Fundamental concepts of SW-CMM	266
12.2 Maturity levels and key process areas of e-procurement CMM	281
12.3 Construction e-business capability maturity characteristics for CeB-CMM	283
12.4 Construction e-business capability maturity model (CeB-CMM)	284
13.1 Industry practitioners participating in the framework evaluations	309
15.1 Social networking registrations and active use, global	345
15.2 The changing social media world	348

16.1	Drivers and barriers of social media implementation in business environment	383
16.2	Interviewee profile	396
16.3	Comparison of results of the study with other studies	399
17.1	Summary of mobile computing benefits	407
17.2	Developed mobile application systems for on-site information management	409

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# 1 Introduction

*Srinath Perera, Kirti Ruikar,  
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## 1.1 Background

The construction industry of most countries is considered the growth engine of the economy often acting as the regulator of economic activity. This makes it important to continually innovate its practice and processes. One of the primary ways of infusing innovation in to the construction industry is through the adoption of Information Communication Technologies (ICT) in to its endemic processes. Many previous reports that analysed the level of adoption of ICT by sectors (e-Business W@tch, 2007, 2008, 2010) and its performance (Kang *et al.*, 2013) reported that the construction industry as one of the sectors that is most IT backward in terms of ICT adoption and use.

These issues of low ICT adoption in the construction industry is further exacerbated due to the fact that it is heavily fragmented in its operations in terms of design and construction, through the involvement of different distinct professions (architecture, civil engineering, structural engineering, mechanical engineering, quantity surveying, construction management, planning, among others) multi-layered supply chains and other silos of separation. This provides a greater role for ICT in the construction industry to act as a catalyst for integration and collaboration creating a platform for innovative applications and process re-engineering. ICT offers a plethora of enabling technologies that create the platform for these developments to take hold. This book aims to explore the use of numerous e-business enabling technologies within the construction industry.

This chapter first defines the term construction e-business and introduces the different types of enabling technologies that are explored in the various chapters of this book. Finally, it provides a guide to the structure and the layout of the book.

## 1.2 Defining construction e-business

This section is an attempt in defining construction e-business by first analysing the definition of e-business and projecting it to application in the construction sector. The term e-business first originated from the work of

IBM (Gerstner, 2002; Chaffey, 2011) and introduced the term e-business as a way of transforming key business processes by using Internet technologies (IBM, 1997). Subsequently they revised the definition giving it a much broader outlook (IBM, 2001: p. 5) as;

the process of using web technology to help businesses streamline processes, improve productivity, and increase efficiency. It is about using the internet infrastructure and related technologies to enable business anywhere and anytime.

However, in the UK, the Department of Trade and Industry (DTI) developed a much broader view of e-business in their international benchmarking study analysing the adoption of e-business by Small and Medium Enterprises (SMEs). They termed e-business as

the integration of Information and Communication Technologies (ICTs) for business processes (DTI, 2000).

Here, ICT is defined as any technology used to support information gathering processing, distribution and use which includes hardware, software and network systems (Baynon-Davies, 2013). This broader definition of e-business as adoption of ICT to business processes indicates that it has transformative potential to reinvent business processes through integration and redefining of business processes (DTI, 2004).

Li (2007) takes a similar approach and defines e-business as

e-business is about developing new ways of working by innovatively exploiting the new capabilities of Information and Communication Technologies in general and the Internet and related technologies in particular.

(Li, 2007: p. 2)

More recently, Chaffey (2011) used a more information centric approach to define e-business activities as

All electronically mediated information exchanges, both within an organisation and with external stakeholders supporting the range of business processes.

(Chaffey, 2011: p. 12)

These definitions identify several central characteristics in defining e-business. Information and its process of communication, the technologies used are primary constructs of the definition. These processes are considered within the context of business applications. This broader approach to e-business definition is supported by many authors (Laudon and Laudon, 2002;

Aranda-Mena and Stewart, 2005; Anumba and Ruikar, 2008; Xu and Quaddus, 2010; Goncalves *et al.*, 2010).

Therefore, the application of e-business with this broader definition in mind, to the processes in the construction industry is termed as construction e-business. In this book the term construction e-business is defined as ‘the application of information communication technologies to construction business processes’. These include business processes utilised by construction companies (be it construction contractors, sub-contractors, suppliers, or consultants such as designers, engineers, managers or surveyors). The process of adoption of ICT to construction processes would naturally lead to creating new ways of conducting business activities which enable transformation of business processes with added value. This is considered as innovation in construction business processes, thus ICT led innovation.

### **1.3 e-Business–enabling technologies**

e-Business–enabling technologies play a vital role in organisations when e-business activities blend with their day to day business practices. The technologies that enable organisations to adopt ICT and reinvent business processes are considered as e-business enabling technologies. Organisations should carefully consider the selections and choices of hardware, software, human resource and IT services as they persuade functional, financial and technical requirements of an organisation (Perera and Karunasena, 2008). The IT solutions generated through the use of e-business enablers are the driving forces behind the e-business adoption that would pronounce potential competitive advantages for adopting businesses. They have changed not only the way in which businesses communicate and interact, but also the way in which information is stored, exchanged and viewed (Anumba and Ruikar, 2008). The construction e-business enabling technologies discussed in this chapter are briefly explored below.

#### **1.3.1 Internet technologies**

Internet refers to the global information system that is logically linked together by a globally unique address space based on the Internet Protocol (IP) or its subsequent extensions (Leiner *et al.*, 2009). It is able to support communications using the Transmission Control Protocol/Internet Protocol (TCP/IP) suite or its subsequent extensions, and other compatible protocols and provides, users or makes accessible, either publicly or privately, high level services layered on the communications and related infrastructure. The Internet is implemented in three primary methods (Ashworth and Perera, 2015: chap. 23). Firstly, as the World Wide Web where information is provided to the masses through the use of Internet technologies. Secondly, Intranet is its implementation as a private network used exclusively within a company or organisation. It uses the Internet technologies, but does not

necessarily function through the Internet (Vlosky *et al.*, 2000). These are private computing networks, internal to an organisation, allowing access only to authorised users. The third implementation is the Extranets. It is a network that links business partners to one another over the Internet (Volsky *et al.*, 2000) and this linkage is usually occurring by companies allowing their partners to access certain areas of their intranet (Greengard, 1997). It is private to a group of users defined by membership of the group. Chapter 8 explores the use of Extranets for project collaboration. Although there are no other dedicated chapters on the Internet and its variations most enabling technologies discussed are often implemented either fully or partially using Internet technologies.

### ***1.3.2 e-Commerce and its infrastructure***

e-Commerce involves use of electronic transactions in commercial processing related activities of businesses. There are a number of definitions that explains e-commerce in many ways. This book considers e-commerce as a subset of broadly defined e-business. Chapter 2 of this book explores the e-commerce infrastructure, its classifications, technologies and drivers and barriers.

### ***1.3.3 Cloud computing***

Cloud computing (CC) can be defined as ‘a model for enabling convenient, on demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction’ (Mell and Grance, 1999). Organisations can use CC as a service to obtain software, platform, infrastructure or data storage (Sultan, 2010). CC makes e-business concept more accessible by providing a foundation and cost effective infrastructure for e-business activities. e-Business services can be borrowed through public clouds, private clouds, community clouds or hybrid clouds. There are many advantages of using CC as an enabling technology for e-business within an organisation as on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service (Dillon *et al.*, 2010). In construction context, CC can be utilised to develop cost effective collaborative and data sharing solutions. Chapters 9, 10 and 11 explore the use of BIM within a cloud-based environment for collaborative design.

### ***1.3.4 e-Procurement***

e-Procurement originated with the use of various digital media such as CDs for media common formats such as EDI for data exchange, but found its natural residence in Internet technologies. Chaffey (2009) defines e-procurement as ‘electronic integration and management of all procurement activities

including purchase request, authorisation, ordering, delivery and payment between purchaser and supplier'. e-Procurement includes sourcing, tendering, invoicing, auctions and transactions completed utilising electronic means (Ashworth and Perera, 2015). In the construction industry e-procurement includes on the one hand sourcing of labour, material and plant by contractors, and on the other hand the e-tendering processes followed to procure buildings and other structures as well as for materials procurement. Chapter 3 explores e-procurement in details followed by Chapter 4 dealing with e-procurement within a BIM environment.

### ***1.3.5 BIM***

Building information modelling (or management) is one of the fastest growing enabling technologies that have high relevance and applicability to the construction industry. In the UK and in many other parts of the world there is significant government led promotion of use of BIM in the construction industry. BIM represents a building or structure as a hierarchical computer based object model often using object oriented modelling techniques. It enables to define buildings and its constituent elements and components in a hierarchical object structure that represent the characteristics of each object in terms of attribute–value pairs. This information rich platform has great potential for integrating the fragmented construction industry provided it is used in the right way as a collaborative tool. These aspects of BIM are explored in Chapters 5, 6 and 7 with industry case studies explaining successful applications of the technology. Chapters 9, 10 and 11 further explore use of BIM as collaboration tools both at project level and district level modelling.

### ***1.3.6 Social media***

Social media is one technology that has surpassed the scope of its own original purpose of social interactions to become one of the greatest applications of Internet technologies for business purposes. The advent of Web 2.0 technology has propelled social media beyond mere social interactions to marketing, recruitment, sourcing to many other business applications (Ashworth and Perera, 2015). Chapter 15 provides the background knowledge related to social media in construction with Chapter 16 providing a case study analysis followed by Chapter 17 exploring mobile computing.

### ***1.3.7 AI-agents***

Artificial Intelligence grew from its origins of Turing experiments to the popular research paradigm in the 1980s and 1990s to becoming a major part in modern hardware to software applications. The potential for application of AI is limitless. Some construction industry specific applications are based on the paradigm of Multi-Agent Systems (Vermeulen and Pyka, 2015).

Chapter 19 reviews the use of multi agent systems in construction e-business operations taking APRON (Obonyo *et al.*, 2005) a prototype for the specification and procurement of construction products as one such example.

#### **1.4 Structure of the book**

This book is an attempt to provide a coherent monograph of the state of construction e-business and its advancements following from Anumba and Ruikar (2008) fulfilling a knowledge gap in construction ICT literature. The book consists of 20 chapters structured in to seven sections:

- 1 Introductions: Chapter 1 defining the scope of the subject and the text.
- 2 Procurement: chapters dealing with ICT applications enhancing construction procurement (Chapters 2, 3 and 4).
- 3 Building information modelling (BIM): reviewing the state of application of BIM (Chapters 5, 6 and 7).
- 4 Cloud and Collaboration Technologies: reviewing the use of many collaboration technologies such as extranets, cloud computing and BIM (Chapters 8, 9, 10 and 11).
- 5 Process Issues: analysing the methodologies and status of ICT adoption related process issues and their management (Chapters 12, 13 and 14).
- 6 Social and Media Technologies: reviewing the state of Internet based technologies such as social media (Chapters 15 and 16), communication technologies such as mobile computing (Chapter 17) and visualisation technologies such as virtual reality (Chapter 18).
- 7 Conclusions: providing trends and development for the future with a review of agent technology (Chapter 19) and with conclusions and future trends (Chapter 20).

The following paragraphs provide a quick overview of the individual chapters in the book.

Chapter 1 provides an introduction to the book providing the background context within which this book has been conceived. It defines construction e-business and provides an overview of the e-business enabling technologies that have been reviewed within this book.

Chapter 2 discusses the use of e-commerce with the construction industry exploring e-commerce classifications and technologies used based on features of e-commerce. The chapter provides a detailed account of drivers and barriers for e-commerce in construction.

Chapter 3 analyses the advances in e-procurement in the construction industry taking a step by step detailed look at the various stages of the procurement process. It reviews the European e-advertising requirements for construction contracts. The electronic awarding and e-auctions are analysed in detail explaining the stages involved in each of these e-procurement

methods. It also tracks major government backed initiatives that promote e-procurement.

Chapter 4 reviews the drivers for e-procurement and BIM in the construction industry. It compares and contrasts the drivers and barriers to BIM with those of e-procurement. It also looks at the interoperability between the two systems.

Chapter 5 sets the background for building information modelling/management (BIM) within the context of UK government and other countries taking active steps towards implementation and adoption of BIM within the construction industry. BIM has been reviewed as a radical, disruptive and fast-moving phenomenon. It provides a state of the art account with a full coverage of BIM from its origins to current level of development and beyond, to its future potential.

Chapter 6 is an attempt to showcase the implementation of BIM in the construction industry taking three case studies of BIM applications. Each case study describes the project and its uses of BIM in place of conventional design and construction processes, and then looks at the challenges and solutions developed as part of the BIM adoption throughout these projects.

Chapter 7 provides a detailed single case study of a public sector organisation implementing BIM as a test case. It provides an account of the BIM journey for implementing BIM for the Manchester Central Library and Town Hall Extension Project. The influences of key decisions during this journey and on behaviours that enhance collaboration and cooperation in understanding of BIM requirements are discussed in the chapter.

Chapter 8 provides the latest highlights on extranets for web-enabled project management. Extranet software use in the construction industry enables its participants to communicate, exchange information, data storage and collaborate across a standard platform. The chapter provides details on how extranets have changed everyday business operations and the challenges in the future if such technologies are to be implemented within day to day practice in the construction industry.

Chapter 9 describes the use of business rules associated with semantic knowledge in order to identify appropriate environmental and health policies on the Web. The authors discuss techniques for semantically enhancing policy documents within an open BIM model by exchanging information via BIM XML and representational state transfer (REST) 'systems-of-systems' they adopted to realise their objective of creating a 3D virtual representation model connected to policy documents.

Chapter 10 discusses the development of a context-specific conceptual-model ontology, which can support the discourse of requirements engineering while also providing a robust and universally applicable framework for evaluating the communication capabilities of BIM. The authors outline their use of this approach to develop a model for waste in BIM process interactions in their 'WIMBIM' project.

Chapter 11 discusses the district information modelling concept (DIM) and presents it as a feasible approach in efforts directed at scaling up the impact of energy efficiency models from the individual building to neighbourhood level. DIM is presented in this chapter as a new concept based on integration building information modelling (BIM) and geospatial information systems (GIS) with real-time data. The chapter includes a description of an open platform being developed as part of ongoing research for real-time data processing and visualization at the district level based on information about buildings, the energy distribution grid and user behaviour.

Chapter 12 presents capability maturity modelling (CMM) of construction e-business processes as a ICT process-management methodology that enables organisations to seek improvements to their e-business processes. It reviews CMM concepts and different approaches used in various sectors and evaluates their applicability in the construction industry. It also provides a detailed account of a construction e-business capability model that has been developed for use within the construction industry.

Chapter 13 discusses the development of a novel strategic e-business framework that highlights the aspects to be considered internally (within an organisation) and externally (within projects) to enhance collaboration and derive business benefits from the implementation. It focuses on the development and implementation of the framework. The chapter starts from the discussion of the crucial needs of industry organisations when formulating their e-business strategies, and the introduction of the adopted methodology for developing the framework. This is followed by a review of the different relevant approaches for strategy formulation and framework development. The main body of the chapter presents a detailed description of the framework and its evaluation. Future implementation consideration is also discussed in the concluding section of the chapter.

Chapter 14 presents SMEs in construction as a very good source for e-business, thereby demonstrating that e-business is not just a tool for larger organisations but also a good tool that will be well received if positioned well among smaller businesses. This chapter reinforces the position of e-business use not only by examining e-business use that are appropriate for SME and micro organisations in construction but it also reports from a developing country case of the Ghanaian construction industry to demonstrate the importance of e-business within their industry.

Chapter 15 provides a brief introduction to and history of the emergence of social media, highlighting the evolution from the first-generation 'Web 1.0' technologies of the early 1990s to more user-friendly and interactive 'Web 2.0' Internet platforms. It also discusses the use of social media in the construction industry and uses examples and case studies for added context.

Chapter 16 defines social media, classifies the various social media platforms, discusses the emergence of the social media platforms against a timeline and discusses the benefits of, drivers of and barriers to social media usage across various industries. It then specifically discusses the application

of social media in the construction industry using two case studies. Conclusions and discussions highlight the most popular social media platforms among construction organisations, including the drivers and barriers of social media implementation in construction organisations.

Chapter 17 introduces mobile computing in construction as a technology, which is widely being publicised as a means to cope with the problems associated with the hazardous nature of the construction industry. Innovation is generated in this area to link various facets of construction with the power of emerging mobile computing technologies. The chapter provides a very good literature review and a synthesis and also discusses a case of application of mobile services for on-site environmental surveillance. The discussion here will be beneficial for many upcoming practitioners in the construction industry.

Chapter 18 provides a state-of-the-art review on visual communication tools based on an analysis of published literature and selected case studies. The chapter discuss trends that are continue to enhance the interactive and customization features within visualization tools such as 3D modelling, animation/walkthrough, virtual reality, augmented reality, building information modelling, and others.

Chapter 19 discusses the benefits of using agent-based systems in information and knowledge management for construction. In described first generation agent-based models that were generally speaking, agent-centred multi-agent systems' (ACMAS). The authors discuss the potential for scaling up their impact through the design and use of organization-centred multi-agent systems' (OCMAS). They also examine feasibility of adapting solutions-driven agent models to enhance data-driven decision support tools.

Chapter 20 provides a conclusion to the book. It first provides a brief summary of the key issues covered in each chapter before following on to advancements and enablers in ICT in construction. It then provides an account of key barriers to e-Business in construction and explores the benefits of adoption of ICT in construction processes and practices. Finally it provides an overview of future directions in e-Business in Construction.

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# Drivers for electronic procurement and building information modelling in the construction industry

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## Conclusions Summary, the status quo and future trends

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